ENVIRONMENTAL MANAGEMENT FOR ROADING CONTRACTORS

I. OVERVIEW & CASE STUDY

Transfund New Zealand Research Report No. 130

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AN IMPORTANT NOTE FOR THE READER

The research detailed in this report was commissioned by Transfund New Zealand.

Transfund New Zealand is a Crown entity established under the Transit New Zealand Act 1989. Its principal objective is to allocate resources to achieve a safe and efficient roading system. Each year, Transfund New Zealand invests a portion of its funds on research that contributes to this objective.

CONTENTS

EXECUTIVE SUMMARY

Introduction

A project, *Environmental Management for Roading Contractors*, was undertaken in 1997-98 to prepare two sets of provisional environmental guidelines for roading contractors carrying out road works in New Zealand.

Its objectives were to:

- provide specific and simple policies and guidelines about the environmental effects of road works, particularly those related to construction, and aimed for use by roading contractors;
- assist roading contractors to understand the environment within which they work, and
- improve the environmental image of roading contractors.

Structure of Project

The results of the project are presented as three reports:

I. Overview & Case Study: *Transfund New Zealand Research Report No. 130.*

II. Provisional Guidelines for Erosion & Sediment Management during Road Works: *Transfund New Zealand Research Report No. 131.*

III. Provisional Guidelines for Environmental Management during Road Works: *Transfund New Zealand Research Report No. 132.*

The first task of the project was to carry out a literature review of relevant guidelines, and undertake a case study with an associated environmental effects assessment. In this first report, *I. Overview & Case Study,* the initial work used to develop the guidelines is described. It is in two parts: an overview, and a case study.

The guidelines, which form parts II and III of the project (Transfund New Zealand Research Reports 131 and 132), have been developed in order to minimise adverse effects of erosion and sediment run-off created by construction of roads, and to improve environmental management by roading contractors. They are to help contractors achieve a favourable environmental outcome and also to help promote compliance with the Resource Management Act 1991 (RMA).

1. Overview

Road construction operations can have potentially adverse effects on the environment, particularly as a result of sediment run-off which enters waterways. Such effects can also cause additional costs for contractors as a result of extra work, site clean-up and time delays. In cases of serious negligence, there is also potential for litigation under the RMA.

The potential for adverse environmental effects associated with road construction results from site disturbance in both the long-term effects of the road or road modification, and the short-term effects of the construction activity itself.

The method of research for the guidelines comprised:

- Review of existing information gathered from regulatory authorities and other sources (summaries of the reviews of the documents are given in an Appendix);
- Structured interviews with roading contractors and regulatory authorities: these interviews assessed past and present practices, levels of understanding of environmental effects and the RMA, and features of the guidelines that would be most useful;
- A case study and associated environmental effects assessment of a construction project where sediment run-off control measures were implemented and associated resulting water quality monitoring was undertaken.

To ensure that the provisional guidelines achieve the desired outcomes, they have been made available to contractors on a trial basis. After the trial, amendments could be made and the guidelines could then be published as operational documents.

2. Case Study

The case study and associated environmental effects assessment used to develop the guidelines are summarised in Part 2 of this report. A suitable construction project for a case study in the 1997-98 construction period was that of an access road, reservoir platform, and a haul road in the Korokoro Stream catchment, Lower Hutt, New Zealand.

The study includes a description of the project, the issues of sediment control associated with the construction, and the measures employed by the contractor to minimise sediment run-off.

Assessment of the environmental effects of construction concentrated on:

- Water quality by measuring clarity, turbidity and suspended solids, dissolved reactive phosphorus (DRP) and nitrate-nitrogen (NO3-N);
- Aquatic biota by measuring benthic macro-invertebrate community index (MCI) and biomass, production of algal food source.

Conclusions from the case study are:

- Mobilisation of sediment by stormwater was not a major source of contamination as the weather was unusually dry.
- Significant sediment discharge did occur at temporary stream fords, which were under-designed for the heavy use by trucks.
- A major reduction in water clarity, but only minor changes in the benthic invertebrate community, resulted from sediment contamination which was sourced at the stream crossings.
- A comprehensive approach to sediment control is needed during construction of roads.
- Reliance on any one single measure is unlikely to produce a satisfactory outcome, and silt control issues associated with each component of the operation need to be identified at an early stage and addressed by applying appropriate sediment control methods.

ABSTRACT

A project, *Environmental Management for Roading Contractors*, was undertaken in 1997-98 to prepare two sets of provisional environmental guidelines for roading contractors carrying out road works in New Zealand.

Objectives of the project were to:

- provide specific and simple policies and guidelines about the environmental effects of road works, particularly those related to construction, and aimed for use by roading contractors;
- assist roading contractors to understand the environment within which they work, and
- improve the environmental image of roading contractors.

The results of the project are presented as three reports:

I. Overview & Case Study: *Transfund New Zealand Research Report No. 130.*
II. Provisional Guidelines for Erosion & Sediment Management during Road Works: *Transfund New Zealand Research Report No. 131.*
III. Provisional Guidelines for Environmental Management during Road Works: *Transfund New Zealand Research Report No. 132.*

This first report consists of an overview and a case study with an associated environmental effects assessment used to develop the guidelines.

The guidelines, which form parts II and III of the project (Transfund New Zealand Research Reports 131 and 132), have been developed in order to minimise adverse effects of road works associated with erosion and sediment run-off created by construction of roads. They are also to help improve environmental management, and promote compliance with the Resource Management Act 1991, by roading contractors.

PART 1 OVERVIEW

1. INTRODUCTION

1.1 Background

This project was undertaken in 1997-98 to prepare two sets of provisional guidelines for roading contractors - one for managing any erosion and sediment movement that may occur during road works, and the other for environmental management during road works. The guidelines aim to provide clear sets of principles and methods to ensure that the environmental effects of road works on the surrounding environment can be minimised by roading contractors. They are intended to be used primarily by roading contractors.

The results of the project are presented as three reports:

I. Overview & Case Study: *Transfund New Zealand Research Report No. 130.*

II. Provisional Guidelines for Erosion & Sediment Management during Road Works: *Transfund New Zealand Research Report No. 131.*

III. Provisional Guidelines for Environmental Management during Road Works: *Transfund New Zealand Research Report No. 132.*

The first task of the project was to carry out a literature review of relevant guidelines, and undertake a case study which identified associated environmental effects. The project included input from users and regulatory authorities. This first report, *I. Overview & Case Study,* describes the initial work used to develop the guidelines.

These guidelines have initially been produced as provisional to provide the opportunity for refinement following their trial use by roading contractors. They are not substitutes for resource consents or for any additional conditions or rules used by regulatory authorities. Instead, they are a practical tool to alert contractors of the legal context in which they are working and of the potential for adverse environmental effects arising from their activities. The provisional guidelines also identify ways to avoid, remedy and mitigate potential adverse effects.

Transfund New Zealand is committed to minimising the adverse effects of the road infrastructure on the environment. Part of this commitment included developing these guidelines to inform roading contractors of their responsibilities under the Resource Management Act 1991 (RMA), thereby avoiding costly measures to clean up any adverse effects, and also the costs of possible litigation.

The benefits associated with adopting these guidelines include:

- Better understanding of sustainable practices and methods;
- Protection of water quality and aquatic life;
- Time and cost savings associated with design and review input, with standardisation of some solutions, and with contractual disputes and litigation;
- Compliance with the RMA, and avoiding potential abatement and enforcement notices;

- Improved public perception of contractors, and
- Assistance to obtain, or to avoid the need for, some resource consents.

Road construction operations can potentially adversely affect the environment, particularly as a result of sediment run-off which enters waterways. Such effects can also cause additional costs for contractors as a result of extra work, site clean-up and time delays. In cases of serious negligence, there is also potential for litigation under the RMA.

Adverse environmental effects associated with road construction may result from site disturbance in both the long-term effects of the road or road modification, and the short-term effects of the construction activity itself.

These guidelines are intended for use by roading contractors to identify practices and methods to avoid the adverse environmental effects of road works.

1.2 Other Guidelines

Three other relevant guidelines are concurrently being developed, as follows:

- **Operator RMA Manual**

(a draft guideline, being prepared by the NZ Contractors' Federation Inc.) - a guideline for a range of civil construction activities to help meet the requirements of the RMA. It explains the requirements of the RMA but, although it details effects to be avoided, it does not include methodology.

- **Environmental Management Code of Practice: NMM Physical Works**

(a draft, being prepared by Opus International Consultants Ltd (Opus)) - to provide clear environmental performance objectives for all Network Management & Maintenance (NMM) work carried out on the State Highway Network on behalf of Transit New Zealand.

- **Draft Protocol between Department of Conservation (DOC) and Transit New Zealand for Highway Maintenance in the Nelson/ Marlborough Regions**

(a draft, being prepared by DOC Nelson and Constantine Planners Limited) - a document to alleviate a number of concerns that were held by DOC, Transit New Zealand and Forest and Bird (Royal Forest & Bird Protection Society of New Zealand) during the process of commenting on the Proposed Marlborough Sounds Resource Management Plan.

2. TRANSFUND NEW ZEALAND GUIDELINES

The Transfund New Zealand guidelines developed in this project deal specifically with road construction and maintenance. They outline methods for managing environmental effects of road works that are tried and true, practical and affordable.

The possibility that the above documents duplicate each other has been recognised, but they are in fact complementary. For example, the attached provisional guidelines provide descriptive means for contractors which will assist contractors in meeting the requirements of the draft NMM Code of Practice.

Discussions have been held with the Contractors' Federation, Opus and DOC about their draft guidelines. Members of the Contractors' Federation were interviewed as part of our information gathering process, and they have had the opportunity to make comments, as have Opus and DOC. Literature reviews, interviews, and a case study with an environmental effects assessment have been carried out in order to develop the guidelines. These are detailed in Parts 1 and 2 of this report. Any comments received have been incorporated in the provisional guidelines, presented as Transfund New Zealand Research Reports 131, 132 of the project.

2.1 Provisional Guidelines for Erosion and Sediment Management during Road Works

The results obtained from these processes have been incorporated in

II. Provisional Guidelines for Erosion & Sediment Management during Road Works: *Transfund New Zealand Research Report No. 131.*

2.2 Provisional Guidelines for Environmental Management during Road Works

As for the guidelines above, the results obtained from the reviews, interviews and studies have been incorporated in

III. Provisional Guidelines for Environmental Management during Road Works: *Transfund New Zealand Research Report No. 132.*

3. DEVELOPMENT OF GUIDELINES

The method of developing the guidelines comprised the following:

1. Review of existing information gathered from regulatory authorities and other sources (see Section 3.1 of this report);
2. Structured interviews with roading contractors and regulatory authorities: these interviews assessed past and present practices, levels of understanding of environmental impacts and of the RMA, and features of the guidelines that would be most useful (see Section 3.2);
3. A case study with associated environmental effects assessment of a construction project where sediment run-off control measures were implemented, and monitoring of the resulting water quality was undertaken. The actual impacts on water quality and on aquatic ecosystems resulting from inappropriate sediment control practices was part of the case study (see Part 2 of this report).

3.1 Literature Review

The documents listed below have been reviewed, and are summarised in the Appendix to this report. These documents are from a variety of sources around New Zealand and Australia, but it is not exhaustive.

1. *Draft Protocol between the Department of Conservation and Transit New Zealand for Highway Maintenance in the Nelson/Marlborough Regions* (Draft 29.5.1997).
2. Draft *Operator RMA Manual,* NZ Contractors' Federation Inc. (March 1998 version).
3. Draft *Environmental Management Code of Practice: NMM Physical Works*, Transit New Zealand (January 1998 version).
4. *Design Guidelines for Earthworks, Tracking and Crossings*, Environment Waikato (1995).
5. *Guidelines for Silt Control Associated with Mass Earthworks*, Wellington Regional Council (1988).
6. Extract from *Earthworks and Construction*, Wellington Regional Council (1994).
7. *Construction Techniques for Sediment Pollution Control,* Environment Protection Authority, Victoria, Australia (1991).
8. *Better Drainage: Guidelines for the Multiple Use of Drainage Systems*, prepared by Land Systems EBC Pty Ltd for the New South Wales Government Department of Planning, Australia (1993).
9. Draft *Managing Urban Stormwater: Strategic Framework*, prepared by the New South Wales Environment Protection Authority for the State Stormwater Coordinating Committee, Australia (1997).
10. Draft *Managing Urban Stormwater: Construction Activities*, prepared by the New South Wales Environment Protection Authority for the State Stormwater Coordinating Committee, Australia (1996).
11. Draft *Managing Urban Stormwater: Treatment Techniques*, prepared by the New South Wales Environment Protection Authority for the State Stormwater Coordinating Committee, Australia (1996).
12. *Proposed Regional Plan: Sediment Control*, Auckland Regional Council (ARC) (1995).
13. *Erosion and Sediment Control Guidelines for Earthworks*, ARC (1995 - updated version of the 1992 guidelines).
14. *Stormwater Treatment Devices: Design Guideline Manual*, prepared for ARC by Beca Carter Hollings and Ferner Ltd (1992).
15. *New Zealand Forest Code of Practice* (2nd Edition), New Zealand Logging Industry Research Organisation (LIRO), Rotorua (1993).
16. *Roading Projects under the Resource Management Act*, Terry Brown, Regional Manager, Auckland, Transit New Zealand (undated).
17. *Planning for a Safe and Efficient State Highway Network under the Resource Management Act 1991*, Transit New Zealand (1994).
18. *Transit New Zealand and the Environment*, Transit New Zealand (1993).
19. *Adopt a Highway Scheme*, Transit New Zealand (1993).

3.2 Interviews

Interviews were conducted with the following people and organisations. Their comments and assistance have been invaluable in developing these draft guidelines.

NAME	Organisation/ Position	Contact Details
Rob Robson	Wellington Regional Council Policy Unit	(04) 384 5708 PO Box 11 646, Wellington
Dave Brash Eric Pile	Ministry for the Environment, CEO	(04) 917 7410 PO Box 10362, Wellington
Pieter Burghout	Chief Executive, New Zealand Contractors' Federation Inc.	(04) 496 3273 PO Box 12013, Wellington
Kevin Turner	Works Civil Construction	HO (04) 495 3238 PO Box 47008, Trentham, Upper Hutt or Orewa (09) 427 8600
Richard Balsillie, Warren Higgs	Stevensons Construction	(09) 476 1351 PO Box 9400, South Auckland Mail Centre
Kevin Fisher, Craig Smart, Mike Buchan	Works Civil Construction	(07) 847 0699 PO Box 15226, Hamilton
Graeme Ridley, Al Shaver	Auckland Regional Council	(09) 379 4420 Private Bag 92012, Auckland
Bryan Hudson	Waipa District Council	(07) 871 7133 Private Bag 2402, Te Awamutu
Neil Prendiville, Simon Guillemin	Waitakere City Council, Roading Assets Engineer	(09) 836 8000 Private Bag 93109, Henderson
Bill Horn	Rodney District Council Roading Engineer	(09) 426 5169 Private Bag 500, Orewa
George Griffiths	Canterbury Regional Council, Group Manager - Environmental Monitoring	(03) 365 3828 PO Box 345, Christchurch
John Haugh	Works Civil Construction	(03) 343 0650 PO Box 11326, Christchurch
George Jason Smith	Waimakariri District Council Roading Assets Manager	(03) 313 6136 Private Bag 1005, Rangiora
Peter Christophers, Richard Pettinger, Barry Johnson	Otago Regional Council	(03) 474 0827 Private Bag 1954, Dunedin
Murray Burns	Clutha District Council	(03) 418 1350 PO Box 25, Balclutha
Ken Swinney, Ian Welsh	Southland Regional Council	(03) 215 6197 Private Bag 90116, Invercargill
John Whyte	Fulton Hogan	(03) 488 3059 Private Bag 1962, Dunedin
Jim Westwood	Duffill Watts and King	(03) 477 7133 PO Box 910, Dunedin
Trevor Tattersfield	Southroads	(03) 215 9191 PO Box 968, Invercargill
Graham Henderson	Works Civil Construction	(03) 488 4155 PO Box 13031, Dunedin
Andrew Fenemor	Tasman District Council	(03) 544 8176 Private Bag 4, Richmond
Mike Edridge	Edridge Contractors	(03) 571 6082 Pelorus Bridge, RD2, Rai Valley
Ross MacArthur	Works Civil Construction	(03) 546 4681 PO Box 540, Nelson

4. IMPLEMENTATION

To ensure that the provisional guidelines achieve the outcomes that they are designed to produce, they have been made available to a number of contractors on a trial basis.

To facilitate this, workshops may be useful to introduce contractors to the guidelines. Following the trial, appropriate amendments and adjustments could be made to the provisional guidelines and they could then be published as an operational document.

PART 2 CASE STUDY

5. INTRODUCTION

A case study was carried out in 1997-98, in order to assist in the development of the two sets of provisional guidelines for environmental management during road works. As part of the methodology for this research programme, tasks that were proposed included:

Task C Case Studies
Identify appropriate projects in the coming construction season and undertake and document a number of physical tests of sediment run-off control measures and associated resulting water quality. This will be done in conjunction with contractors.

Task D Impact Assessment
Undertake an assessment of the actual impacts on water quality and aquatic ecosystems resulting from inappropriate sediment control practices. This would include an assessment of impacts resulting from nutrients, organic material, suspended sediments, reduced visual clarity.

The work undertaken and the associated results of the above tasks are outlined in this Part 2 of the report. Given the dry summer experienced over the 1997-98 construction period and the lack of road construction projects taking place alongside water courses, only one case study was appropriate for this component of the work. The project was part of the Rahui Water Supply Reservoir construction in the Korokoro Stream catchment, Lower Hutt, New Zealand.

5.1 Description of Project Area

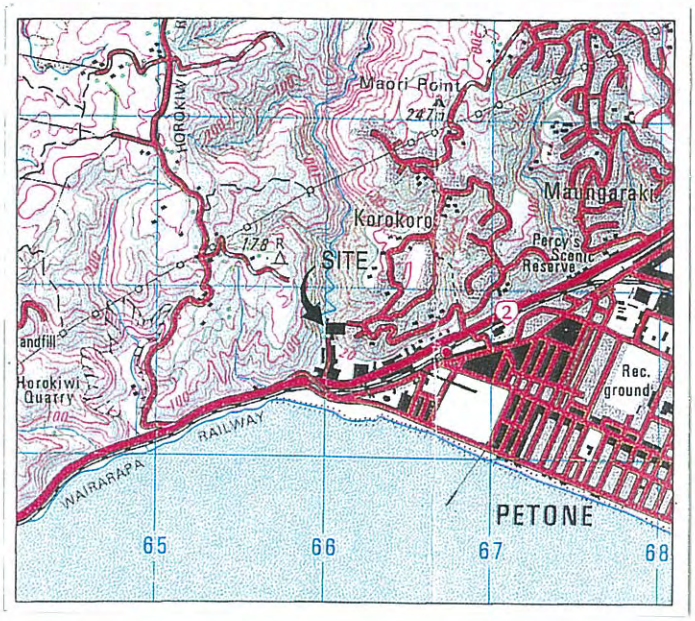
The Korokoro project involves the construction of a major water supply reservoir in the hills above the Hutt Valley. The works include road construction and major excavations on a steep slope with difficult access. The project is located partly within the Belmont Regional Park, and many of the construction activities have occurred close to Korokoro Stream which is recognised as having high ecological and recreational values (Figure 5.1).

The case study includes the following components:

- description of the existing environment;
- description of construction and road work activities;
- identification of potential sediment control issues;
- description of sediment control measures employed;
- discussion of the effectiveness of measures employed;
- monitoring of receiving water quality and aquatic biota.

This information was then used to undertake an assessment of effects on the receiving waters of Korokoro Stream.

Figure 5.1 Location of Korokoro Reservoir Project.



5.2 Existing Environment

Belmont Regional Park is a recreational reserve of significant size, administered by the Wellington Regional Council. The dominant feature of the park is Korokoro Stream which drains a largely undeveloped catchment, 15.9 km^2 in area, with extensive vegetation cover including large areas of regenerating bush. The stream is a moderately small water course with a median flow of 173 ℓ/s, but occasional large flood flows are experienced giving a five year return maximum flow of 41 m^3/s.

Monitoring of stream water quality to 1996 has shown consistently high water clarity and low contaminant levels (WRC 1996). The stream supports a moderately abundant population of small brown trout and at least nine species of native fish including white bait species, bullies and eels. Also the WRC monitoring of macro-invertebrate communities in the lower stream showed a moderate species diversity, in which the sensitive Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (Caddisfly) groups were well represented. The community composition was indicative of healthy in-stream conditions.

5.3 Description of Construction & Road Works

The Rahui Water Supply Reservoir site is located on a steep scrub-covered spur overlooking the Korokoro Valley. The earthworks and site preparation works included the excavation and removal of 24,000 m^3 of spoil from the reservoir site, and the construction of two short sections of road. An access road runs for 250 m around the head of a steep-sided gully from suburban Korokoro to the reservoir site.

A separate haul road runs 220 m along the floor of the Korokoro Valley crossing Korokoro Stream at three locations.

Spoil excavated from the reservoir site is conveyed down a steep slope by a chute to the valley floor from where it is trucked off-site along the haul road. The terrain presents potential difficulties in controlling sediment run-off because of the steep slopes and closeness of the works to the water course.

The main construction activities are summarised as:

- Construction of the access road and reservoir platform;
- Construction of haul road with three stream crossings;
- Spoil removal requiring 4000 truck-trailer movements along haul road.

5.4 Construction of Access Road & Reservoir Platform

5.4.1 Construction & Road Works

Realignment and extension of a road to the reservoir site entailed clearance of scrub and small trees and significant earthworks forming a series of cut faces up to a height of 6 m. These works were undertaken on a steep slope in regenerating native bush. The access road terminates at the reservoir site where the excavation of 24,000 m^3 of spoil forms a circular benched platform about 50 m in diameter butting up to a 15 m-high cut face. The spoil is pushed off the ridge down a purpose-built chute which conveys it to the floor of Korokoro Valley.

5.4.2 Sediment Control Issues

The primary sediment control issues were:

- Vegetation removal and soil disturbance associated with the access road construction and excavation of reservoir platform. These works cover an area of around 5000 m^2 at the head of a steep gully which drains into Korokoro Stream. A small ephemeral water course in the gully could potentially carry a significant sediment load to Korokoro Stream during a heavy rain event.
- Potential dust nuisance associated with earthworks.

5.4.3 Mitigation Measures

The mitigation measures employed were:

- Minimising the area of exposed or disturbed earth.
- Diverting "clean" stormwater away from areas of disturbed soil. Stormwater channels and culverts were established at an early stage of development, to allow stormwater to pass under the new road. Most of the earthworks took place inside low earth bunds, and later inside concrete kerbing, so that most stormwater is now diverted under the road at established culverts, without passing through significant earthworks.
- Implementing a comprehensive re-vegetation plan as soon as practicable.

5.5 Construction of Haul Road

5.5.1 Construction & Road Works

Spoil excavated from the reservoir site was conveyed down a spoil chute to the floor of Korokoro Valley. The haul road runs from the base of the chute along the valley floor beside Korokoro Stream for 250 m to the industrial area of Petone. The haul road crosses the stream by fords at three locations. The two upper fords are temporary and have been constructed of clean rock contained in wire-mesh gabion baskets. A permanent concrete ford has been installed at the lower stream crossing at the park entrance where a new car park will be developed. The haul road was finished in chipseal.

5.5.2 Sediment Control Issues

The primary sediment control issues were:

- Construction of the three stream crossings would cause significant disruption to the stream bed in the immediate vicinity of the works. Also more widespread downstream water-quality degradation could be caused by the release of silt.
- Construction of stream crossings could present a barrier to fish passage. Fords were selected in preference to culverts or other means of crossing the stream, because the over-riding objective was to minimise modifications to the natural character within the regional park.
- Vegetation removal and soil disturbance over sections of the haul road and a car park area on flat land adjacent to the stream were stripped of vegetation and re-shaped by heavy machinery.

5.5.3 Mitigation Measures

The mitigation measures employed were as follows:

- All construction works in Korokoro Stream were undertaken over the summer period and no in-stream works were permitted during the period from 31 May to 30 September. This restriction was implemented to minimise adverse effects on fish spawning activities.
- The stream was diverted around the ford (and pipeline) construction works. Diversion works were implemented in a manner that provided for fish passage, except for very short periods. This was achieved by the use of small upstream weirs and temporary pipe work to carry stream flows past the works area.
- Construction activities were limited to the hours 7am to 7pm Monday to Saturday, with no work on Sundays. Aside from minimising social impacts, this had the effect of ensuring stream water quality returned to near-ambient conditions for around 50% of time during the construction period.
- The road was strengthened with base coarse and finished in chipseal.
- A comprehensive re-vegetation plan is to be implemented as soon as practicable.
- Filter-cloth fences were positioned at the vehicle turn-around area (at the base of the chute) where vehicles and loaders were operating in close proximity to the stream.

5.6 Spoil Removal

5.6.1 Construction & Road Works

Approximately 4000 truck-trailer movements along the haul road over a 7-month period were required to remove the spoil excavated from the reservoir site. A front end loader and digger were used at that point to gather in the spoil from the chute and to load the trucks.

5.6.2 Sediment Control Issues

The primary sediment control issues were:

- The spoil stockpile, loading area and the haul road turn-around area, are susceptible to sediment mobilisation by stormwater run-off during heavy rain.
- The continual stream crossings made by truck trailer units at one permanent and two temporary fords are a potential source of sediment contamination in the stream during both dry and wet conditions.
- Wind-blown dust is a potential secondary cause of contamination of stream water during dry weather.

5.6.3 Mitigation Measures

The primary mitigation measures employed were as follows:

- The provision of earth bunds and filter-cloth fences around the spoil stockpiles;
- Wheel-wash facilities for vehicles exiting the works area;
- Provision of water-misting facilities for dust control under dry conditions;
- The provision of well constructed ford structures which, once in place, would enable vehicles to cross without further release of sediment to the stream.

6. ENVIRONMENTAL EFFECTS ASSESSMENT

6.1 General

Monitoring the quality of the receiving water has been undertaken as part of this investigation to assess the effects of the construction activities on the water quality and biota of Korokoro Stream. Five monitoring sites have been selected: K1, K2, K3 and K4 on Korokoro Stream, and T1 at the ephemeral creek on the side gully (Figure 6.1).

Water quality at all sites was monitored on three occasions during dry weather and on two occasions during wet weather. Samples could not be collected at T1 on any of the sampling occasions because the flow was not sufficient. This is a result of the unusually dry weather conditions that were experienced during the construction period. Macro-invertebrate communities were sampled at K1 and K2 midway through the survey.

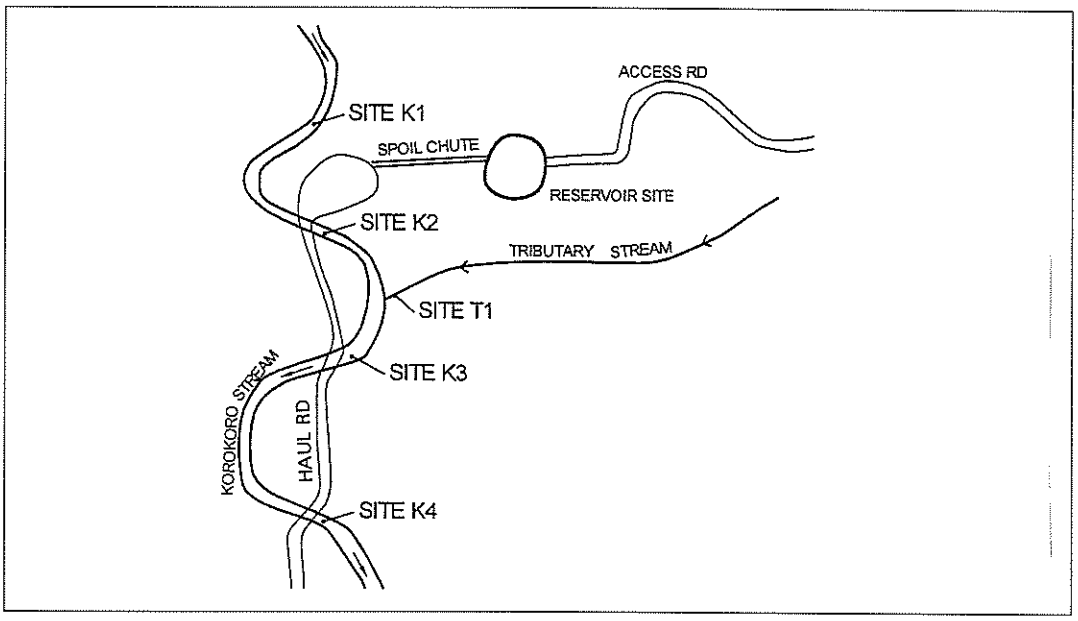


Figure 6.1 Locations of monitoring sites in Korokoro Stream.

6.2 Water Quality

Results of water quality measurements made at sites on Korokoro Stream and its tributary under both dry and wet weather conditions during the construction period are summarised in Table 6.1.

Water clarity was measured by horizontal visual black disc range (BDC). The related parameters "turbidity" (Turb, NTU[1]), i.e. cloudiness, and "suspended solids" (SS), i.e. concentration of suspended particulate matter in a water sample, were also measured. Nutrient content was assessed by measuring dissolved reactive phosphorus (DRP) and nitrate nitrogen (NO_3-N). The pH of stream water and electrical conductivity (Cond. μS/cm) were also tested as general water quality indicators.

The water quality data show a major deterioration in turbidity, suspended solids and water clarity at sites downstream of the works area. Some of the poorest water quality was recorded during periods of dry weather and was caused almost entirely by vehicles crossing the stream at the temporary fords. Each vehicle crossing caused a pulse of sediment to discharge into the stream. This occurred at frequent intervals throughout the day and caused wide fluctuations in water clarity. However water clarity increased rapidly at the completion of work each day.

Neither of the two rain events had caused any surface water flow in the ephemeral tributary at the time the samples were collected. Any run-off from the access road and reservoir construction site appears to have soaked into soils and gravels en-route to the stream. A rain gauge located at Puketiro School, Maungaraki, about 4 kilometres from the site, indicated that 22.8 mm and 15 mm fell on 7/5/98 and 14/5/98 respectively.

[1] NTU Nephelometric turbidity unit

Table 6.1 Results of water quality measurements for Korokoro Stream.

Site	*Date*	*Weather*	*Flow*	*Machines operating*	*pH*	*Cond. (µS/cm)*	*Turb. (NTU)*	*SS (g/m³)*	*BDC (m)*	*DRP (g/m³)*	*NO_3-N (g/m³)*
K1	2/4/98	dry	low	yes	7.4	252	0.3	3	5.8	0.03	0.5
	8/4/98	dry	low	yes	8.0	220	2.5	2	5.6	0.05	0.5
	29/4/98	dry	mod	yes	7.7	230	1.0	<2	5.3	0.1	1.7
	7/5/98	wet	mod	yes	7.6	276	0.9	<2	5.2	0.2	0.6
	14/5/98	wet	mod	no	7.5	269	6.3	2	5.0	<0.1	0.4
					(7.6)	(249)	(1.3)	(1.8)	(5.4)	(0.07)	(0.74)
K2	2/4/98	dry	low	yes	7.4	254	80.1	158	<0.5	0.02	0.5
	8/4/98	dry	low	yes	7.9	247	4.5	3	1.0	0.06	0.4
	29/4/98	dry	mod	yes	7.7	257	85	60	<0.5	<0.1	0.8
	7/5/98	wet	mod	yes	7.5	272	77.1	33	<0.5	<0.1	0.6
	14/5/98	wet	mod	no	7.4	276	10.9	6	1.8	<0.1	0.6
					(7.6)	(261)	(52)	(52)	(0.7)	(0.05)	(0.6)
K3	2/4/98	dry	low	yes	7.3	247	119	164	<0.5	0.02	0.4
	8/4/98	dry	low	yes	7.7	242	4.1	2	2.4	0.07	0.5
	29/4/98	dry	mod	yes	7.8	242	150	226	<0.5	<0.1	0.7
	7/5/98	wet	mod	yes	7.5	262	124	108	<0.5	<0.1	0.6
	14/5/98	wet	mod	no	7.5	277	5.7	9	2.3	<0.1	0.4
					(7.6)	(254)	(81)	(102)	(1.0)	(0.05)	(0.5)
K4	2/4/98	dry	low	yes	7.3	248	91.6	115	<0.5	0.02	0.4
	8/4/98	dry	low	yes	7.7	245	27.9	18	<0.5	0.04	0.4
	29/4/98	dry	mod	yes	7.8	247	87	100	<0.5	<0.1	0.8
	7/5/98	wet	mod	yes	7.4	269	223	176	<0.5	<0.1	0.6
	14/5/98	wet	mod	no	7.5	274	5.1	7	2.4	<0.1	0.4
					(7.5)	(257)	(87)	(83)	(0.7)	(0.04)	(0.5)
T1	2/4/98	dry	none	yes	nr	nr	nr	nr	nr	nr	nr
	8/4/98	dry	none	yes							
	29/4/98	dry	none	yes							
	7/5/98	wet	none	yes							
	14/5/98	wet	none	no							

Note - Mean values are given in brackets
nr - not recorded

Rain falling onto the haul road turn-around and spoil loading areas while vehicles were operating (7/5/98), did cause significant sediment contamination in Korokoro Stream. The second rain event (14/5/98), which produced only moderate stormwater flows, and when vehicles were not operating, had very little effect on stream water clarity.

6.3 Aquatic Biota

A survey of benthic macro-invertebrates was undertaken in the middle of the construction season at sites K1 and K4, upstream and downstream of the construction site (Figure 6.1). The data show a loss of the mayflies *Coloburiscus* and *Deleatidium* at the downstream site, and a reduction in both species richness and the macro-invertebrate community index (MCI) value.

The increased sediment load and reduced water clarity reported in Table 6.1 are likely to have reduced the production of algae on the stream bed by the deposition of a silt and the reduction of light levels. This may reduce or eliminate the food source for grazing animals such as mayflies and stoneflies and probably accounts for the loss of

two mayfly species at K4 (Table 6.2). The total invertebrate biomass could be expected to gradually reduce with time while the poor in-stream conditions continue.

Table 6.2 Macro-invertebrate survey results
(from three replicate kicknet samples collected from each site on 2/4/98)

Macro-invertebrate Data	Site K1	Site K4
Ephemeroptera (mayfly) Plecoptera (stonefly) Trichoptera (caddisfly)	223	24
Species Richness	17	12
MCI (Macro-invertebrate Community Index)	106	97

These effects are likely to be temporary however and a rapid return to a normal benthic community composition could be expected as water quality improves at the end of the earthworks programme.

Reduced water clarity and declining food production would reduce the suitability of this area as fish habitat and it is likely that, during the earthworks programme, the lower reach of Korokoro Stream would have a reduced fish population. Fish that were normally resident in this reach were likely to have moved upstream above the area affected by the works.

One of the key mitigation measures of the construction programme was that in-stream works would not be undertaken during the period 31 May to 30 September to avoid disruption of any fish spawning activities. Water quality, benthic fauna and fish habitat are likely to recover rapidly and to maintain good condition during this winter period.

7. SEDIMENT MANAGEMENT MEASURES

7.1 Access Road and Reservoir Platform

As the catchment area is limited, large surface water flows would not occur except during exceptionally heavy rain events. Rain water falling directly onto the works area would, in most cases, pond or percolate into the ground. In those instances where surface run-off did occur, the flow could run from the works area 30 m overland to an ephemeral stream and then for about 150 m into Korokoro Stream.

The original mitigation method proposed for the reservoir platform site was the construction of a ring drain around the construction area. This drain would be sized to have a surface area equal to 1% of the works area. It would act as a settling pond for all run-off from exposed earthworks in this area. The ring drain would discharge to the gully. However, in practice, no formal sediment control structure was constructed because it was considered to be unworkable given the steep slopes and

limited space. It was also considered to be unnecessary because of the successful diversion by bunds of most stormwater overland.

Monitoring undertaken in this study (Section 6 of this report) indicates that the volumes of stormwater running off this area were low, and have contributed little or no silt contamination to Korokoro Stream.

7.2 Haul Road Construction

The stream diversions and construction of fords (and pipeline stream crossing) were undertaken in January and February during dry weather when stream flows were low. As expected, these works caused major sediment discharges to the stream intermittently over a period of about three weeks. Visual assessment indicates however that stream water cleared quickly at the end of each working day so that "normal" water clarity was maintained for 10 to 12 hours each day. The stream diversions were implemented quickly so that fish passage was directly obstructed for a total of no more than 8 days.

Apart from the stream crossings, the remaining sections of the haul road were completed quickly in dry conditions. The disturbed soil was reinstated and the road surface was sealed, with little mobilisation of sediment.

The least satisfactory element of the haul road sediment control measures was the treatment of the truck turn-around and spoil loading area at the base of the chute. Disturbed soil remained exposed in this area down to the edge of the stream. Some nominal attempt to control sediments was shown by the placement of filter-cloth fences beside the stream but these were rather ineffectual, particularly when vehicles were operating in wet conditions. Water quality monitoring indicated that the operation of vehicles during heavy rain resulted in significant sediment mobilisation at the truck turn-around area.

The preferred method would have been the provision of a 2 to 3 m-wide vegetated strip between the turn-around area and the stream, in addition to the strategic placement of filter fences.

7.3 Spoil Removal

During the peak spoil haulage period, truck/trailer units made up to 50 movements per day along the haul road.

While the permanent concrete ford performed well, the two temporary rock basket fords proved to be a problem. The reason for this was that the rock basket structures flexed up and down with each truck crossing. This movement gradually eroded the stream bed substrate and pumped fine particulate material into the stream. The rock baskets gradually settled into the stream bed and had be built up by adding further material at intervals.

Water quality monitoring showed that truck movements along the haul road were capable of producing suspended solids concentrations in the stream in excess of 200 g/m^3, and reducing visual clarity (black disc) to less than 50 cm. Truck movements across the temporary fords were the single most important cause of sediment discharge to the waters of Korokoro Stream, in both wet and dry weather conditions.

7.4 Effectiveness of Sediment Management Measures

The monitoring undertaken in this study (Section 6) indicated that volumes of stormwater running off this area were low and have contributed little or no silt contamination to Korokoro Stream.

Sediment management measures employed at Korokoro included:

- Bunds and culverts to divert clean stormwater around works area;
- Minimised extent of earthworks;
- Comprehensive re-vegetation programme;
- Temporary sealing of haul road;
- Settling pond (not implemented);
- Filter-cloth fences to reduce run-off velocity;
- Stream diversions to minimise effects of in-stream construction works;
- Daily and seasonal restrictions of hours of in-stream works.

The most efficient and cost-effective means of sediment control employed at Korokoro was, wherever possible, to divert clean stormwater away from the earthworks. This is obviously easier to achieve when the area of disturbed land is small and large tracts of undisturbed vegetation are left in place.

Areas that are disturbed can be rapidly stabilised by hydroseeding and early implementation of a planting programme. All temporary roads and stream crossings were constructed to a high standard. However, the temporary stream crossings were unsuccessful in this regard and only the permanent (concrete) ford performed satisfactorily.

The need for a settling pond in this situation was avoided by the effective use of the first two methods listed above.

Filter-cloth fences were relatively ineffective at this site and in retrospect a greater effort could have been made to maintain vegetated buffer strips beside the stream. This combination would have been more successful.

Stream diversions can be used to minimise the sediment discharge associated with works within the stream bed. Nevertheless significant short-term sediment mobilisation is likely to occur. Instead the effect of such works on the aquatic biota can be minimised by sensible programming of in-stream activities, i.e. imposing daily and seasonal restrictions.

8. CONCLUSIONS

The construction programme was greatly assisted by unusually dry weather through the summer and autumn, which enabled rapid progress through the earthworks and site preparation stage. The stormwater diversion drains and most of the earthworks were completed before any significant rainfall occurred. Consequently in this case the mobilisation of sediment by stormwater was not a major source of contamination.

However, significant sediment discharge did occur at temporary stream fords which were under-designed for the heavy use they received by truck and trailer units. This was an ongoing source of sediment contamination in the stream which caused a major reduction in water clarity.

Minor changes in the benthic macro-invertebrate community structure was also observed. However the in-stream works and haulage operation were programmed for completion by the end of May 1998 to minimise any effects on fish spawning activities. No long-term adverse effects in the receiving waters of Korokoro Stream are anticipated.

This investigation has highlighted the need for a comprehensive approach to sediment control during road construction. Reliance on any single measure is unlikely to produce a satisfactory outcome. Rather, silt control issues associated with each component of the operation need to be identified at an early stage and addressed by the application of appropriate sediment control methods.

9. REFERENCE

Wellington Regional Council (WRC). 1996. *Baseline Water Quality of Rivers and Streams in the Western Wellington Region.* File 1995/1996, WRC/RINV-T-96/32.

APPENDIX

APPENDIX SUMMARIES OF LITERATURE REVIEWS

(The documents summarised in this Appendix are listed in Section 3.1 of this report.)

Draft Protocol between the Department of Conservation and Transit New Zealand for Highway Maintenance in the Nelson/Marlborough Regions
(Draft 29.5.1997)

- A protocol - prepared to alleviate concerns of interested parties, and by following it to avoid, remedy or mitigate the adverse effects of road maintenance.

- Water clarity by sedimentation - is of particular concern, and particularly noticeable where water clarity is naturally high. Protect water clarity by the following actions.
  - Minimise direct stormwater run-off into waterways during construction; protect disturbed areas from run-off above site, e.g. diversion; keep on-site run-off velocities low (methods given);
  - Inspect and maintain control measures;
  - Keep disruption of waterways to smallest area and for shortest time period possible; minimise area of bare soil; account for season and weather; stage the works; stabilise quickly; revegetate after each stage; repeat revegetation if required;
  - Take into account sensitive site conditions, e.g. swamps; limit development to appropriate terrain;
  - Control erosion at source;
  - Stabilise disturbed areas as soon as possible (structural and revegetation methods);
  - Retain existing vegetation where feasible;
  - Avoid sensitive times of year for certain fish species;
  - Consult DOC, and Fish and Game Council;
  - If reduction in visual clarity exceeds 20% (black disk method), install sediment traps (methods for grass-filter strips, sediment traps are described).

- Fish passage and habitat - are affected by culverts that constrict or are raised above stream bed; and by clearance between culvert and stream. Protect by the following actions.
  - Ensure fish passage is unimpeded;
  - Restore stream beds, wetlands, adjacent vegetation;
  - Retain vegetation near waterways;
  - Retain natural shape in cross section & longitudinal slope when channel shaping;
  - Avoid in-stream works at sensitive times of year for certain fish species;
  - Replant with native vegetation.

- Spoil disposal - can be visually unacceptable and damaging to natural habitats, specially in coastal marine areas (CMA), native vegetation, and wetlands.
  Avoid CMA, native vegetation, streams and wetlands.

- Vegetation control - retain native vegetation, avoid introduced species, control noxious weeds

- Coastal marine area - effects on habitats of biota; filling of inlets reducing tidal flushing of inlets; avoid filling in valuable CMA.

- Historical/archaeological sites - if uncovered in excavations, avoid further damage.

Draft *Operator RMA Manual*, NZ Contractors' Federation Inc.
(March 1998 version)

- A draft manual, prepared by the NZ Contractors' Federation Inc. - for contractors who are undertaking a range of civil construction activities, to help them meet the requirements of the RMA.

- It explains the requirements of the RMA, and details effects to be avoided. It does not include methodology.

Draft *Environmental Management Code of Practice: NMM Physical Works*,
Transit New Zealand (January 1998 version).

- A draft code, prepared by Opus International Consultants Ltd, to provide clear environmental performance objectives for all maintenance work carried out on the State Highway Network, on behalf of Transit New Zealand.

- It is designed to embed the policy statements which have preceded it, and to provide performance standards to be met by contractors and consultants to ensure that their performance meets Transit New Zealand's environmental standards for network maintenance operations.

- It provides a matrix to illustrate where roading activities impact on environmental issues.

- It provides key environmental points and comments to consider when undertaking various roading operations.

Design Guidelines for Earthworks, Tracking and Crossings,
Environment Waikato (1995)

- A practitioner's technical guide: describes erosion and sediment control measures, and principles that need to be adopted when an operation is being planned, and need to be appropriately programmed into the work as it progresses.

- It provides some generalised guidelines for erosion control structures and methods, such as:
  - run-off diversion channels;
  - culverts, cutoffs, humps and hollows;
  - contour drains;
  - sediment retention ponds;
  - check dams;
  - silt fences;
  - hay-bale barriers;
  - stormwater inlet protection;
  - topsoiling, re-vegetation, mulches and vegetated buffer strips;
  - culvert crossings and bridges.

***Guidelines for Silt Control Associated with Mass Earthworks*,**
Wellington Regional Council (1988)

These guidelines are aimed for use in planning erosion and silt control associated with mass earthworks, land development and quarrying.
They include general guidelines for the purposes of :

- silt control (stream channel efficiency, aquatic life, compliance, etc.);
- construction programming (seasons, staging, silt control);
- stormwater systems (diversion, structure or traps, cutoff drains);

They give design criteria for silt ponds and drawings of:

- float-operated outlet structures for large or permanent silt ponds;
- float-operated inlet structures for these;
- silt traps, graded V-drains and contour drains;
- silt ponds in series;
- minor silt ponds and silt traps;
- silt retention fences;
- while accounting for very steep terrain.

Extract from *Earthworks and Construction*, Wellington Regional Council (1994)

This extract gives information about:

- Site preparation (plan cut and fill, fence, erosion control, stripping topsoil);
- Stormwater control (for control and draining stormwater, construction at early stage in project, with benches sloping back and graded longitudinally);
- Subsoil drainage;
- Fill batters;
- Fill material.

***Construction Techniques for Sediment Pollution Control*,**
Environment Protection Authority, Victoria, Australia (1991)

- This is a guideline which summarises erosion and sedimentation controls needed during land development. Detailed design information is not included.
- Benefits of control are listed (e.g. reduced aquatic damage, improved appearance, reduced treatment costs, earlier completion of works, less chance of complaints by neighbours, less mud on roads, reduced downtime after rain).
- Water pollution effects are summarised (e.g. contamination, soil nutrients and chemical pollutants attach to and can be transported by sediment particles, blocked waterways).
- General principles summarise the controls needed, and are most easily achieved through early planning, and actions include:
  - Avoid critical locations (e.g. steep slopes, along streams);
  - Plan controls (before commencing works, calculate water discharge rates);
  - Protect drainage lines (by buffers, gradients);
  - Minimise soil exposure (area, staging, retain vegetation);
  - Install sediment traps, dams and basins (to good engineering standards, before commencing work);

- Install drainage early;
- Stabilise early;
- Divert water;
- Control waste (oil, grease, litter, etc. from the site);
- Maintain and re-assess controls.

- Standards for suspended solids, turbidity, pH and other pollutants, are given.

- Advice is provided about:
  - Early planning (prior planning, avoid sensitive areas, site and catchment plans, water discharge calculations);
  - Clearing vegetation (clearing controls, minimise and prevent, windrows, burning off, cultivation);
  - Providing buffer vegetation (boundaries, drainage);
  - Establishing vegetation (techniques, irrigation)
  - Using mulching;
  - Planning earthworks (e.g. protect exposed soil, dry and wet season work, staging earthworks, soil testing and treatment, batters, topsoil, retaining walls, avoid water jetting;
  - Preventing erosion of stockpiles of topsoil and building materials (e.g. by location, techniques);
  - Controlling dust (causes, solutions);
  - Designing drains, diversions and streams (erosion causes and solutions are given in some detail with respect to gully head erosion, channel bank and bed erosion.

- Channel stabilisation techniques outlined include:
  - Grass, mulch matting, plants, fences, rock armouring, gabions, pipes, structures, soil stabilisers, gully filling, pavement and temporary stabilisation;
  - Water drop or chute structures (some engineering standards and photos are given);
  - Dams and basins (guidelines for siting and building are given in some detail, including site investigations, capacities, inlet baffles, batters, wave protection, outlet structures and freeboard, leachate control, and safety);
  - Sediment and litter traps (e.g. for use when space is insufficient for dams or basins; information is provided about location, materials, traps, tenches and pits, gradients, capacities, stabilisation, litter, maintenance);
  - Water treatment (if trapped muddy water needs treatment before discharge, and information is given about pumping out, flocculation, settling, filters);
  - Vehicles and roads (road and track stabilisation, restrict access, intercept culverts, stream crossings, dirt on roads, cleaning vehicles and equipment, recycling, waste minimisation, pumps, oil separation)
  - Maintenance and waste disposal (waste control and removal, spillages, bunding).

***Better Drainage: Guidelines for the Multiple Use of Drainage Systems*,**
prepared by Land Systems EBC Pty Ltd for the New South Wales Government Department of Planning, Australia (1993)

- Guidelines to improve the management of open space that is used for drainage, e.g. using drainage corridors for recreation as well. Their emphasis is on urban drainage systems.

- Engineering requirements and guidelines are given for the development of drainage channels and flow control structures.
- Public safety considerations are outlined.
- Water quality (problems of urban run-off are outlined).
- Guidelines for landscape development and amenity values of water bodies.
- Maintenance (needs, problems, costs).

Draft *Managing Urban Stormwater: Strategic Framework*, prepared by the New South Wales Environment Protection Authority for the State Stormwater Coordinating Committee, Australia (1997)

- Promotes catchment-based stormwater management plans, and the management of stormwater quantity and quality as opposed to the traditional focus on flood mitigation and drainage.
- Outlines current policy and administrative framework within which a strategic approach to stormwater management can be supported.
- Urban stormwater and the environment (stream flow, water quality, riparian vegetation, aquatic habitat, watercourses, etc.).
- Urban stormwater management planning (plans, monitoring, catchment audits, stormwater source control).

Draft *Managing Urban Stormwater: Construction Activities*, prepared by the New South Wales Environment Protection Authority for the State Stormwater Coordinating Committee, Australia (1996)

- Provides technical guidance on managing urban stormwater during construction activities and land disturbance.
- General site management (waste disposal, co-ordination of work, minimising stormwater and land disturbance, routine inspections).
- Material handling (conserving topsoil, managing stockpiles).
- Soil stabilisation (re-vegetation, seeding, turf stabilisation, mulching, soil binders).
- Water control (earth banks, waterways, dams).
- Sediment control (grass-filter strips, minor sediment filters and traps, sediment-filter fencing, earth, rock, wire-mesh and geofabric traps, kerbline turf strips and various inlet filters).

- Major sediment retention basins (dry basins, rock and gabion construction dry basins, earth sediment basins with porous rider, wet (non-draining) basins, wet earth basins, sump pits and lined sediment sumps).
- Infiltration techniques (infiltration (absorption) trenches, basins, grass swales).
- Other management practices (stabilised site access, control of wind erosion, utility construction and flocculation).

Draft *Managing Urban Stormwater: Treatment Techniques*, prepared by the New South Wales Environment Protection Authority for the State Stormwater Coordinating Committee, Australia (1996)

- Provides technical guidance on the selection and functional design of stormwater treatment techniques for new urban residential areas, but not for roading projects which "have specific stormwater treatment requirements which differ to those applicable to residential areas".
- Stormwater treatment selection (selection approach, design, safety, maintenance).
- Pollutant trapping processes (summarised in a table).
- Stormwater treatment measures (litter baskets, racks and booms, continuous deflective separators, catch basins, water quality inlets, filter strips, grass swales, sediment traps, gross pollutant traps, extended detention basins, wet basins, constructed wetlands, infiltration trenches, infiltration basins, porous pavements and sand filters).

***Proposed Regional Plan: Sediment Control*, Auckland Regional Council (ARC)** [undated]

Auckland Regional Council has identified sediment discharge as the main pollutant, by volume, of the waterways of the region. Sediment discharge is addressed by this Regional Plan. It is a proposed plan, which incorporates changes from submissions received, and

- Suggests mechanisms for addressing sediment discharge from bare earth surfaces (examples including sediment retention ponds, geotextile silt fences, hay-bale barriers, filter measures, vegetated buffer strips, run-off control, minimum earthworks).
- Explains effects of sediment discharge to waterways (biological, effects on other pollutants, stream blockage, water quality for irrigation/drinking, etc., aesthetic values, damage to property and public utilities, significance to tangata whenua).
- Like other regional plans, it incorporates issues, objectives, policies, methods, rules, reasons and anticipated environmental results.

***Erosion and Sediment Control Guidelines for Earthworks*, Auckland Regional Council** (1995 - updated version of the 1992 guidelines)

- Outlines the Auckland situation.
- Processes and principles of erosion and sediment control are given:
  - keep disturbed areas small;
  - protect disturbed areas against run-off from above site;
  - keep on-site run-off velocities low;
  - retain sediment on site;

- stabilise disturbed areas;
- inspect and maintain control measures.

- Design considerations (earthworks, contaminated sites, channel works, road works, clean fills).
- Run-off control (diversion channels, contour drains, earth bunds).
- Sediment control (sediment ponds (general and design criteria are given), silt fences, hay-bale barriers, check dams, stormwater inlet protection). Diagrams for each method are given.
- Re-vegetation (topsoiling, re-vegetation, vegetated buffer strips).

Stormwater Treatment Devices: Design Guideline Manual,
prepared for ARC by Beca Carter Hollings and Ferner Ltd (1992)

- Provides guidelines for the design of devices to treat stormwater.
- Stormwater hydrology and quality (hydrology, nature of pollutants, etc.).
- Measures to improve quality (source abatement, run-off control, treatment devices).
- Choice of treatment device (advantages and disadvantages, and typical design constraints).
- Brief outline is provided for each of: extended detention (ED) sedimentation ponds, wet ponds, combined wet/ED ponds, marsh, dual purpose ponds, coarse sediment traps, filtration devices, infiltration trenches, swales, vegetated filter strips, oil separators, porous pavement and grid concrete pavement.
- Table summarises, for each device, its description, land use considerations, treatment performance, hydrological benefits, visual appeal and acceptability and maintenance.
- Example design is given for each device type listed below, along with device sizing, other design considerations and maintenance:
  - Ponds;
  - Coarse sediment traps;
  - Filtration devices;
  - Infiltration trenches;
  - Swales;
  - Vegetated filter strips;
  - Oil separators.

New Zealand Forest Code of Practice **(2nd Edition),**
New Zealand Logging Industry Research Organisation (LIRO), Rotorua (1993)

- This Code is designed to reduce impacts of forest operations on environmental and social values. It applies to both planted and indigenous forests.
- Outlines the use of the Code in the environmental planning process, and environmental legislation relevant to forest operations.
- Identifies important environmental values (soil and water, scenic, cultural sites, scientific and ecological).
- Outlines an impact appraisal process (gives an impact checklist).

- Provides an "Operations Database" which contains information on forest practices that can be used to select cost-effective low impact techniques and reduce adverse impacts of the operation. It is divided into the six stages of forest development (access, land preparation, establishment, tending, protection and harvesting). Appendices provide information on sources of information and advice, and environmental legislation and other requirements for forestry operations.

Roading Projects under the Resource Management Act,
by Terry Brown, Regional Manager, Auckland, Transit New Zealand [undated]

- A 9-page paper which addresses the procedures required under the RMA and the practices following some recent projects in the Auckland Region.
- Covers environmental impact assessments; consultation and Maori culture; physical effect of roads; effects of the RMA on roading projects.

***Planning for a Safe and Efficient State Highway Network under the Resource Management Act 1991*, Transit New Zealand (1994)**

- A guideline prepared by Transit New Zealand.
- Prepared to assist councils in the revision of their planning instruments (after the RMA passed into law) with the identification of key resource management issues affecting their respective districts, and in the identification of some of the inter-relationships between these issues.
- To promote debate and discussion on the issues and options identified in the document, as background to the preparation of recommended district objectives, policies and rules.
- Identifies inter-relationships between the factors that can adversely affect the roading network.
- Discusses concepts of resource management and road planning.

***Transit New Zealand and the Environment*, Transit New Zealand (1993)**

- Outlines Transit New Zealand's current and intended response to environmental issues as they relate to land transport projects (such as road construction and maintenance), and to the increasing use of vehicles in New Zealand.
- Focuses on the effects of land transport development on the landscape, traffic noise, air pollution, greenhouse effect, water resources, plant and wildlife habitats, social disruption, historical and culturally sensitive sites and material resources used in construction and maintenance work.

***Adopt a Highway Scheme*, Transit New Zealand (1993)**

- About trialing a scheme that offers community groups and organisations the opportunity to contribute to the community in partnership with Transit New Zealand, to improve the road environment in their area and generate publicity for their efforts.