Auckland Regional Council
TE RAUHITANGA TAIAO

A Survey of Sediment Sources on Streams in the Mahurangi Catchment

August 2004 Technical Publication 270

Auckland Regional Council
Technical Publication No. 270, August 2004
ISSN 1175 205X ISBN 1-877353-884

www.arc.govt.nz

A SURVEY OF SEDIMENT SOURCES ON STREAMS IN THE MAHURANGI CATCHMENT

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For Auckland Regional Council

August 2004

ACKNOWLEDGMENTS

Acknowledgments are due to several people who facilitated the survey : Tony Thompson, for initial project arrangements; Neil Dingle for adapting Ipaq data logger software and assistance with GIS map; Shelley Trotter, for accompanying Emma Hawcridge in the field on several occasions; Dominic McCarthy for comments on survey design and draft report; Shane Kelly for helpful suggestions about statistical analysis of data. In particular, thanks are due to many landowners who enabled the survey by providing access across their properties.

EXECUTIVE SUMMARY

This report contains the findings of a survey of sediment sources on streams in the Mahurangi river catchment. It was commissioned by the Auckland Regional Council (ARC), as one of the Council's investigations to provide background data about the Mahurangi Harbour and its catchment, prior to launching an initiative in July 2004, to help local residents maintain health of the estuarine environment and quality of its habitats.

What kinds of landform, vegetation or land use supply sediment, can be ascertained quite quickly, by investigating a representative sample of streams. The value of doing so, is that sample data may highlight situations where remedial measures are needed and can have a beneficial effect. It may also highlight situations where remedial measures are not needed or may have little impact.

30 randomly selected stream segments were surveyed. Individual reaches along each stream segment were inspected by walking the banks. The pacing procedure enables length of reach occupied by any particular combination of features to be expressed as percent of reach length (directly from number of paces), or as metres of reach length (by calculating average pace length between start and end points). Codes were used to record channel and bank features for each reach. Data from the field sheets and data logger were entered for permanent storage on ARC's computer and collated into a summary spreadsheet for all reaches.

The survey has identified five processes of sediment entry into streams :

- scour of bed and banks,
- deposition on bed and banks,
- bank collapse,
- sheetwash on exposed soil next to banks,
- delivery by small tributaries which drain adjacent terraces, footslopes or hillsides.

Each process has a natural component, a component induced by animals, and a component induced by human activities.

30% of sample reach length currently delivers sediment to streams. 10% entails natural processes, 16% entails disturbance by stock, and 4% entails disturbance by machinery.

Scour of bed and banks affects 8% of sample reach length. Of this 4% is natural, 2% is stock-induced, and 2% is machine-induced.

Deposition on bed and banks affects 4% of sample reach length. 3% is natural, 7% is trampled in by stock, and 1% is dumped by machines.

Bank collapse affects 4% of sample reach length. 2% is entirely natural, 2% is exacerbated by livestock, and <1% is induced by earthworks, drainage or channel obstruction.

Adjacent soil is exposed to sheetwash on 14% of sample reach length. 1% is natural, 5% is due to stock browsing or trampling, and 1% is due to tracks or other earthworks.

Sediment is delivered from adjacent slopes by small tributaries on 1% of sample reach length. <1% is natural, <1% is exacerbated by livestock, and <1% is exacerbated by machinery.

All stream landforms have active sediment sources on a high percentage of sample reach length, ranging from 26% along infilled lowland channels to 38% along infilled hillslope channels.

Bank vegetations have active sediment sources on variable percentages of sample reach length : from 3% in modified wetland to 39% where wetland is degraded by heavy grazing; from 23% in rank pasture fenced from stock to 54% in open pasture on grazed banks; from 3% in lightly grazed hardwood woodlots to 45% in heavily grazed bank stability plantings; from 20% amongst intact scrub and bush to 54% where under-storey vegetation is grazed by stock.

Sediment sources occupy a moderate to high percentage of sample reach length, relative to all adjacent land uses : up to 30% in reaches that pass through conservation land; up to 21% in commercial forests; up to 56% next to livestock farms; up to 25% next to intensive land uses; and up to 24% next to non-rural uses.

Conclusions are that :

- Sample data do not show how much sediment enters streams in the course of a year (Doing this was not part of the survey design. Sediment load can only be measured in-stream, and sediment yield by repeat measurements for at least a year and preferably several).
- Sample data measure where and how sediment enters freshwater streams. (This is what the survey was designed to find out).
- Where and how, are partly natural and partly induced - not by the *type* of land use, but certain *activities* that are common to several uses.
- A third of sediment sources are entirely natural, over half are induced or exacerbated by farm livestock, and an eighth are created by human modifications to channel beds or banks.
- Any particular type of sediment source is inactive on most reaches in the network, but is highly active on a small proportion.
- The cumulative result when all combine, is that a large percentage of the Mahurangi's freshwater stream network has sediment sources that are currently active.

High sediment loads may simply be the product of certain activities, carried out on a few reaches in the Mahurangi, at any particular time. Activities which stand out in the list are :

- Earthworks adjacent to channels,
- Channel excavation (includes drain-cleaning),
- Sedimentation behind dams (though these trap some of the sediment),
- Trampling of swampy alluvium or colluvium by livestock next to infilled channels,
- Browsing and trampling of steep banks by livestock next to incised channels.

There are several implications for any initiative to control sediment entering freshwater streams in the Mahurangi :

- It will be necessary to target reaches where there are clear signs of sediment entry, irrespective of stream landform, or bank vegetation, or land use.
- On any particular reach, what is proposed needs to match the type of sediment source that is present and the activity that is causing it.

- Regardless of what vegetation is planted - or isn't - fences to exclude livestock potentially could remove about half of current sediment sources.

- Avoidance of earthworks in or adjacent to channels - drain-cleaning, drainage, damming, track construction and culverted crossings - potentially could remove another eighth of sediment sources.

- Even if all possible measures are taken to control induced sediment sources on streambanks, sediment sources will remain at about one third their current length catchment-wide, due to natural processes.

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1 INTRODUCTION

This report contains the findings of a survey of sediment sources on streams in the Mahurangi river catchment. It was commissioned by the Auckland Regional Council (ARC), as one of the Council's investigations to provide background data about the Mahurangi Harbour and its catchment, prior to launching an initiative in July 2004, to help local residents maintain health of the estuarine environment and quality of its habitats.

The survey was designed by Dr. D. Hicks of Ecological Research Associates Inc. Field survey of stream reaches was carried out by Ms. E. Hawcridge, a recent environmental sciences graduate employed as a contract worker by ARC. Ms. Hawcridge also undertook data entry and analysis, while Dr. Hicks interpreted results and wrote the report.

Mahurangi Harbour enters the Hauraki Gulf some 40 kilometres north of Auckland. The harbour, formed by sea-level rise at the end of the last ice age, reached its maximum extent of 23 km2 some 6,000 years ago. Since then it has gradually filled with deposits of estuarine sediment. Today, a long deep-water channel extends some 18 kilometres upstream to Warkworth, flanked on both sides by tidal sandbanks, mudflats and shellbeds.

Numerous freshwater streams discharge into the harbour. The largest is the Mahurangi River at Warkworth. Its catchment is some two-thirds of 122 km2 that drains to the estuary. Pukapuka, Dyer, Hepburn, Hamilton and Duck Creeks account for much of the rest. Terrain is diverse in the freshwater catchments. Steep hill country dominates, on upthrust blocks of Waitemata Group sandstone and siltstone. Pockets of rolling terrain outcropping in fault-angle depressions are crushed rocks of Northland Allochthon. Dissected terraces are widespread north and west of Warkworth, where the older rocks are veneered by Tauranga Group river sediment. Many valley bottoms contain narrow flats, alluvium deposited by streams recently in geological time.

Mahurangi Harbour has been a transport route and a source of seafood since Maori settlement of the area. European settlers continued these uses; though in recent decades marine transport has become recreational rather than commercial, while seafood gathering has become commercial with establishment of seven oyster farms since the 1970s. Local residents now voice concerns about the harbour. Silting of the upstream channel restricts navigation. Mangroves colonise mudflats that were formerly bare. Sandbanks become higher and muddier. Shellfish are scarcer. Sewage contamination or algal blooms sometimes prevent oyster harvest.

In 1994, ARC commenced an on-going monitoring programme in the harbour and streams that drain towards it. Some of the monitoring has been carried out by ARC staff; much has been done by the National Institute of Water and Atmosphere (NIWA). Ten years on, trends can now be seen. The Mahurangi's environmental condition is still good compared with many estuaries elsewhere in the country - but it is slowly deteriorating, as regards sedimentation, water quality, and aquatic habitat (see reports listed in references for details).

To help local residents counter deterioration, ARC will launch the Mahurangi Action Programme in July 2004. Essentially this entails assistance to undertake various measures that can reduce sediment, chemicals and organic pollutants entering the harbour directly or by way of freshwater streams. Some of the measures can also restore aquatic habitat along shorelines and streambanks.

One question raised by NIWA's investigations is : where does the sediment come from? A proportion may be re-working of sand and mud from the upper estuary to the lower. Some may enter directly in runoff across the tidal shore-line. ARC and NIWA measurements show that rivers and streams carry 80,000 tonnes a year. Of this, 50,000 tonnes passes direct to the estuary, while 30,000 tonnes is temporarily deposited in stream channels or on their banks. 80,000 tonnes equates to an annual sediment load of 700 tonnes from each square kilometre of the catchment's area.

Where does it come from? Scour of the channels, erosion of their banks, or both? How much is transported into streams by rainfall running off across adjacent land? Does sediment enter streams throughout the catchment, or does it just get into some streams but not others? Is sediment entry associated with particular landforms, vegetation covers, or land uses?

Some questions cannot be answered quickly. For instance accurate measurements of *how much* sediment enters from a particular source, can only be obtained by field sampling over a range of stream flows for at least a year. *Exactly where* sediment enters channels, can be ascertained only by walking every stream in the catchment; a task which would take many months. *What kinds of landform, vegetation or land use supply sediment*, can be ascertained quite quickly, by investigating a representative sample of streams. The value of doing so, is that sample data may highlight situations where remedial measures are needed and can have a beneficial effect. It may also highlight situations where remedial measures are not needed or may have little impact.

2 SURVEY DESIGN

Sampling strategy

To provide valid answers, sample data have to represent streams within the Mahurangi. They must not be selected in a way that shows bias towards - or against - some part of the catchment. Equally, streams must not be included if they provide data that cannot be sensibly analysed, for instance a stream that has mixed landforms, bank vegetations, or land uses.

1 A number was assigned to all stream segments depicted on the NZMS 260 topographic map. A segment is a length of channel between two junctions. What is depicted on the map, corresponds to second-order or higher-order streams but excludes first-order i.e. very small headwater streams without tributaries (these flow intermittently so do not contribute much water or sediment).

2 The first number was assigned to a reach on the Mahurangi River's main channel, extending from the weir at Warkworth bridge (tidewater junction) upstream to its first tributary (freshwater junction). Successive numbers were assigned to main channels and tributaries, moving clockwise round the stream network, until the last number was assigned to a small un-named stream draining to Te Kapa Inlet just inside Mahurangi Heads. A total 334 segments were numbered.

3 Segment numbers were randomly ordered, using the random number function in an Excel spreadsheet.

4 For initial numbers on the list, aerial photographs were inspected to check whether they had consistent landforms, bank vegetation and land use. Some were dropped on grounds of inconsistency. Examples of inconsistency are : alluvial terrace on one bank and hillslope on the other; grass on one bank and trees retained or planted on the other; pine plantation on one bank and scrub on the other.

5 Aerial photo inspection confirmed each of the remainder could be sub-divided into one or more reaches. A reach is defined as a length of stream where landform, bank vegetation and land use are the same on both banks. For instance a segment where both banks are alluvial terrace can be subdivided into two reaches if both banks are in native forest for part of their length, and dairy pasture for the remainder. If the dairy pasture reach is grazed on both banks for part of its length, but has fenced-off wetland plants on the remainder, it can be further subdivided.

6 The Digital Cadastral Data Base (DCDB) was used to identify landowners, who were contacted by telephone to arrange access. 16 stream segments were initially walked (permission was denied on another 4 selected). Actual sub-division into reaches was carried out while walking the banks. For practicality, reaches were retained in the sample if they contained short lengths of anomalous landform, bank vegetation or land use. If they contained gross anomalies, they were dropped.

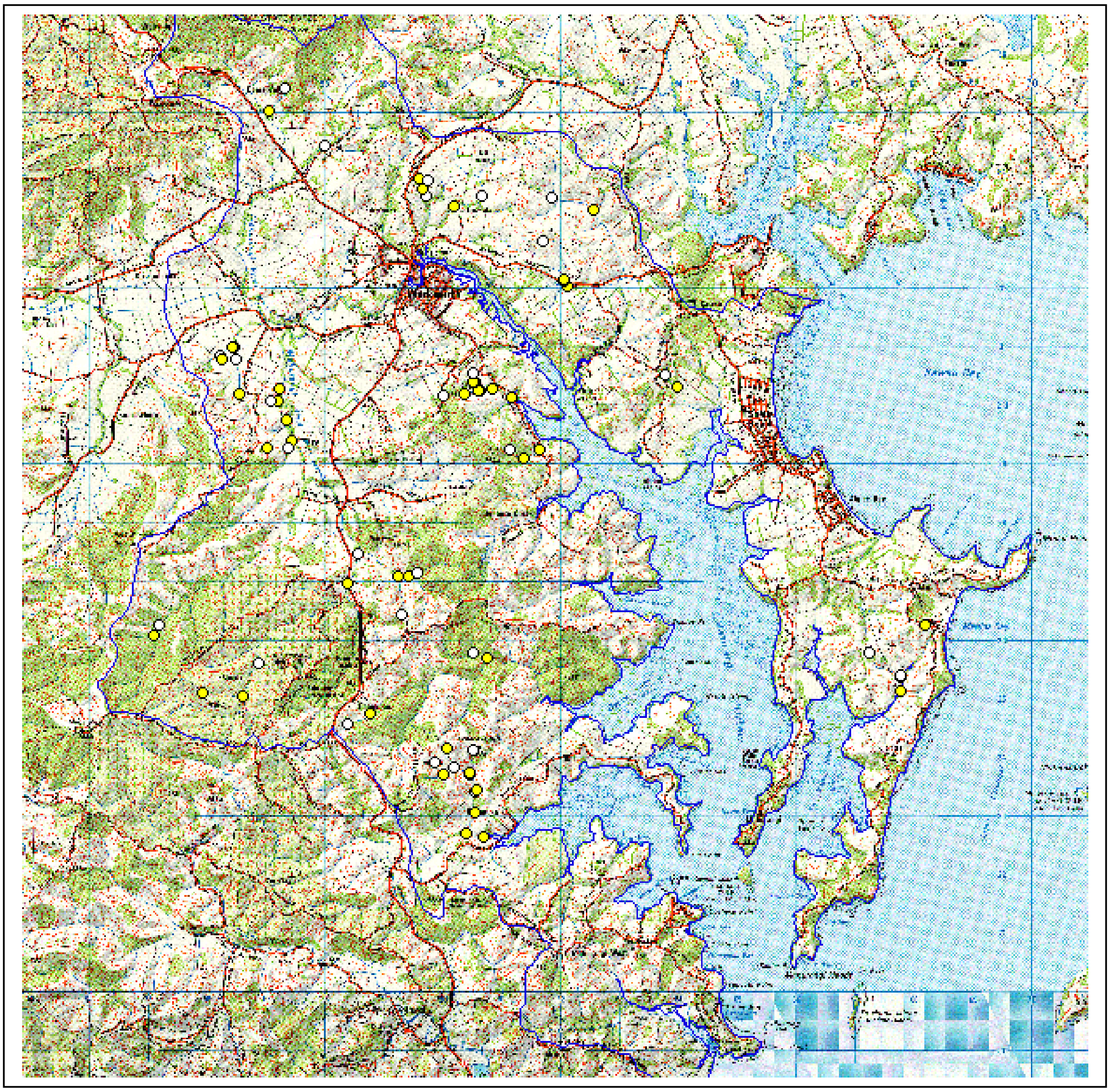
7 This procedure created a sample of N reaches during field inspection. N should be a number of reaches, such that sampling error for the parameter "% of reach length occupied by sediment sources" falls below an acceptable threshold. An initial estimate (based on data from similar survey designs) suggested that a threshold of +-5% (2 s.e.@ 95% conf.) could be passed with a sample of 16 reaches. A greater number of reaches would be desirable, if data are to be analysed for the effects of landform, bank vegetation and land use. A target of n = 20 reaches was adopted for each category.

8 Provisional data analysis (May 2004) showed that 16 segments inspected so far had enabled n=20 for some categories but not others. Steps 4 to 6 were repeated for another 7 stream segments from the random number list. A similar repetition was carried out for a final 2 stream segments in August.

9 Map 1 shows where stream segments were located for sampling, relative to a NZMS 260 topographic map of the Mahurangi catchment. These segments provided a total 211 reaches.

Table 1 gives the breakdown of reach numbers in each category. The target n = 20 was attained for all categories except exotic scrub, intensive land uses and non-rural uses.

Start and Finish Points of Stream Reaches Surveyed within the Mahurangi Catchment



Start and finish of reach

Catchment boundary

Map 1

TABLE 1: STREAM REACHES IN THE SAMPLE					
By stream landform	**No.**	**By bank vegetation**	**No.**	**By land use**	**No.**
Hillslope channels (incised)	29	Wetland	63	Conservation	31
Hillslope channels (infilled)	45	Grass	74	Tree plantations	20
Valley bottom channels (incised)	30	Exotic scrub	0	Livestock farms	145
Valley bottom channels (infilled)	49	Indigenous scrub	12	Intensive uses	4
Lowland channels (incised)	31	Exotic trees	31	Non-rural uses	11
Lowland channels (infilled)	27	Indigenous trees	31		
Totals:	**211**		**211**		**211**

Field procedure

Individual reaches along each stream segment were inspected by walking the banks. Data were initially recorded on a paper sheet, and later on an electronic data logger. A subsidiary aspect of this survey was the development of a procedure for recording streambank data on a data logger interfaced with a GPS receiver (see Appendix A written by E. Hawcridge). Distances were measured by fixing the start point of each segment, pacing the bank, recording the pace numbers where a feature changed, and fixing the end point.

This procedure may seem imprecise, but it is a good deal more practical than the alternatives:

- surveyors wheel - inoperable on rough terrain,
- measuring tape - inaccurate where obstacles are present on bank,
- EDM instruments - no line of sight where bank vegetation is dense,
- GPS receiver - no reception beneath tree cover.

The pacing procedure enables length of reach occupied by any particular combination of features to be expressed as:

- percent of reach length (directly from number of paces),
- metres of reach length (by calculating average pace length between start and end points),

From a statistical viewpoint, it is valid to analyse data using the unit of field measurement i.e. the pace. For a large number of measurements (paces), errors (pace variations) are normally distributed. Once they accumulate, under-estimates cancel over-estimates enabling the average pace to provide a close approximation of true distances and percentages. Average pace length was calculated to be 0.73 metres, with a standard deviation of 0.10 and a standard error of 0.02 These figures may be used to convert sample data to metres of reach length if desired.

Codes used when recording data

The following codes were used to record channel and bank features for each reach. Descriptions of channel types etc. are given in Sections 3 to 6 of this report, accompanied by photographic illustrations.

Channel type
af alluvial, on floodplain
at alluvial, in terrace
cv colluvial, in valley bottom
ch colluvial, on hillslope
wv weathered rock, in valley bottom
wh weathered rock, on hillslope

Channel features
f fast-flowing
p pool
w wetland
r rock bar
a alluvial bar (fine)
g gravel bar (coarse)
t tunnel (natural)
s snag (dead timber)
o obstructive vegetation (from bank)
aq weed (aquatic)
mman-made structure

Sediment sources
c natural channel scour
cd disturbance of channel (stock or human)
d natural sediment deposit in channel
md disturbance of channel deposit (stock or human)
b natural bank collapse
bd disturbance of bank (stock or human)
s natural sediment deposit on bank
sd disturbance of bank deposit (stock or human)
r soil above bank, exposed to runoff over natural ground
rdsoil above bank, exposed to runoff over disturbed ground (stock or human)
t tributary through bank, capable of delivering natural sediment
tdtributary through bank, capable of delivering disturbed sediment (stock or human)

Bank vegetation
W wetland
w' disturbed wetland
g grazed grass
g' rank grass
z exotic weed
e exotic scrub
i indigenous scrub
e exotic trees
i indigenous trees
c grain, greenfeed or vegetable crop
f fruit trees or vines
n none

Vegetation density
c continuous/dense
o spaced/open
s scattered/sparse
a absent

Bank fence

p	permanent
t	temporary
n	none
ra	at right angle or tangent to stream

Adjacent land use

c	conservation (forest, scrub, wetland)
t	tree plantation
p	drystock pasture
d	dairy pasture
c	cropping (grain, fodder or vegetable)
o	orchard or vineyard
f	farm buildings and yards
u	urban buildings and yards
q	quarries
r	roads

Table 2 is an example of how data was recorded on field sheets.

Data storage

Data from the field sheets and data logger were entered into Excel spreadsheets for permanent storage on ARC's computer. The spreadsheet format enables point counts to be obtained by alphanumeric sorts or by pivot table analysis (a quicker procedure).

Pivot tables were generated for each reach and are also stored on ARC's computer. The pivot table is a comprehensive summary of each reach's data, but is not easy to decipher. Key data items were extracted and entered into summary spreadsheets for each reach. These are informative for individual reaches, but collectively difficult to work with (there are 211).

The same data items were collated into a summary spreadsheet for all reaches. This was sorted by channel form, bank vegetation, land use, and sediment source. The summary is attached to this report as Appendix B.

TABLE 2: EXAMPLE OF FIELD SHEET LAYOUT AND RECORDING

Reach Number: 120gl									
Distance			Channel Type	Channel Features	Sedi-ment Sources	Bank Vegeta-tion	Vegeta-tion Density	Bank Fence	Adjacent Land Use
Paces/metres)									
Record all data for first point									
Record any changes at subsequent points									
	1	1	ww	r + p		i	o	p (1b)	p
gl/1 trampled by stock	55	2			bd	B	S		
	72	3		p					
	83	4							
	85	5		p		g + i	116 + s		
	96	6							
g1/2	116	7		r + p					
Old regrassing slump	123	8			b				
Old regrasing slump	155	9		p	b	i	o		
Fence av range to bank	99	10						p (b)	
g1/3 p1 11	258	11			b				
Probably scour as no	292	12							
other comment	311	13				g + 1	c + 5	p (1b)	
	327	14		5				p (1b)	
	346	15		p				n	
	363	16		r					
	375	17		p					
Grassed over slump	385	18			b				
	412	19		s					
g1/4	422	20		r					
	436	21		p					
	458	22			b				
Ephem	471	23			+ b (1b)				
Regrassed but trampled	501	24							
dumps	540	25			b (1 + (b)				
	545	26							
	563	27		o	b				
Probably scour	582	28						p (rb)	
as no other comment	586	29				g			
	619	30							
g1/5	639	31							
Stock tramp (1b)	645	32			d				
Series ?	667	33		r		s	o		
Regrass steep rock bars	669	34			b (b)				
g1/6 & short	700	35			+				
Stock tramp (1b) pools	718	35		m, p				p (1b)	
		36							
		37							
		38							
		39							
		40							
		41							
		42							
		43							
		44							

etc.

3 STREAM LANDFORMS IN THE MAHURANGI CATCHMENT

Catchment features which influence sediment supply to streams

Under natural conditions, the amount of sediment entering streams is determined by channel geomorphology. It is axiomatic that a stream channel is formed by water running over solid rock, through rock that has weathered into earth, and through rock fragments or earth particles that the stream has deposited as alluvium along its course.

An all-too-common mistake in sediment source investigations, is to analyse sediment sources, load or yield relative to catchment characteristics such as geology, soils, or vegetation cover. These characteristics are a step removed from the geomorphological processes which actually erode or deposit sediment. Such analyses may demonstrate statistically significant association between sediment sources and - say - a particular rock type. They do not explain where, how or why sediment enters streams.

Instead, this investigation focuses on the geomorphology of streams, viewed in the field by walking their banks. Section 3 will set the scene by describing stream landforms in the Mahurangi. Being a fairly small catchment just 122 km2 in area, it has a limited number. Table 3a summarises sample data relative to six that have been identified.

TABLE 3a: SEDIMENT SOURCES ON STREAM LANDFORMS

Long section	Cross section	Reaches (number)	Length (paces)	% of sample	sample error (+-2 s.e.)	Sediment sources (paces)	% of sub-sample	sub-sample error (+-2s.e.)
hillslope	incised	29	3430	12.6	0.4	1139	33.2	1.6
(steep)	infilled	45	5257	19.3	0.5	1970	37.5	1.3
valley	incised	30	3359	12.3	0.4	1173	34.9	1.6
(moderate)	infilled	49	6980	25.6	0.5	1723	24.7	1.0
lowland	incised	31	4890	17.9	0.5	1317	26.9	1.2
(flat)	infilled	27	3345	12.3	0.4	879	26.3	1.5
Totals:		211	27261	100.0	0.0	8201	30.1	0.5

Lowland channels incised in alluvial terraces (Photo 1)

Main channels of the Mahurangi River between Warkworth and the Falls, its Left Branch upstream to Dome Valley, its Right Branch upstream to Redwoods, and un-named tributaries at Perry Road and Goatley Road.

Beds are 5 to 10 metres wide with long pools, almost zero gradient, separated by stepped rock bars. Rock bars are beds of tuffaceous sandstone or volcanic tuff within Waitemata Group rocks that underlie most of the catchment. Pools are where the main channels have cut down into softer marine sandstone or siltstone beds within the Waitemata Group. The main channels' banks are typically 3 to 6 metres high, and locally as high as 10 metres. Bank angle is variable - it can be rolling (16 to 25 degrees) on inside bends - or vertical on outside bends that are undercut - but on straight reaches is very steep (35 to 60 degrees). Bank material is alluvial sediment within the Tauranga Group. It is sandy clay - soft, consolidated but not cemented, and highly weathered.

These channels carry substantial low flows at all times of year, and very large discharges when in flood. Their high banks contain most floods; floodwater rarely spills across the terraces. Incised lowland channels are 18% of the sample. Sediment sources occupy 27% of their reach length.

Photo 1: Lowland channel incised in alluvial terrace

Lowland channels infilled with alluvium (Photo 2)

Tributary channels within alluvial terraces, adjacent to main channels of the Mahurangi. Alluvial terraces extend west to a low divide with the Kourawhero stream, north towards the foot of the Dome Hills, and up southern valleys as far as Dome Valley (Left Branch) and Redwoods (Right Branch).

These channels are the downstream reaches of tributaries which drain higher ground around the catchment's northern and western watersheds. They are typically 2 to 5 metres wide, with shallow rapid reaches flowing at a low gradient across beds of recently deposited stream alluvium. Banks range from near-flat swampy alluvium where channel form is diffuse, to short vertical cuts no more than a metre high in dry alluvium where channel form is single-thread. Bank material is recent stream alluvium, deposited as a narrow flat 5 to 10 metres wide. It is silty or sandy clay, soft, loose, and unweathered. Its organic content appears quite high, possibly from decay of wetland vegetation. Either side of each flat, rolling scarps rise 3 to 6 metres to old terraces, underlain by Tauranga Group alluvial sediment.

These channels carry smaller low flows than the incised lowland channels. Flood discharges are also smaller but still substantial, as headwater areas are large. Their channel form has no flood capacity;