Tristan Connelly
33 Connelly Lane
R.D.2 Katikati
Phone: (07) 549 0722
Bay of Plenty Polytechnic
Diploma in Environmental Management Year Two

Andrew Jenks
140 Wharawhara Road
Phone: (07) 549 0064
Wild About New Zealand
Programme Co-ordinator

Bay of Plenty Polytechnic
70 Windermere Drive
Windermere
Phone: (07) 544 0920

Cover photo: McKinney downstream.

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Preface

There has been no previous evidence of work completed on the Boyd and McKinney Streams concerning water clarity, total volume and total suspended solids. The Quarry Stream however has had previous sediment source sampling due to concerns with flooding of the Katikati Quarry tailings pond on neighbouring properties.

The idea for study arose when Dianne Connelly-Cook visited a friend's house on Hot Springs Road, 5 Km north of Katikati with concerns of chlorine and chemicals entering a nearby stream from the Sapphire Springs hot pools. The concerns prompted me to consult Lawrie Donald of Environment Bay of Plenty. Constant monitoring was already in place and Lawrie suggested consulting Andrew Jenks for some ideas of study. An idea arose concerning sediment source inputs into the Uretara River near Katikati causing silt build-up within the estuary.

Andrew Jenks suggested sampling the three streams Quarry, Boyd and McKinney to find out which of these streams is contributing to most of the silt build-up in the harbour estuary. Up- and downstream would also be of interest to find out whether the sediment was coming from the Kaimai Ranges or lowland horticultural or agricultural areas. The streams were easily accessible by road or walking distance.

Acknowledgements

Thank you to G & N Colquhoun, B & B Gordon, C Sanger, K Hall for stream access on their properties. Filter system and scales provided by Marionne Silvester of Katikati College. Special thank you to Andrew Jenks for his time, knowledge and commitment in bringing large amounts of information together for this report.

Executive Summary

This report investigates sediment source within the Quarry, Boyd and McKinney Streams as a factor in sediment input into the Tauranga Harbour through the Uretara River. The Uretara River flows behind the Katikati township and is silting up rapidly, with loss of habitat and aesthetic values. The build-up of silt is affecting the Uretara Estuary, which is an essential part of our coastal environment. Estuaries are important to recreation, such as boating and swimming, commercial and recreational fishing and as a refuge and nursery for wildlife. Estuaries provide shelter and food for a variety of birds, fish and other animals. They are also places where the biggest populations of people tend to congregate. Cities and towns were commonly formed around harbours because the main form of transport was once shipping.

The Quarry, Boyd and McKinney Streams sediment source report was completed over three months from July the 14th 2005 to September the 30th 2005. The Quarry, Boyd and McKinney Streams were divided into up- and downstreams and each was sampled 15 times over the three months. Each up and down stream was sampled after no rain, light rain and heavy rainfalls for the previous 24 hours. Out of the 15 samples, 6 days had no rain, 5 days had light rain and 4 days had heavy rain.

The objectives of this report were to sample the water clarity using clear tubing with an indicator marker; water velocity by measuring out 10 metres and floating an orange downstream three times; total suspended solids by filtering water through a fine filter paper and funnel, measuring the filter paper before and after testing; and the total volume/ area of water at each downstream site.

Up- and downstream Quarry were predominantly the murkiest (poor clarity) after no rain, light rain and heavy rain. Overall results showed the Boyd stream was the cleanest, least murky out of the three streams. There were large variances in water velocity between up- and downstream Quarry, compared to similar results for Boyd and McKinney streams respectively. All three streams, Quarry, Boyd and McKinney showed similar results with little variance in suspended solids. Results showed that as the rainfall increased, the weight or suspended solids increased. The McKinney Stream is subsequently the widest and deepest with an average water velocity resulting in the greatest volume of water flowing downstream thus contributing the greatest build-up of silt within the Uretara Estuary.

Recommendations for future work include collecting more thorough background information as possible and get an even number of days to compare (5 with no rain, 5 light rain, 5 heavy rain). A major finding is that all stream sites should be adjacent to each other at similar distances from the estuary as the McKinney downstream was further downstream and may have been altered by excavation or culverting.

1.0 Introduction

This report investigates sediment source within the Quarry, Boyd and McKinney Streams as a factor in sediment input into the Tauranga Harbour through the Uretara River. The Uretara River flows behind the Katikati township and is silting up rapidly, with loss of habitat and aesthetic values. The build-up of silt is affecting the Uretara Estuary which is important to recreation, such as boating and swimming, commercial and recreational fishing and as a refuge and nursery for wildlife

This report concentrates on describing the comparison of sediment source inputs between the Quarry, Boyd and McKinney Streams. Comparisons are between up- and downstream's Quarry, Boyd and McKinney, after no rain, light rain (0-10ml) and heavy rain (10ml and above) for the previous 24 hours. The aim is to find out which of these three streams is the greatest contributor to the build-up of silt in the Uretara River and the harbour estuary.

The objectives are to sample the water clarity using clear tubing with an indicator marker; water velocity by measuring out 10 metres and floating an orange downstream three times; total suspended solids by filtering water through a fine filter paper and funnel, measuring the filter paper before and after testing; and the total volume/ area of water at each downstream site.

1.1 Background

The Bay of Plenty Region is sheltered from New Zealand's prevailing westerly winds by the high country of the North Island and its position on the East Coast. The Region has one of the sunniest climates in the country, especially in the coastal areas, and dry spells are common (EBoP, 1996 (a)). Daily variations in weather depend largely on wind directions and speed. The Region is largely exposed to northerly and north-easterly airstreams. These are often humid and as such the majority of rainfall over much of the Region occurs during periods when these air streams are prevalent (EBoP, 1996 (b)).

A combination of the Bay of Plenty's northerly aspect as well as the sheltering effects of the Kaimai Ranges on three sides, provides rainfall that is generally lower than many other parts of New Zealand and dry spells that are more common than in many other parts of New Zealand. The Region can be subject to heavy rainfalls, although rainfall is frequently lower than in many other parts of the country. Annual rainfall follows variations in topography and varies from 1400 mm near the coast to 4000 mm on the highest parts of the Kaimai Ranges, (EBoP, 1996 (a)).

Estuaries are an important part of our coastal environment. They are important to recreation, such as boating and swimming, commercial and recreational fishing and as a refuge and nursery for wildlife. Estuaries provide shelter and food for a variety of birds, fish and other animals. They are also places where the biggest populations of people tend to congregate. Cities and towns were commonly formed around harbours because the main form of transport was once shipping (NIWA, 2000).

There are 301 estuarine systems that have been identified in New Zealand, ranging in size from a few hectares to more than 1500 hectares. Of these 301 systems, 164 are bar-built estuaries, 56 are drowned river valleys, 65 are lagoons and 16 are fiords (NRC, 2005). There are other areas of high significance within New Zealand such as the Manukau Harbour and Kaipara Harbour.

Estuaries have high value to many New Zealander’s and especially Maori people, providing fish and shellfish, birds, flax and other traditional items. Eels were an important food source, and were caught by hand with an eel-pot or bob consisting of a huhu grub attached to string or flax (NRC, 2005).

Estuaries are among the most productive places of all, when compared with other biological zones. Scientists say they are four times more productive in plant matter than fertile farmland, and 20 times more productive than the open sea (NRC, 2005). Estuaries grow a wide variety of plants which provide food for crustaceans, fish, birds and animals. In estuaries, most of the primary production occurs in the marshes and mudflats where wetland plants such as sedges and rushes, mangroves, bottom-dwelling algae, sea lettuce and eelgrass grow in abundance (NIWA, 2000).

Herbivores only manage to eat a small part of the plants produced in the estuary. The rest - over 90 per cent - dies down to become food for a host of bacteria, fungi, protozoa and other micro-organisms. These in turn become food for bigger consumers such as crabs, bivalves, snails and fish. This is an example of the complicated food chains forming a food web in the estuary. Each organism is depending on others for survival, with all of them linked. Estuaries support up to five times as many bird species as an equivalent area of native bush (NIWA, 2000).

Estuaries collect sediments from the ocean and from the streams that feed into them. Sediments can be sand or mud and silt. This swirls around in estuaries with the waters that mix there from the sea and rivers, until it settles to form sand and mud flats (NRC, 2005). These areas become rich environments for plants and creatures to set up homes. The plants and trees such as mangroves that take root there help to stabilise the sediment. An electrochemical reaction when sediment-laden fresh water meets salt water also causes the sediment particles to clump together, and settle to the estuary floor (NRC, 2005).

1.1.1 Quarry

The Quarry Stream rises in the Kaimai Ranges and comprises of about 50% steep bush and 50% rolling to easy farms and orchards.
Investigation into causes of pollution in response to a petition signed by 171 residents in 1970 found the quarry has caused silting in the lower reaches of the stream. Cow sheds and piggeries also have a major effect on the water quality of the stream. Complaints of siltation and discoloration of the stream have been made from the 1990’s onwards. Quarry assists in channel works to improve the channel waterway near the quarry (EBoP, 1999).

Figure 1.1 Quarry upstream   Figure 1.2 Quarry downstream

1.1.2 Boyd

The Boyd Stream rises in the Kaimai Ranges and until it emerges with the Uretara River, has a total length of 6.5km. The Boyd Stream runs adjacent to Busby Road in Katikati and is surrounded by farmlands with 30% used for horticultural purposes. Bank vegetation consists mainly of grasses, where frequent stock tracks to the stream edge expose the banks making them more susceptible to erosion (EBoP, 1999).

Figure 1.3 Boyd upstream

Figure 1.4 Boyd downstream

1.1.3 McKinney

The McKinney Stream has a total length of 4.6km and starts near the top of Lindemann Road from the formation of small tributaries. The Stream is 0.5m – 1m wide, with loose rocks forming the bed. The Stream is bordered with bush, and the banks have good vegetation cover (EBoP, 2002).


Figure 1.5 McKinney upstream   Figure 1.6 McKinney downstream

Upstream McKinney is predominately bush and farmland areas. The relief is moderate to very steep and fertiliser and weed control sprays on farmland are susceptible to runoff during rain (EBoP, 2002). Downstream McKinney, situated near State Highway 2 heading North, is well vegetated. The stream is not fenced off allowing access to cattle which drink out of the stream. This section of the stream lies within a soggy wetland and is susceptible to flooding.

2.0 Methods

Three streams were selected which included the Quarry, Boyd and McKinney. The streams were identified on the map (figure 5.1) and divided into up- and downstream's being easily accessible from road or walking and each relatively adjacent to each other along the streams.

Equipment was then sourced and collected; ninety 2 litre milk bottles, ninety 1 litre milk bottles, stop watch, ninety medium sized oranges, 1m ruler, measuring tape, water clarity tube and magnet, analytical scales, filter system (funnel and bottle), and one hundred filter papers.

A total of 15 days were sampled at approximately 4 pm each day. Out of the 15 days, 6 days has no rain for the previous 24 hours, 5 days had light rain (0-10 ml) for the previous 24 hours and 4 days had heavy rain (10 ml and above) for the previous 24 hours.

2.1 Water Clarity

Water clarity was sampled at every up- and downstream Quarry, Boyd and McKinney sites. Altogether 90 samples were collected and labelled (site and date) in 2 litre milk bottles over the 15 days of sampling. A water clarity tube and indicator marker where used to test the clarity in measures of centimetres.

2.2 Water Velocity

Water velocity was measured at every up- and downstream Quarry, Boyd and McKinney sites over the 15 days of sampling. The water velocity was measured using 3 medium sized oranges purchased from the supermarket. Each of the 3 medium sized oranges were floated down stream along a 10 metre measured distance (preferably straight piece of stream) and times were recorded. The 3 times were added together then divided by 3 to find the average water velocity in metres per second (m/sec).

2.3 Total Volume of Water

The total volume of water was measured on a day with normal weather conditions at each downstream Quarry, Boyd and McKinney sites. The width of the stream was measured using a measuring tape and divided into 5 to be used to find different depths. Each of the 5 points was then measured using a 1 metre ruler and recorded. Each of the 5 depths were then added and divided by 5 to find the average depth of the stream. The total area was found by multiplying the average depth by the width (m^2). The total volume of water was found by multiplying the total area by the average water flow or velocity and measured in metres per second (m^3s-1).

2.4 Total Suspended Solids

Total suspended solids were sampled at every up- and downstream Quarry, Boyd and McKinney sites. Altogether 90 samples were collected and labelled (site and date) in 1 litre milk bottles over the 15 days of sampling. Each filter paper was measured on analytical scales, labelled and weight recorded before being testing. Each 1 litre sample was then filtered through the filter paper into a bottle and then left to dry for 30 minutes. The weight of the filter paper was then measured on the analytical scales and weight recorded. The total suspended solids were found by subtracting the weight after being tested by the initial weight before testing and measured as concentration in grams per metre (g/m^3).

Figure 2.1. Uretara River Catchment.

3.0 Results

These results compare the three streams, Quarry, Boyd and McKinney which lead into the Uretara River creating the build-up of silt in the estuary. The stream's were sampled 15 times up- and down, over the space of 3 months from July the 14th 2005 to September the 30th 2005 after no rain, light rain and heavy rain for the previous 24 hours in advance. The different months (seasonal), do not influence the results produced. Out of the 15 samples, 6 days had no rain, 5 days had light rainfall and 4 days had heavy rainfall (appendix 1).

3.1 Water Clarity

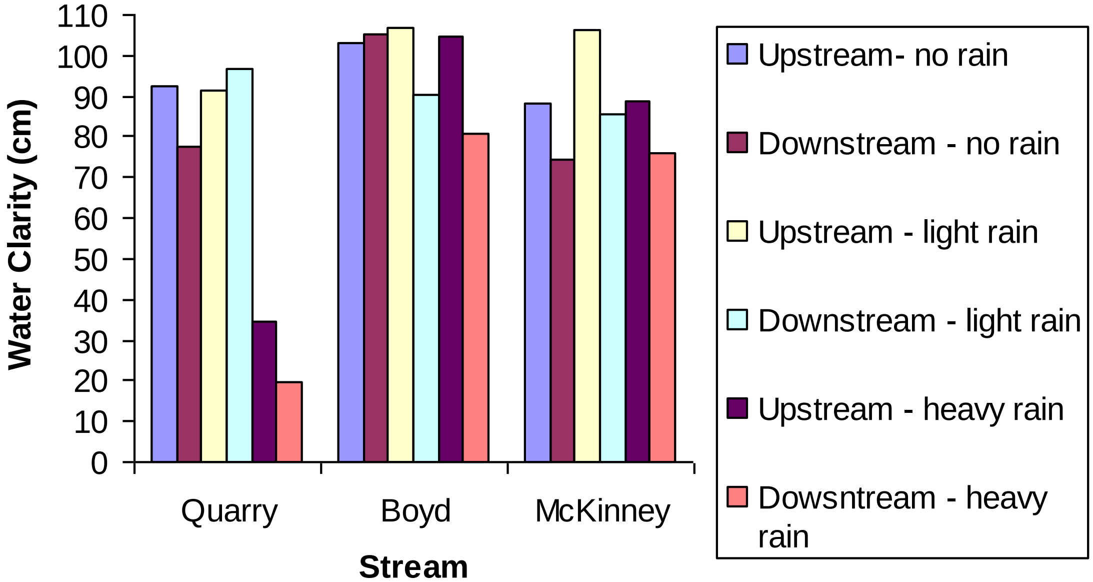

Figure 3.1 Average water clarity comparing no rain, low rain and heavy rainfalls up- and downstream's of the Quarry, Boyd and McKinney. Out of the 15 days of sampling, 6 days had no rain, 5 days had light rain (0-10 ml) and 4 days had heavy rain (10 ml and above) for the previous 24 hours (appendix 1).

3.2 Water Velocity

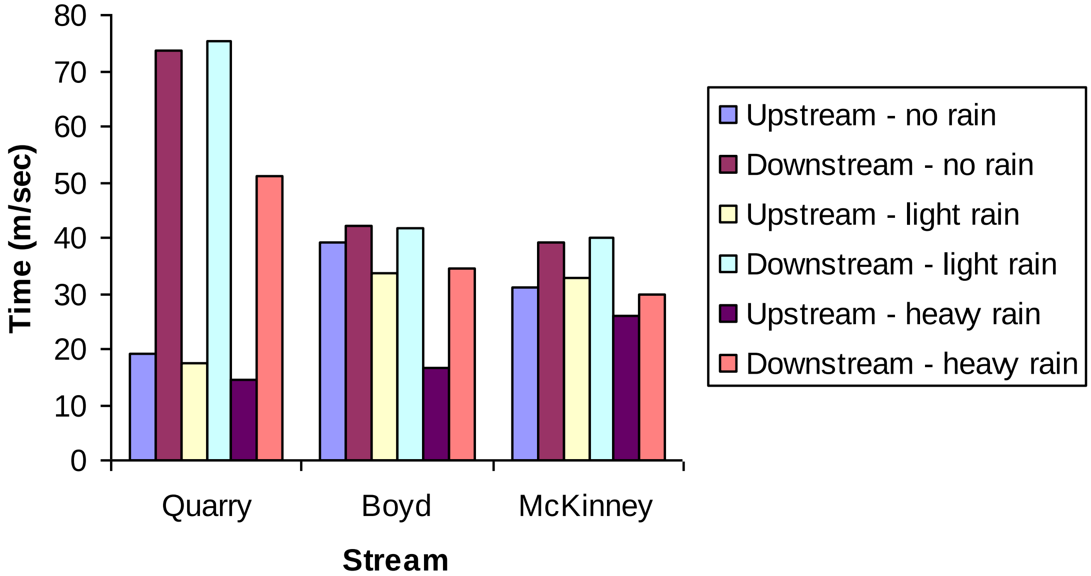

Figure 3.2 Average water flow comparing no rain, low rain and heavy rainfalls up- and downstream's of the Quarry, Boyd and McKinney. Out of the 15 days of sampling, 6 days had no rain, 5 days had light rain (0-10 ml) and 4 days had heavy rain (10 ml and above) for the previous 24 hours (appendix 1).

3.3 Total Suspended Solids

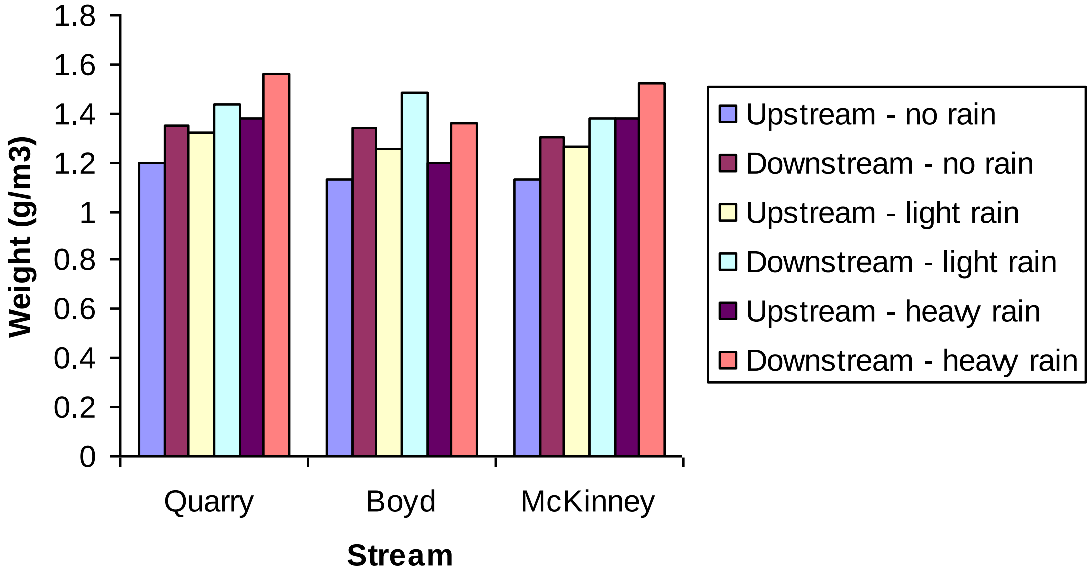

Figure 3.3 Average weight comparing no rain, low rain and heavy rainfalls up- and downstream's of the Quarry, Boyd and McKinney. Out of the 15 days of sampling, 6 days had no rain, 5 days had light rain (0-10 ml) and 4 days had heavy rain (10 ml and above) for the previous 24 hours (appendix 1).

3.4 Total Volume of Water

Table 3.4 Total volume of water flowing downstream's Quarry, Boyd and McKinney under normal weather conditions (appendix 5).

	STREAMS		
	Quarry	**Boyd**	**McKinney**
Width (m)	1.9	4.34	3.04
Average Depth (m)	0.42	0.30	0.61
Total Area (m^2)	**0.79**	**1.3**	**1.86**
Average Velocity (m/sec)	0.13	0.27	0.35
Total Volume of Water (m^3s^{-1})	**0.10**	**0.35**	**0.65**

4.0 Discussion

Reduced water clarity in the Quarry is the higher bed load, as sediment is continually fed in through the Quarry wash water, site runoff etc it will move slowly down through the stream system. The higher energy flows will strip away the sediment from these temporary storage positions, resuspending it and flushing it away. That plus the material washed in from the places such farms and orchards (runoff, wash water pond overflows) make this much dirtier during high rainfall events. The reduction in sediment outputs from the quarry after light rainfall events, the water is much clearer than it used to be. The Katikati Quarry is in the process of preparing for its first Resource Consent, so there are obviously significant changes taking place with site management.

Significant differences were evident in the murkiness after heavy rain between the Quarry Stream (Fig 3.1) with up- and downstream averages being substantially lower than Boyd and McKinney. This was a result of larger volumes of water flowing downstream collecting debris and sediment from stream banks, riparian zones and wetland areas, producing flooding. Higher levels of sediment can lead to habitat destruction or direct affects on the stream-life. The water becomes warmer because suspended materials absorb heat from the sun. This also decreases the amount of oxygen present in the water (cold water can hold more oxygen) (Jenks, 2005, (b)). Shaded waterways will be less affected. Suspended materials or reduced water clarity can ruin habitat for aquatic life. The suspended material restricts light passing through the water column (Jenks, 2005, (b)). These significant changes in the murkiness of all three streams, Quarry, Boyd and McKinney have reduced light that limits plant growth that in turn affects aquatic life such as eel, trout, and freshwater fish relying on the plants for food. As well as loss of habitat for many plants and aquatic life, poor water clarity affects aesthetic values of not only streams but also the Uretara Estuary restricting recreational use from boaties and swimmers.

The flow rate of a stream will have a strong influence on all of the water quality parameters that are routinely measured. In particular water velocity determines how much waste material can remain suspended in the water (Jenks, 2005 (b)). There was a wide variance in water velocity between up- and downstream Quarry after no rain, light rain and heavy rain (Fig 3.2). Downstream topography appeared to be much wider and less steep which would have reduced water velocity. Up- and downstream's Boyd and McKinney showed no real significance in water velocity apart from downstream's being slightly slower due to wider and flatter relief.

Rainfall intensity and duration are key determinants on how often and how large flood events are. Large-scale catchment features such as geology, soil type, slope, degree of vegetative cover and percentage of hard surfaces are other important contributors (EBoP, 2000). It was evident that Quarry, Boyd and McKinney upstream water flows were substantially faster than downstream (Fig

3.2). This was a result of softer, darker soil, a steeper slope, and narrower streams with smaller rocks. Higher flows than normal will disrupt community structure by flushing away algae and stream plants and increasing sediment levels due to stream bed scouring or bank collapse. Lower than normal flows can lead to increased temperatures, lower oxygen levels, less dilution for other waste inputs and increased algae and plant growth (Jenks, 2005, (a)). Human activities have changed this balance in estuaries in various ways – mainly by increasing erosion and by changing water-flow patterns and sediment movements (NIWA, 2000).

Sediment consists of particles of all sizes, including fine clay particles, silt, sand, and gravel. In a water quality context the particles of greatest concern are the fine clays and silts. Sediment in the water column is usually referred to as suspended sediment or solids (Environment Canterbury, 2004). Most of the mean suspended solid concentrations in the Bay of Plenty Streams lie within natural ranges. Ecosystem effects of increased suspended solids depends on suspended solids concentrations (the extent and duration of soil types, rainfall and stream bank erosion), and the proximity and ‘sensitivity’ of receiving waters (EBoP, 2000). Total suspended solids of down streams Quarry, Boyd and McKinney were subsequently higher in concentration compared to upstream sites. Sediment levels are increased where stock have direct access to the stream, through stream bed disturbance and damage to the stream bank.

Rain washes silt and other soil particles off all surfaces, but particularly those where the vegetative cover has been disturbed. Consequently, soil erosion, and activities such as earthworks, vegetation clearance, and cultivation can result in sediment movement into surface water, particularly after heavy rainfall. Stock trampling in the bed of a stream or trampling the margins and banks can release large amounts of sediment into the water (Environment Canterbury, 2004). Erosion can be caused by the clearfelling of forests and by construction projects such as new subdivisions; the fine particles in eroded material may end up in estuaries. In fact, any activities that lead to extra mud and silt settling on estuary floors pose a threat to New Zealand estuaries (NIWA, 2000). Overdosing on fine sediments can easily push the sedimentation balance towards irreversible infilling. In addition, the estuarine ecosystem may suffer: the many animals that live in estuaries may be harmed if sediment inputs and patterns change too quickly (NIWA, 2000).

Rainfall influences the suspended solids within a stream catchment. Results showed that the up- and downstream Quarry are slightly greater in weight than that of the Boyd and McKinney (Fig 3.3). Subsequently every result showed exponential growth due to an increase in density of rain. This also proves that as the suspended solids flow downstream, the concentration gradually increases as the number of solids increases and bind together. Although suspended solids mainly consist of clay, sand and silt particles, make-up can be from other forms such as horticultural and agricultural chemicals. There are four main pollutants arising from farms and orchards in the Katikati region which include nitrogen, phosphorus, sediment and faecal matter (containing bacteria and viruses). These four pollutants affect clarity, freshwater fish and plant growth within the streams and the Uretara Estuary from surface runoff, soil runoff, subsurface drains, discharge ponds and stream bank collapses (EW, 2003). Herbicide sprays are often used to control weeds along stream banks because sprays are cheaper than mechanical clearing. Spraying is effective but can have some damaging effects on stream life and water quality. Some sprays such as diquat and paraquat are toxic to freshwater life, even at low concentration levels (EW, 2003).

The shape or make-up of a stream affects the total area and volume of water flowing downstream. The shape or make-up of the Quarry, Boyd and McKinney streams vary dramatically (Fig 3.4). The McKinney Stream is subsequently the widest and deepest with an average water velocity resulting in the greatest volume of water flowing downstream thus contributing the greatest build-up of silt within the Uretara Estuary.

5.0 Conclusion & Recommendations

Up- and downstream Quarry was predominantly the murkiest (poor clarity) after no rain, light rain and heavy rain. Overall results showed the Boyd stream was the cleanest, least murky out of the three streams. There were large variances in water velocity between up- and downstreams Quarry, compared to similar results for Boyd and McKinney streams respectively. All three streams, Quarry, Boyd and McKinney showed similar results with little variance in suspended solids. Results showed that as the rainfall increased, the weight or suspended solids increased. The McKinney Stream is subsequently the widest and deepest with an average water velocity resulting in the greatest volume of water flowing downstream thus contributing the greatest build-up of silt within the Uretara Estuary.

Recommendations for future work include collecting more thorough background information as possible and get an even number of days to compare (5 with no rain, 5 light rain, 5 heavy rain). When testing for water flow or velocity, be sure to measure 10 metres and mark either end; use a relatively straight piece of river/stream; and use the same sized oranges, as all these factors can cause variations in results. A major finding is that all stream sites should be adjacent to each other at similar distances from the estuary as the McKinney downstream was further downstream and may have been altered by excavation or culverting.

6.0 References

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Appendices

Appendix 1 – Dates and Weather Conditions

14th July 2005 – fine with clear skies, no wind and a temperature of 13ºC.

26th August 2005 – morning showers (2 ml overnight), afternoon clearing, temperature 14ºC and slight westerly winds.

27th August 2005 – overcast, and clearing by afternoon with blue sky patches. Light westerly winds and a temperature of 13ºC.

05th September 2005 – overnight showers (4 ml), overcast with light north-westerly winds and a temperature of 13ºC.

14th September 2005 – heavy showers (17 ml overnight), afternoon overcast and clearing. No wind with a temperature of 18ºC.

15th September 2005 – heavy showers (18 ml overnight) with isolated showers in the afternoon. Strong south-westerly winds and a temperature of 14ºC.

19th September 2005 – very heavy rain all weekend, Sunday night (68 ml). Isolated showers in the afternoon with strong south-westerly winds and a 13ºC temperature.

20th September 2005 – heavy rain overnight (20 ml), afternoon showers with strong winds and a cold temperature of 11ºC.

22nd September 2005 – no rain in the morning turning to isolated showers in the afternoon. Light winds and a temperature of 15ºC.

23rd September 2005 – 1 ml of rain overnight with clear skies in the afternoon. Light southerly winds and a temperature of 16ºC.

26th September 2005 – no rain over the weekend, light north-easterly winds and a temperature of 17ºC.

27th September 2005 – overcast all day with dark patches but no rain. Light south-westerly winds and a temperature of 16ºC.

28th September 2005 – isolated showers (2.5 ml overnight), with dark rainy patches in the afternoon. Cold temperature of 13ºC and strong south-westerly winds.

29th September 2005 – 1.5 ml of rain overnight with an overcast day. A mild temperature of 15ºC and light southerly winds.

30th September 2005 – no rain overnight with an overcast day. Light south-westerly winds and a temperature of 15ºC.

Appendix 2 – Water Clarity Results

WATER CLARITY

DATE	QUARRY	BOYD	McKINNEY
14.07.05			
UPSTREAM	75	106	65
DOWNSTREAM	120	120	29
26.08.05			
UPSTREAM	120	120	108
DOWNSTREAM	101	120	92
27.08.05			
UPSTREAM	107	120	120
DOWNSTREAM	87	120	112
05.09.05			
UPSTREAM	105	120	116
DOWNSTREAM	98	108	95
14.09.05			
UPSTREAM	14	103	88
DOWNSTREAM	9	77	38
15.09.05			
UPSTREAM	29	120	120
DOWNSTREAM	45	111	120
19.09.05			
UPSTREAM	15	76	81
DOWNSTREAM	5	54	27
20.09.05			
UPSTREAM	81	120	65
DOWNSTREAM	#N/A	#N/A	120
22.09.05			
UPSTREAM	95	120	79
DOWNSTREAM	101	120	63
23.09.05			
UPSTREAM	76	55	79
DOWNSTREAM	86	120	84
26.09.05			
UPSTREAM	79	72	48
DOWNSTREAM	83	#N/A	57

27.09.05

UPSTREAM	79	102	120
DOWNSTREAM	120	91	120

28.09.05

UPSTREAM	85	120	108
DOWNSTREAM	79	62	71

29.09.05

UPSTREAM	71	120	120
DOWNSTREAM	120	43	#N/A

30.09.05

UPSTREAM	120	97	96
DOWNSTREAM	64	75	65

Appendix 3 – Water Velocity Results

WATER VELOCITY in seconds

	URETARA		BOYD		McKINNEY	
DATE	upstream	downstream	upstream	downstream	upstream	downstream
17.07.05						
Test 1	11.15	51.24	23.52	35.45	33.63	31.03
Test 2	11.55	52.45	20.18	36.78	27.66	29.00
Test 3	9.20	48.86	21.70	35.01	27.07	25.38
AVERAGE	10.63	50.85	21.80	35.75	29.45	28.47
26.08.05						
Test 1	16.99	82.35	40.24	42.31	28.77	37.38
Test 2	18.69	79.21	33.69	40.51	31.97	39.71
Test 3	16.44	80.13	28.08	41.63	24.43	36.32
AVERAGE	17.37	80.56	34.00	41.48	28.39	37.80
27.08.05						
Test 1	17.31	83.65	31.35	39.87	29.91	35.43
Test 2	18.11	79.01	34.12	41.23	30.12	37.76
Test 3	17.68	79.56	32.27	41.26	28.76	36.23
AVERAGE	17.70	80.74	32.58	40.79	29.60	36.47
05.09.05						
Test 1	15.43	78.52	37.86	42.56	32.54	39.86
Test 2	16.32	81.23	36.96	40.88	28.97	37.85
Test 3	16.78	79.65	39.52	39.65	30.12	38.11
AVERAGE	16.18	79.8	38.11	41.03	30.54	38.61
14.09.05						
Test 1	13.09	67.70	15.77	34.68	29.58	58.23
Test 2	13.32	43.37	15.49	40.01	24.11	61.78
Test 3	12.37	49.37	16.68	37.31	25.83	53.35
AVERAGE	12.93	53.48	15.98	37.33	26.51	57.79
15.09.05						
Test 1	24.73	76.17	15.73	36.35	34.36	29.30
Test 2	16.65	74.82	22.01	33.71	33.37	32.40
Test 3	25.88	72.90	16.74	39.24	35.03	24.92
AVERAGE	22.42	74.63	18.16	36.43	34.25	28.87
19.09.05						
Test 1	9.87	35.63	14.37	28.65	20.17	15.15
Test 2	8.63	33.28	15.12	25.11	18.32	14.27
Test 3	9.65	34.89	13.05	27.34	19.27	15.29

AVERAGE	9.38	34.6	14.18	27.03	19.25	14.90
20.09.05						
Test 1	14.82	41.56	16.78	35.62	22.8	17.73
Test 2	12.79	40.23	18.31	39.87	23.18	17.47
Test 3	12.31	40.9	17.31	34.98	27.63	17.07
AVERAGE	13.31	40.90	17.47	36.82	24.54	17.42
22.09.05						
Test 1	14.74	43.66	21.13	38.68	32.03	19.16
Test 2	16.03	44.59	23.93	39.21	25.73	16.8
Test 3	14.75	48.22	32.56	37.25	27.18	18.13
AVERAGE	15.17	45.49	25.87	38.38	28.31	18.03
23.09.05						
Test 1	15.47	46.87	35.88	39.88	34.83	44.94
Test 2	17.24	44.32	29.01	35.32	33.12	48.47
Test 3	16.34	49.11	27.73	41.56	34.82	#N/A
AVERAGE	16.35	46.77	30.87	38.92	34.26	46.71
26.09.05						
Test 1	21.42	87.65	27.83	47	31.81	64.79
Test 2	19.89	89.01	29.28	46.56	30.17	65.68
Test 3	20.43	89.65	38.48	47.12	30.26	76.33
AVERAGE	20.58	88.77	31.86	46.89	30.75	68.93
27.09.05						
Test 1	22.34	91.35	33.84	48.57	37.72	56.27
Test 2	21.27	89.62	35.55	45.12	29.12	52.35
Test 3	21.09	91.07	30.42	48.33	34.11	48.69
AVERAGE	21.57	90.68	33.27	47.34	33.65	52.44
28.09.05						
Test 1	19.07	84.66	29.9	43.05	32.07	46.25
Test 2	19.79	85.33	27.18	44.56	31.43	46.09
Test 3	17.44	82.51	40.17	43.22	28.26	43.3
AVERAGE	18.77	84.17	32.42	43.61	30.59	45.21
29.09.05						
Test 1	19.97	85.69	33.07	44.12	41.12	32.48
Test 2	18.01	83.55	32.23	41.03	40.57	34.56
Test 3	18.93	84.21	31.97	45.79	41.17	31.07
AVERAGE	18.97	84.48	32.42	43.65	40.95	32.70
30.09.05						
Test 1	18.39	85.62	38.43	43.58	28.92	31.02
Test 2	19.01	85.01	35.23	41.03	35.43	32.68
Test 3	18.6	83.12	34.93	42.78	37.22	31.06
AVERAGE	18.67	84.58	36.20	42.46	33.86	31.59

Appendix 4 – Total Suspended Solids Results

TOTAL SUSPENDED SOLIDS

	QUARRY		BOYD		McKINNEY	
WEIGHT	**Upstream**	**Downstream**	**Upstream**	**Downstream**	**Upstream**	**Downstream**
14.07.05						
Before (g)	1	1	1	1	1	1
After (g)	1.9	2	1.9	2.6	1.8	1.9
TOTAL	0.9g	1g	0.9g	1.6g	0.8g	0.9g
26.08.05						
Before (g)	1	1	1	1	1	1
After (g)	2.1	2.1	1.9	2.3	2.2	2.3
TOTAL	1.1g	1.1g	0.9g	1.3g	1.2g	1.3g
27.08.05						
Before (g)	1	1	1	1	1	1
After (g)	2.3	2.4	2	2.1	1.9	2.1
TOTAL	1.3g	1.4g	1g	1.1g	0.9g	1.1g
5.09.05						
Before (g)	1	1	1	1	1	1
After (g)	2.2	2.4	2.1	2.2	2.1	2.4
TOTAL	1.2g	1.4g	1.1g	1.2g	1.1g	1.4g
14.09.05						
Before (g)	1	1	1	1	1	1
After (g)	2.5	2.6	2.3	2.6	2.7	2.5
TOTAL	1.5g	1.6g	1.3g	1.6g	1.7g	1.5g
15.09.05						
Before (g)	1	1	1	1	1	1
After (g)	2.4	2.5	2	2.2	2.1	2.4
TOTAL	1.4g	1.5g	1g	1.2g	1.1g	1.4g
19.09.05						
Before (g)	1	1	1	1	1	1
After (g)	2.7	2.6	2.2	2.3	2.5	2.9
TOTAL	1.7g	1.6g	1.2g	1.3g	1.5g	1.9g

20.09.05						
Before (g)	1	0	1	0	1	1
After (g)	1.9	#N/A	2.3	#N/A	2.2	2.3
TOTAL	0.9g	0	1.3g	0	1.2g	1.3g
22.09.05						
Before (g)	1	1	1	1	1	1
After (g)	2.1	2.3	2.1	2.2	1.9	2.3
TOTAL	1.1g	1.3g	1.1g	1.2g	0.9g	1.3g
23.09.05						
Before (g)	1	1	0	1	1	1
After (g)	2.5	2.6	#N/A	2.8	2.2	2.3
TOTAL	1.5g	1.6g	0	1.8g	1.2g	1.3g
26.09.05						
Before (g)	1	1	1	0	1	1
After (g)	2.4	2.4	2.2	#N/A	2.5	2.6
TOTAL	1.4g	1.4g	1.2g	0	1.5g	1.6g
27.09.05						
Before (g)	1	1	1	1	1	1
After (g)	2.5	2.7	2.5	2.5	2.3	2.4
TOTAL	1.5g	1.7g	1.5g	1.5g	1.3g	1.4g
28.09.05						
Before (g)	1	1	1	1	1	1
After (g)	2.3	2.6	2.7	2.5	2.2	2.5
TOTAL	1.3g	1.6g	1.7g	1.5g	1.2g	1.5g
29.09.05						
Before (g)	1	1	1	1	1	0
After (g)	2.5	2.5	2.3	2.6	2.6	#N/A
TOTAL	1.5g	1.5g	1.3g	1.6g	1.6g	0
30.09.05						
Before (g)	1	1	1	1	1	1
After (g)	2.2	2.3	2.1	2.3	2.4	2.5
TOTAL	1.2g	1.3g	1.1g	1.3g	1.4g	1.5g

Appendix 5 – Total Volume of Water Results

TOTAL VOLUME OF WATER

	Quarry	**Boyd**	**McKinney**
Width	1.9m	4.34m	3.04m
Depth 1	0.326m	0.48m	0.654m
Depth 2	0.404m	0.37m	0.813m
Depth 3	0.51m	0.307m	0.871m
Depth 4	0.536m	0.183m	0.427m
Depth 5	0.301m	0.147m	0.289m
Average Depth	**0.42sec**	**0.30sec**	**0.61sec**
Water flow (velocity) 1	76.17sec	36.35sec	29.3sec
Water flow (velocity) 2	74.82sec	33.71sec	32.4sec
Water flow (velocity) 3	72.9sec	39.24sec	24.92sec
Average water flow (velocity)	**74.63sec**	**36.43sec**	**28.87sec**