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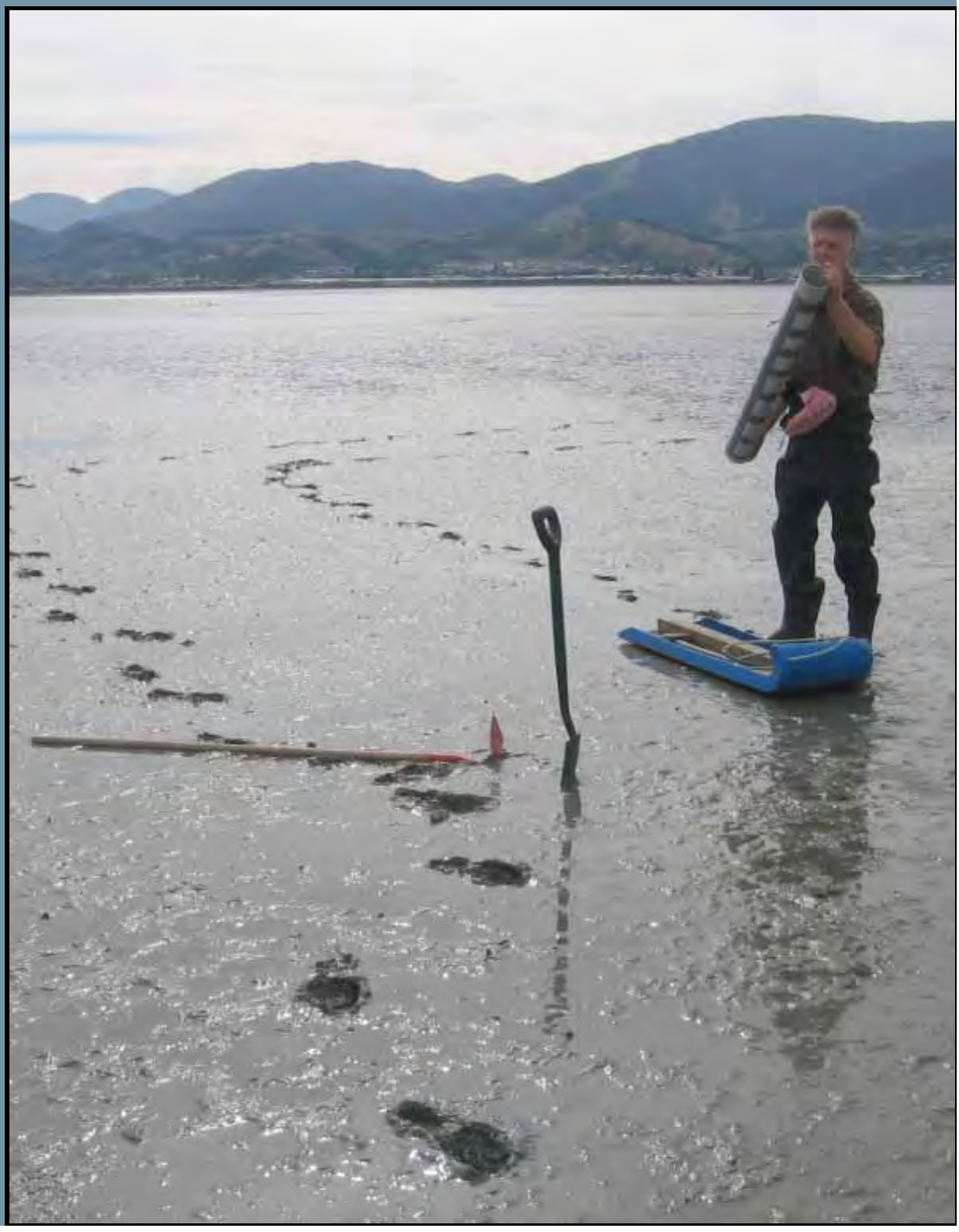
Waimea Inlet

Historical Sediment Coring 2011



Prepared for

Tasman District Council

June 2011

Cover Photo: Preparing to collect the historic sediment core from the eastern arm of Waimea Inlet (Site 1).

Dragging the core across the extensive fine soft muds near the Research Orchard Road site, January 2011.

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Prepared for
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By

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EXECUTIVE SUMMARY

This report summarises the sampling and analysis of two historic sediment cores collected in Jan. 2011 from representative intertidal settling areas within Waimea Inlet. Site 1 was located on intertidal flats in the eastern arm between Headingly Lane and Saxton Island, and Site 2 in the Research Orchard Road embayment. Analysis used established caesium (^{137}Cs) and lead (^{210}Pb) radio-isotope dating techniques to estimate the rate of sediment inputs to the estuary over time. The purpose was to help clarify the relationship between past land-use activities and sediment inputs to the estuary, and to guide estuary and catchment monitoring and management priorities in an estuary where sedimentation has been identified as a major issue (e.g. Robertson and Stevens 2009, Stevens and Robertson 2010).

RESULTS

- Grain size analyses showed the estuary was historically dominated by sand and shell/gravel (71-73%), with little mud and a plentiful population of large shellfish.
- Over time, sediments have become much muddier (from ~30% to 40-60% at Site 1, from ~30% to 60-80% at Site 2).
- Muds have a high colloid and clay content which have a strong adverse influence on water clarity, sediment oxygenation, and contribute to lowered biodiversity and lowered aesthetic and human use values in the estuary.
- Cores indicated large increases in mud coincided at times with a notable decrease in shellfish.
- Caesium analyses indicated sediment deposition since 1964 met a condition rating of "moderate" (see below), but identified significant inputs at Site 2 between 1953-1964 (rating "very high").
- Lead analyses were unable to distinguish differences between surface and deeper samples, therefore more detailed ageing of cores sections was not possible.

CONDITION RATINGS

Period	Site 1	Site 2	Comment
1964-present	MODERATE 1.5mm/yr	MODERATE 1.3mm/yr	Based on 46 years since the maximum year of atmospheric ^{137}Cs deposition recorded in NZ
1953-present	MODERATE 1.6mm/yr	HIGH 3.5mm/yr	Based on 57 years since the start of atmospheric test deposition in NZ
1953-1964	MODERATE 1.8mm/yr	VERY HIGH 12.7mm/yr	Consistent with anecdotal reports of sediment inputs during development of orchard land in the 1950's and 1960's

RECOMMENDED MONITORING

Because the results of this study, and previous monitoring (e.g. Robertson and Stevens 2009), reinforce the need to manage fine sediment inputs to the estuary:

- **Establish additional sediment plates** to more accurately assess overall estuary sedimentation and provide a means of checking that management targets are being met.
- **Annually monitor sedimentation rate** at the 9 existing buried plate sites established by TDC since 2008/09.
- **Continue fine scale estuary monitoring** (including sedimentation rate, RPD depth and grain size at the 4 established intertidal sites at 5 yearly intervals (scheduled for Jan-Feb 2011 but deferred until 2013).
- **Continue broad scale habitat mapping** (including area of soft mud) at 5 yearly intervals (next scheduled for summer 2015/16).
- **Measure catchment sediment budget** by monitoring major sediment inputs to the estuary for one year (including high and low flow periods) to determine annual sediment inputs, validate catchment models, and identify areas of high sediment release.

RECOMMENDED MANAGEMENT

- **Set Catchment Load Guidelines for Suspended Sediment.** Limit catchment suspended sediment inputs to levels that will not cause excessive estuary infilling i.e. limit sedimentation rates to an estuary average of 1mm/yr.
- **Identify Hot Spots and Implement BMPs** Identify and implement catchment Best Management Practices (BMPs) to prevent avoidable sediment runoff from catchment "hotspots" or land disturbance activities.
- **Maintain Vegetated Margins** Encourage the retention and restoration of saltmarsh habitat and vegetated margins around the estuary and catchment waterways.

1. INTRODUCTION

Estuaries are a sink for sediments, and the natural cycle of estuaries is to slowly infill with fine muds and clays. However, over the last 150 years the rate of infilling in New Zealand's estuaries has accelerated as a result of extensive catchment clearance, wetland drainage, and land development for agriculture and settlements. Estuaries were commonly dominated by sandy sediments and had low sedimentation rates prior to European settlement (e.g. <0.5mm/year e.g. Swales et al. 2002, Mead and Moore 2004, Robertson and Stevens 2007, 2007a). Currently average sedimentation rates in NZ estuaries with developed catchments are now typically 10 times or more higher than before humans arrived.

A recent Vulnerability Assessment of Waimea Inlet (Stevens and Robertson 2010) identified sedimentation as a major issue in Waimea Inlet based on the presence of a very high and increasing cover of intertidal soft mud (55%) based on broad scale habitat mapping, along with increasing mud fractions in the surface sediments at fine scale monitoring sites (see Robertson and Stevens 2009). The high mud content in the estuary, sourced from glacial deposits from the Moutere Hills glacial outwash gravels, has had significant detrimental impacts on human uses and ecological values, and has contributed directly to decreased water clarity, reduced cover of high value seagrass, and a shift in the macro-invertebrate community to one more tolerant of fine sediment conditions. Shellfish which are unable to tolerate high concentrations of fine sediment (e.g. pipi, cockles) are also likely to have been displaced from large parts of the estuary by the increase in mud over time (e.g. Lundquist et al. 2003).

Because understanding the rate of sediment increase in the estuary is vital in managing it appropriately, Tasman District Council (TDC) recently (2008/09) established buried sediment plates as part of a long-term monitoring programme to measure the rate of sedimentation throughout the estuary from now into the future. While it will take several years for these plates to confirm current trends in sedimentation rates, preliminary results suggest average deposition in intertidal settling areas throughout the estuary is currently between 0-1mm/yr, with some sites in the east showing slight sediment erosion.

However, past sedimentation rates are likely to have been much higher. To estimate possible rates of sediment input for the Vulnerability Assessment (Stevens and Robertson 2010), cores were dug in two representative intertidal settling basins in the estuary. They showed coarse sand and shells were buried ~1m beneath finer muds. Based on an assumption that sediment deposition prior to intensive human development was likely to be low, and that most catchment development has occurred over the past 150 years, a potential average annual deposition rate across the entire intertidal area of the estuary was calculated at 6-8mm/yr.

Because the assumptions on which these estimates were based are currently unverified, TDC sought to clarify sediment deposition in the estuary by collecting and ageing sediment cores from two representative intertidal settling basins within the estuary using established lead and caesium radio-isotope dating techniques (e.g. Robertson and Stevens 2007, Stevens and Robertson 2007, Swales et al. 2002, 2005).

Wriggle Coastal Management were contracted to undertake this work with the primary aim to estimate the rate of sediment inputs to the estuary over time. The results will enable the effectiveness of current (and recent) land management practices to be better assessed, and help clarify the relationship between past land-use activities (e.g. forest clearance, preparation of orchard blocks) and sedimentation within the estuary to guide management priorities for the estuary and surrounding catchment.

This report describes the methods and results of the sampling and analysis undertaken early in January 2011, and provides recommendations on sedimentation monitoring and management in Waimea Inlet.

2. METHODS

Two intertidal sites were selected within Waimea Inlet (Figure 1) based on the following rationale:

Site 1 - Saxton: Located on intertidal flats in the eastern arm between Headingly Lane and Saxton Island, next to the estuary fine scale site monitoring Site A (see Robertson et al. 2002), and buried sediment plates. The site is relatively exposed with high rates of re-suspension due to wave fetch, but despite this, fine scale monitoring has shown this part of the estuary to be getting muddier (Robertson and Stevens 2009). It has fine muds on the surface, transitioning to coarse sands and shell at around 1m deep. It is expected to provide a good picture of net sediment accrual in the east arm of the estuary which is fed predominantly by the Waimea River, the major source of sediment to the estuary, and also urbanisation around Richmond.

Site 2 - Research Orchard Road: Located in an embayment in the western arm adjacent to areas of intensive past orchard development and with few stream inputs. The surface muds are soft and deep, and overlie gravel and sand substrate in places. Buried sediment plates are located in this location and it is representative of the more sheltered parts of the estuary where sediment is expected to settle and accumulate.

Following site selection, sediment cores were collected at low tide from each location in January 2011 by slowly pushing a 10cm diameter PVC pipe into the estuary muds (see sidebar photos). While insertion through the upper layers of soft mud was relatively easy, at Site 1 the core needed to be hammered through the deeper sandy sediments to reach the target depth of 1m.

After the core was inserted in the sediment, the top cap was removed and any sediment compression in the inserted core recorded. The cap was then replaced and an area adjacent to the core dug out so that a garden hoe could be inserted beside the corer, the blade pushed beneath the bottom edge, and the intact corer lifted vertically from the sediment. Once removed, the corer was carefully laid horizontally and transported from the estuary on a sled for subsequent processing.

Core processing involved splitting open and removing half of the PVC corer (the corer is precut and duct taped together for sample collection). This enabled the intact sediment core to be photographed, and any distinctive visual changes in the core noted. The core was then carefully cut into 1cm sections, with the dominant grain size noted, the size and species of any shellfish present in each section described, before each section was placed into labelled zip lock bags.

Representative sections were then selected and sent to the University of Waikato, Department of Earth & Ocean Sciences, for particle grain size analysis using a combination of wet sieving to determine the sediment shell/gravel (>2mm) fraction, and a Malvern laser particle analyser for sand and mud fractions (<2mm). Laser particle size analysis was used to get a detailed breakdown of the sand and mud components to see whether there was any significant changes in sediment composition over time. To this end, particle grain size analyses were evenly spaced at 10cm intervals throughout the cores, with one exception in the lower section of the Research Orchard Road core where a visually evident shift to silt was targeted at 85cm.

A second subset of samples (split from the above) were sent to the GNS National Isotope Centre in Lower Hutt for radio-isotope analysis using caesium and lead isotopes. All sample preparation for isotope analysis was undertaken by GNS, with samples washed to remove shell and gravel, and retained sediments decanted, dried and crushed before being placed on a high resolution low background germanium gamma detector for analysis. The basis for the use of caesium and lead isotopes is very well described in Swales et al. (2005) and is summarised as follows:

Caesium (^{137}Cs) is an isotope with a half life of 30 years. ^{137}Cs activity, introduced following atmospheric nuclear weapons tests, provides a marker for recent sediment deposition beginning in 1953 when ^{137}Cs deposition was first detected in NZ.

2. Methods (Continued)

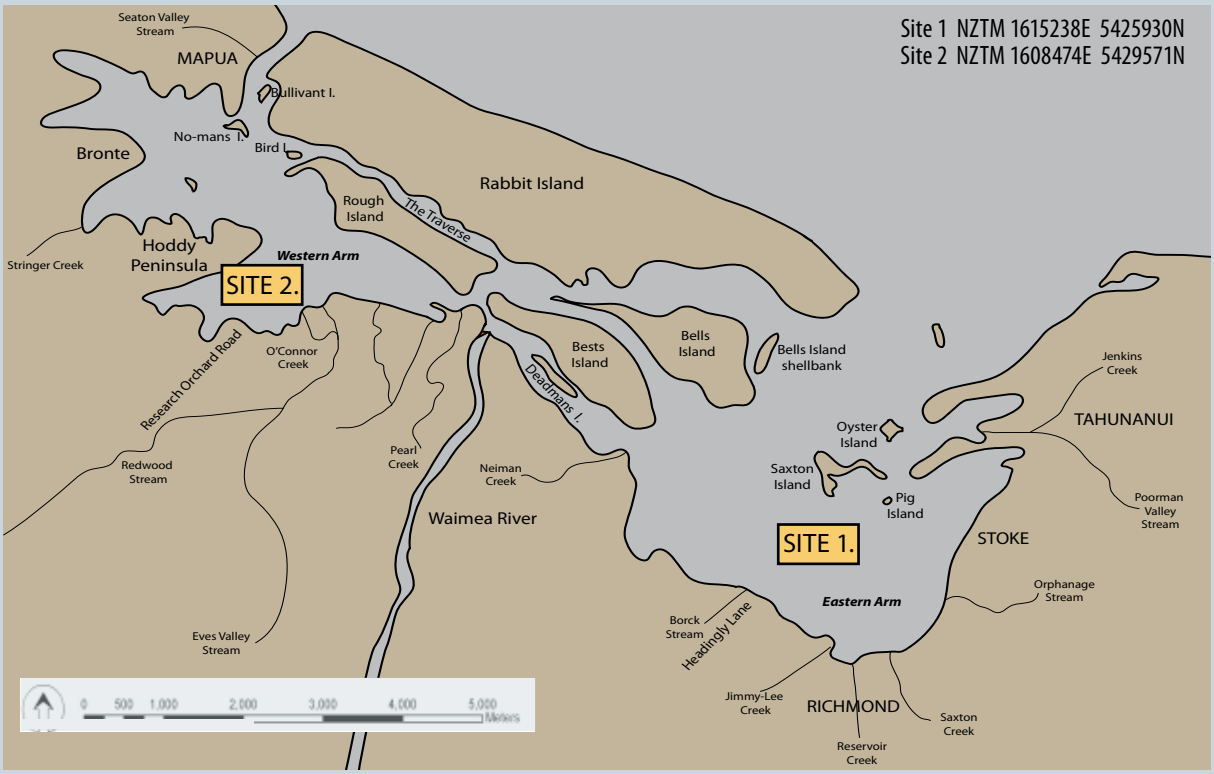


Figure 1. Location of historical sediment core sites within Waimea Inlet.

In addition, the peak atmospheric fallout of ^{137}Cs in NZ (derived from rainfall measurements) occurred in 1964, with elevated levels occurring from 1959-1964 (Cambray et al. 1979; Loughran et al. 1988), thus providing a secondary marker of 1964. As such, ^{137}Cs provides a very good tool for dating gross sediment inputs over the past 46 and 57 years.

Lead (^{210}Pb) is a natural isotope (half life of 22 years) useful in dating sediments up to 100-150 years old. Because the lead derived from atmospheric fallout decays at a different rate when it is buried, it is possible to determine how long it has been buried by comparing decay rates. This is done by using the ^{210}Pb concentration at the surface (supported lead) and the unsupported lead in the underlying sediment (indicated by radium ^{226}Ra). This enables ages to be ascribed to sediments at different depths, with ^{137}Cs being used to provide a fixed time reference for ^{210}Pb values (see Appendix 2 for further details).

There are two main analytical methods for ^{210}Pb dating, gamma or alpha spectrometry. Both have been successfully used to age sediments in NZ estuaries, although gamma spectrometry has less sensitivity because it is subject to higher background interference. Because of the much higher cost of alpha spectrometry, gamma spectrometry was selected as the analytical method for the Waimea Inlet sampling.

The selection of core sections for radio-isotope analysis was based on the expectation that most of the sediments with a ^{137}Cs signal would be in the upper 25cm of the core (based on the TDC sediment plate data since 2008 (0-1mm/yr), and the estimated worst case sedimentation rate in Waimea Inlet of 6-8mm/year). Sections from depths extending to 1m were retained for ^{210}Pb dating, or additional ^{137}Cs dating if needed. Samples were selected for ^{210}Pb dating on the expert advice of GNS scientists, in conjunction with the initial ^{137}Cs results.

For both ^{210}Pb and ^{137}Cs, dating accuracy is influenced by sediment mixing, primarily a result of wave action and bioturbation - the mixing of sediment by estuarine animals. Past estuary coring work has indicated up to 5cm deep mixing is relatively common (e.g. Robertson and Stevens 2007, Swales et al. 2002), and this mixing needs to be accounted for when ageing sediments.

3. RESULTS AND DISCUSSION

The sediment cores results are presented and discussed in the following section. Table 1 presents the results of caesium dating for each core, lead dating results are in Table 2, and particle grain size results summarised in Figure 2 with full details in Appendix 3. Grain size classifications are summarised in Table 3. Figures 3 and 4 show photos of the extracted cores, annotated with the estimated age of the sediments (derived from caesium results), field notes on the core appearance - including the presence of shell material, and particle grain sizes.

Examples of soil erosion in Moutere orchards following intense storms in 1964 (source: Leighs 1977).

CAESIUM

Results in Table 1 show ^{137}Cs was present in both cores, extending to a depth of 9cm in the Site 1 (Saxton) core, and to 20cm in the Site 2 (Research Orchard Road) core. Although ^{137}Cs was still detectable below these depths (to 25cm in both cores), values less than 0.25Bq.kg^{-1} were considered to represent the mixing of more recent surface sediment with older underlying material and were therefore excluded from ageing estimates. No core compaction was observed during sampling. Two estimates of sediment ageing were calculated as follows:

1. The age derived by ascribing the highest ^{137}Cs concentration in the sediments to 1964, the year corresponding to the greatest level of atmospheric deposition recorded in NZ. This gave average sedimentation rates over the past 46 years of 1.5mm/yr at Site 1, and 1.3mm/yr at Site 2.
2. The age based on the maximum depth of ^{137}Cs values >0.25Bq.kg^{-1}, corresponding to the start of atmospheric test deposition in NZ in 1953. This gave average annual sedimentation rates over the past 57 years of 1.6mm/yr at Site 1, and 3.5mm/yr at Site 2.

Sedimentation rates fall within Condition Ratings (see Appendix 1) of MODERATE at Site 1, and MODERATE-HIGH at Site 2. They are ~3-7 times higher than the 0.5mm/yr predicted for an estuary with an undeveloped forest catchment, and as such are likely to be contributing to an ongoing increase in muddiness of the estuary.

To further explore when sediment may have entered the estuary, deposition between the two ^{137}Cs marker dates (1953 and 1964) was calculated. This indicated sedimentation rates of 1.8mm/yr at Site 1, and 12.7mm/yr at Site 2. The very high value at Site 2 is consistent with the development of orchard land in the catchment the 1950's and 1960's, and evidence of significant sediment inputs to the estuary during this period (sidebar photos).

Table 1. Results of caesium radio-isotope analyses used for dating sediment deposition since 1953 in the two Waimea Inlet cores, January 2011.

Caesium	Site 1 - Saxton				Site 2 - Research Orchard Road			
Depth cm	^{137}Cs (Bq.kg^{-1} +/- 2 std dev)	Ascribed date	Sediment rate mm/yr		^{137}Cs (Bq.kg^{-1} +/- 2 std dev)	Ascribed date	Sediment rate mm/yr	
2-3	0.47 (0.32)		1.5	1.6	1.30 (0.74)		1.3	3.5
5-6	0.36 (0.31)				1.40 (0.63)	1964		
6-7	0.50 (0.34)	1964			-		12.7	
7-8	0.48 (0.32)		1.8		-			
8-9	0.37 (0.31)	1953			-			
9-10	0.22 (0.28)	Background			1.37 (0.57)			
14-15	0.22 (0.39)				0.95 (0.49)			
19-20	0.17 (0.29)				0.79 (0.61)	1953		
24-25	0.04 (0.26)				0.23 (0.49)	Background		

^{137}Cs values below 0.25 Bq.kg^{-1} were considered to represent background levels, their trace presence attributed to sediment mixing.
Note: Sediment rates are the cumulative mean annual rate from the ascribed date.

3. Results and Discussion (Continued)

LEAD

Lead results were intended to allow a more detailed interpretation of inputs over time by ascribing dates to sections throughout the cores. However, initial analyses undertaken using gamma spectrometry were unable to distinguish differences between surface and deeper samples (Table 2). Because these initial results showed the collected cores could not be dated using ^{210}Pb, no further ^{210}Pb analysis was undertaken.

Two possible reasons why ^{210}Pb analyses were ineffective are suggested:

1. High sedimentation rates can significantly dilute atmospheric unsupported ^{210}Pb so that the normal curve of concentration (greater at surface, declines at depth) is replaced with a constant supported concentration (Goff et al. 1998; Swales et al. 2005).
2. Fresh inputs of older material, e.g. eroded bedload deposited from rivers and streams, can mask the decay signal. This is supported by the reduced ^{137}Cs signal in the upper part of the core at Site 1 relative to Site 2. Site 1, located in the eastern arm of the estuary, also receives discharges from the Waimea River as well as many smaller streams (Figure 1).

Table 2. Results of lead radio-isotope analyses used for dating sediment deposition in the two Waimea Inlet cores, January 2011.

Lead	Site 1 - Saxton		Site 2 - Research Orchard Road	
Depth cm	Total ^{210}Pb (+/- 2 std dev)	^{226}Ra (+/- 2 std dev)	Total ^{210}Pb (+/- 2 std dev)	^{226}Ra (+/- 2 std dev)
2-3	17 (5)	26 (6)	21 (9)	25 (11)
24-25	8 (6)	13 (8)	20 (8)	24(10)

^{210}Pb activities can not be distinguished from those of ^{226}Ra (=Supported ^{210}Pb) and its decay products, i.e., excess ^{210}Pb cannot be measured in these samples by gamma spectrometry, therefore dating is not possible.

Table 3. Particle Grain Size Classification.

Size Range	Wentworth Classification	
>256 mm	Boulder	
64–256 mm	Cobble	
32–64 mm	Gravel	Very coarse gravel
16–32 mm		Coarse gravel
8–16 mm		Medium gravel
4–8 mm		Fine gravel
2–4 mm		Very fine gravel
1–2 mm	Sand	Very coarse sand
½–1 mm		Coarse sand
¼–½ mm		Medium sand
125–250 µm		Fine sand
62.5–125 µm		Very fine sand
3.9–62.5 µm	Mud	Silt
< 3.9 µm		Clay
< 1 µm		Colloid

SEDIMENT GRAIN SIZE

The results of sediment grain size analyses are presented for the two cores in Figure 2 and Appendix 3. Figure 2 shows that the deeper parts of the Waimea sediment cores (A100 and B85) were dominated by sand (67% and 50% respectively) and shell/gravel (4 and 23%), with relatively little mud (<30%). In addition, each core had evidence of a plentiful population of large shellfish (Figures 3 and 4). This likely to reflect the composition of the estuary before extensive catchment development when inputs of sediment (particularly mud), were low.

In the 10cm overlying these predominately sandy sediments, a significant increase in the mud content is evident (increasing at Site 1 from 29% to 46%, and at Site 2 from 27% to 60%). Although caution needs to be exercised in extrapolating from only two cores, the pattern evident in Waimea Inlet is consistent with other estuaries in NZ (e.g. Robertson and Stevens 2007, 2007a, Swales et al. 2002, 2005) and the increased mud is likely to have come primarily from a combination of catchment inputs following deforestation, wetland drainage and land development.

The general trend at Site 1 is for increasing mud over time, but this is less consistent than for Site 2. Although there is an initial increase over a 40cm section of core (between 60 and 90cm), the mud content then reduces slightly between 20 and 50cm. This may reflect a period of reduced sediment input combined with flushing of fine sediment from the estuary. The upper 20cm shows a trend of increasing mud, ^{137}Cs showing the upper 9cm was deposited since 1953 (Figure 3).

In contrast, Site 2 shows a relatively steady trend of increasing mud content between 10 and 80cm, the increase between 10 and 20cm coinciding with the high rate of deposition from 1953-1964 identified with the ^{137}Cs markers and which most

3. Results and Discussion (Continued)

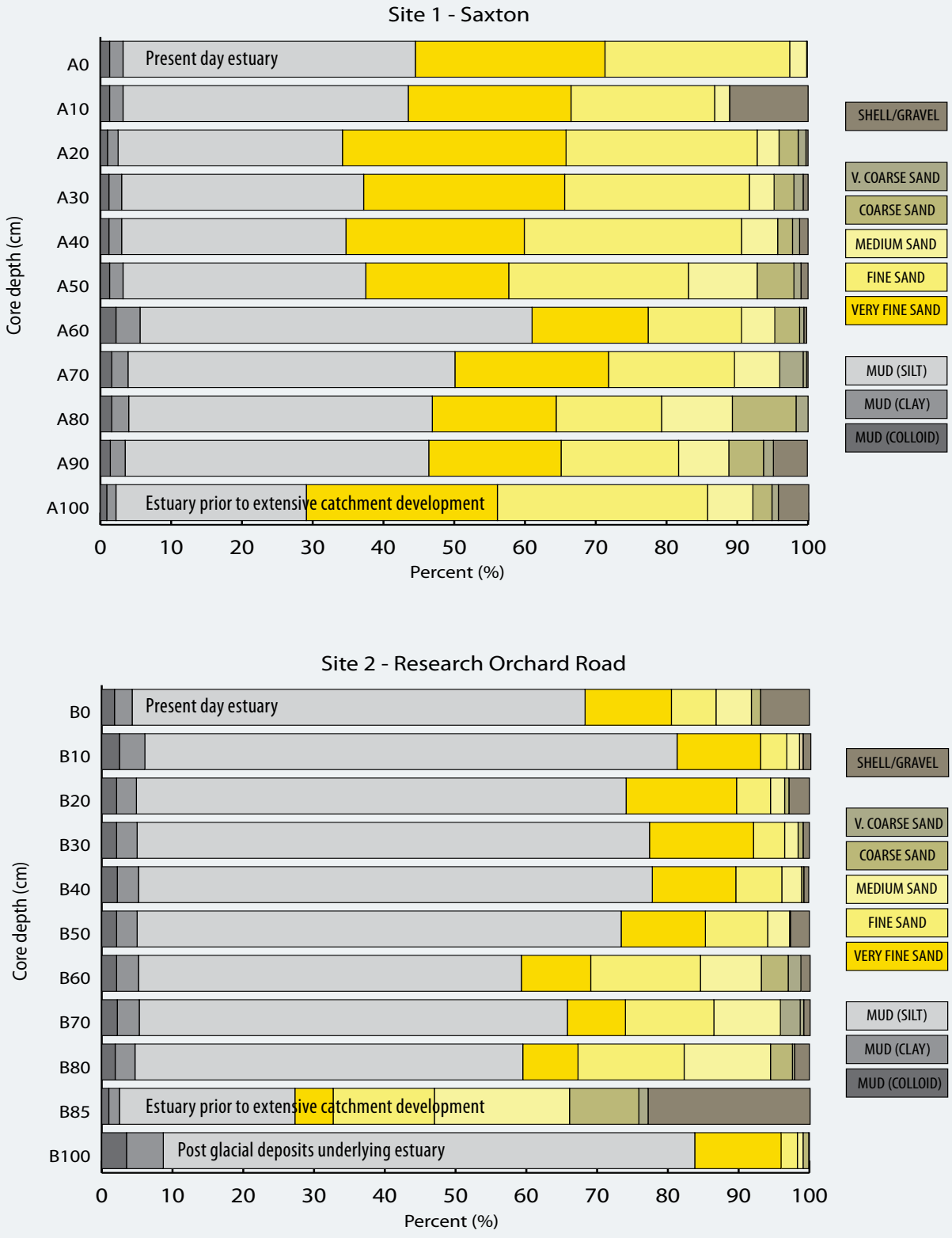


Figure 2. Sediment particle grain size results, Waimea Inlet, January 2011.

3. Results and Discussion (Continued)

SEA LEVEL RISE

Estuary infilling is expected to be partly offset by sea-level rise associated with climatic warming, which will deepen estuaries by about 2 mm/yr, and by the sea flooding low-lying margins which will evolve to saltmarsh and then tidal flats.

The predicted accelerated increase in sea-level rise as oceans expand over the next 50-100 years due to global warming is expected to exacerbate the landward migration or segmentation of barrier islands and dunes, saltmarsh disintegration/displacement, and increase coastal margin erosion. All of these may contribute to increased estuary infilling and will fundamentally change the state of the coast. A coastal vulnerability assessment of the Tasman coastal region is currently being prepared to address issues such as this in more detail.

likely relates to high erosion inputs from orchard land at this time, and earlier (see text box below).

Another key feature of the grain size analyses is the relatively high colloid and clay content of the sediments (Figure 2). These very fine fractions are readily mobilised, easily suspended, and settle slowly in estuary waters. They contribute to poor clarity within the estuary which in turn directly impacts key aquatic vegetation such as seagrass which is restricted to the parts of the estuary where it receives sufficient light to grow - predominantly shallow parts of the well flushed lower estuary. The fine muds also fill the spaces between coarser sediments in the estuary, limiting water exchange and sediment oxygenation. This is a key reason the area of oxygenated sediment (the sediment RPD depth) is relatively shallow throughout the estuary (e.g. Stevens and Robertson 2010). Because most sediment dwelling species live in the oxygenated sediments, a narrow oxygenated area limits their preferred habitat.

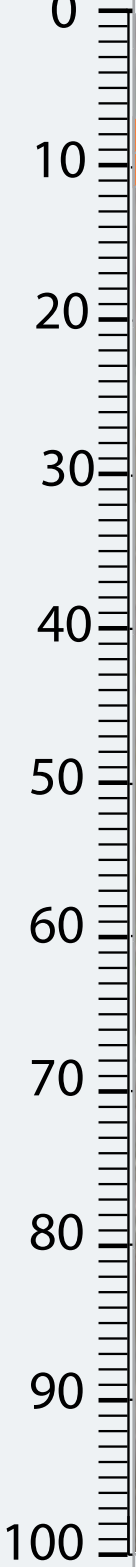
Apart from the ^{137}Cs results, the current study was unable to specifically date sediment deposition in the estuary and relate this to discrete catchment land use activities. However, episodic sediment inputs to estuaries are well documented (e.g. Swales et al. 2002), and indications of pulsed sediment inputs to Waimea Inlet are evident from the shell material present in the cores. At Site 1 the increase in mud between 50 and 90cm coincides with an absence of shellfish from 60-80cm. A similar trend is evident at Site 2 a with a sharp increase in mud from 60-80cm coinciding with a notable decrease in the presence of shellfish (see Figures 3 and 4). This is consistent with a large pulse of sediment smothering or displacing shellfish, particularly those intolerant of high mud concentrations (e.g. cockles). The subsequent reappearance of a few predominantly small cockle shells from 50-60cm at Site 1, but a general absence of larger shells, is consistent with reduced sediment inputs, but less favourable (increased mud) conditions for larger shellfish. This is evidence that past inputs of fine muds have had a detrimental impact on shellfish in the estuary.

Examples of soil erosion in Moutere orchards following intense storms in 1964. A regime of clear cultivation and the ground being kept tilled from mid spring to mid autumn resulted in even light rains producing widespread sheet and rill erosion (source: Leighs 1977).

Erosion of Sediment from Moutere Hills Orchard Land (quoted from Leighs 1977)

From 1910 to 1920 approximately 3600 ha at the seaward end of the Moutere gravels formation were planted in apple and pear orchards. The soils of the Moutere gravels are of low natural fertility, with thin poorly structures topsoil over a hard clay subsoil on weathered gravels. Rainfall infiltration is low and lateral movement of water in the soil is minimal. The topography is undulating to strongly rolling. Orchards were planted on the Moutere Hills using straight rows that was traditional on the flat fruit-growing areas of Britain. Lack of available moisture for the young trees, and reversion to weeds brought the introduction of a regime of clear cultivation; the ground being kept tilled from mid spring to mid autumn. Excessive working created a cultivation pan on the already hard subsoil, and weakened the poorly structured topsoil. As a result even light rains produced widespread sheet and rill erosion. Heavy rainstorms moved large quantities of soil from upper slopes to lower ground and valley floors. Succeeding cultivations tilled the upper subsoil, which in turn was eroded downhill. It was common for the roots of fruit trees on the spurs and upper slopes top be left standing on pedestals of earth, the soils between these trees having been washed down to build up as much as one metre around the lower trees forming swamp on the flats. Completely buried fences have been found. Only pears which were less profitable, could survive the swampy conditions created on the flats.

3. Results and Discussion (Continued)

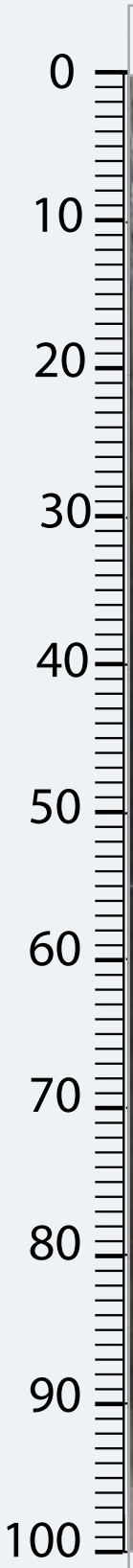


Site 1 - Saxton NZTM 1615238E 5425930N	Isotope analyses		Field description of core overlying generalised grain size results	%Mud	%Sand	%Shell	Extent and type of shells present in core	
	Cs^{137}	Pb^{210}						
	2-3cm	2-3cm	Very fine mud/sand	44.5	55.3	0.1	V. little	Cockles *Austrovenus* @1-2cm.
	5-6cm 6-7cm 7-8cm 8-9cm 9-10cm	+ +	Fine mud/sand Fine mud/sand	43.6	45.3	11.1	Common Abundant	Fragments of trough shell *Mactra ovata* at 2-3cm. Live wedge shell *Macamona liliana*, mud snails *Amphibola crenata* and cockles from
	14-15cm 19-20cm	+ +	Fine mud/sand Fine mud/ increasing sand.	34.2	65.5	0.3	Abundant Rare	Large *Austrovenus* and *Amphibola* shells (20-30mm) Live polycheate worms *Macamona* shell
	24-25cm +	24-25cm +	Sand/fine mud	37.1	62.1	0.7	Rare	*Austrovenus* and *Macamona* shells
	+ +	+ +	Sandy mud	34.7	64.1	1.2	Rare	*Austrovenus* (36mm) and *Macamona* (25-34mm) shells Juvenile *Austrovenus*
	+ +	+ +	Sandy mud	37.5	61.4	1.0	Abundant	*Austrovenus* and *Macamona*
	+ +	+ +	Sandy mud	61.1	38.5	0.4	Rare	*Austrovenus* (mostly small but up to 30mm) and *Macamona*
	+	+	Soft mud/sand. No shell	50.1	49.7	0.2	None	
	+	+	Soft mud/sand	46.9	53.1	0.0	None	
	+	+	Muddy sand	46.4	48.7	4.8	Abundant	*Austrovenus, Amphibola* and *Macamona. Estuarine limpet Notoacmea*
	+	+	Sand with some mud.	29.1	66.6	4.3	Abundant	*Austrovenus* - many large (40mm) and *Macamona.*

+ indicates selected for analysis, values indicate where analysis undertaken.

Figure 3. Summary of the key features of the Site 1 sediment core.

3. Results and Discussion (Continued)



Site 2 - Research Orchard Road NZTM 1608474E 5429571N	Isotope analyses		Field description of core overlying generalised grain size results	%Mud	%Sand	%Shell	Extent and type of shells present in core	
	Cs^{137}	Pb^{210}						
	2-3cm	2-3cm	Very fine soft mud	68.3	24.8	6.9	Common	*Austrovenus* (12-15mm)
	5-6cm	+	Very fine soft mud				Common	*Austrovenus* (1-12mm)
	9-10cm	+		81.2	17.7	1.1		
	14-15cm	+	Very fine soft mud				Common	*Amphibola*, Mudflat whelk *Cominella glandiformis*. Live polycheate worms
	19-20cm	+		74.1	23.0	2.9		
	24-25cm	24-25cm	Very fine soft mud				Rare	*Amphibola, Austrovenus*
	+	+		77.4	21.8	0.9		
	+	+	Very fine soft mud				Rare	*Austrovenus?*
	+	+		77.9	21.4	0.7		
	+	+	Very fine soft mud				Abundant	*Amphibola, Austrovenus, Macomona*
	+	+		73.4	23.9	2.7		
	+	+	Very fine soft mud/some sand				Abundant	*Amphibola, Austrovenus* (25mm), *Macomona, Zeacumantus lutulentus*
	+	+		59.3	39.4	1.3		
			Very fine soft mud/sand				Rare	Crab exoskeletons
	+	+		65.8	33.3	0.9		
			Very fine soft mud/sand				Rare	*Mactra* (37mm)
	+	+		59.5	38.4	2.1		
	+	+	Coarse sand/shell	27.3	49.8	22.9	Abundant	*Macomona* (12mm), *Mactra* (40mm), *Austrovenus* (12mm)
			Silt/sand				None	No shell below 87.5cm
	+	+		83.8	16.1	0.1		

+ indicates selected for analysis, values indicate where analysis undertaken.

Figure 4. Summary of the key features of the Site 2 sediment core.

4. SUMMARY AND RECOMMENDATIONS

SUMMARY	The analysis of two historical sediment cores from intertidal settling basins in Waimea Inlet showed recent sedimentation rates in the MODERATE category for NZ estuaries with developed catchments, with VERY HIGH deposition at Site 2 in the 1950's to 60's. Recent deposition rates were significantly higher than the VERY LOW category attributed to estuaries with undeveloped or very small catchments. In addition, cores showed the historically sandy estuary is now characterised by excessively muddy sediments at the sites sampled. These muds were found to contain very fine fractions (i.e. colloids and clays) which are known to have a strong adverse influence on water clarity, sediment oxygenation, and contribute to lowered biodiversity, aesthetic and human use values in the estuary. These findings, combined with previous fine and broad scale estuary monitoring results (summarised in Robertson and Stevens 2009, and Stevens and Robertson 2010) reinforce the need to manage fine sediment inputs to the estuary.
RECOMMENDED MONITORING	It is recommended that monitoring be initiated or continued as outlined below: **Establish Additional Sediment Plates.** Establish additional sediment plates in representative habitats in the estuary (3-5 extra sites) to provide a more accurate assessment of overall estuary sedimentation and provide a means of checking that management targets are being met. **Annual Sediment Monitoring.** To address problems associated with increasing muddiness, monitor sedimentation rate annually at the 9 existing buried plate sites established by TDC since 2008/09. **Fine Scale Estuary Monitoring.** Continue fine scale monitoring (including sedimentation rate, RPD depth and grain size at the 4 established intertidal sites at 5 yearly intervals (scheduled for Jan-Feb 2011 but deferred until 2013). **Broad Scale Estuary Habitat Mapping.** Continue broad scale habitat mapping at 5 yearly intervals (next scheduled for summer 2015/16). **Measure Catchment Sediment Budget.** Monitor the major sediment inputs to the estuary for one year, including during high and low flow periods, in sufficient detail to determine the annual sediment budget and provide validation for catchment load model predictions. Further sediment monitoring may be required in the future to confirm model predictions once BMPs are in place.
RECOMMENDED MANAGEMENT	The following specific management actions are recommended: • **Set Catchment Load Guidelines for Suspended Sediment.** Limit catchment suspended sediment inputs to levels that will not cause excessive estuary infilling i.e. limit sedimentation rates to an estuary average of 1mm/yr which equates to a SS Input Load of 32kt/yr. It is expected that there will be areas of very high and very low sedimentation throughout the estuary, which together will average 1mm/yr. It is noted that this rate is lower than the 2mm/yr recommended in Stevens and Robertson (2010) following confirmation of a high clay and colloid content in estuary sediments. • **Identify Hot Spots and Implement BMPs.** Identify and implement catchment Best Management Practices (BMPs) to prevent avoidable sediment runoff from catchment "hotspots" or land disturbance activities. This should incorporate the use of existing catchment models such as CLUES to identify current SS loads, highlight "hotspot" areas and assess the potential for load reductions with BMPs in place. In addition, to ensure an adequate policy framework is in place for such BMPs, a review of existing sediment controls and rules for different activities in the catchment is required. • **Maintain Vegetated Margins.** Encourage the retention and restoration of estuarine saltmarsh habitat and vegetated margins around the estuary and catchment waterways. Historical clearance of bush around the terrestrial fringe of the estuary means it is now dominated by grazed pasture, greatly reducing the buffering function provided previously by the bush-covered margin. Additionally, there have been significant areas of saltmarsh and wetland drained for pastoral, agricultural and horticultural use in the past and this has almost certainly contributed to reduced biodiversity and increased sedimentation in the estuary.

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ACKNOWEDGEMENTS

Many thanks to Trevor James (TDC) for his support and feedback, Bob Ditchburn and Mike Sim (GNS) for facilitating the isotope analyses and their feedback on results, and Chris McKinnon (University of Waikato) for input on the particle grain size analyses. Thanks also to the landowners who granted estuary access through their properties.

APPENDIX 1 - SEDIMENT CONDITION RATING

CONDITION RATINGS

Interim fine scale estuary "condition ratings" have been proposed for Waimea Inlet (based on the ratings developed for Southland's estuaries - e.g. Robertson & Stevens 2006). The ratings are based on a review of estuary monitoring data, guideline criteria, and expert opinion. They are designed to be used in combination with each other, and with other fine and broad scale indicators (usually involving expert input) when evaluating overall estuary condition and deciding on appropriate management. The condition ratings include an "early warning trigger" to highlight rapid or unexpected change, and each rating has a recommended monitoring and management response. In most cases initial management is to further assess an issue and consider what response actions may be appropriate (e.g. develop an Evaluation and Response Plan - ERP).

Sedimentation Rate

Elevated sedimentation rates are likely to lead to major and detrimental ecological changes within estuary areas that could be very difficult to reverse, and indicate where changes in land use management may be needed.

SEDIMENTATION RATE CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Low	0-0.5mm/yr (typical pre-European rate)	Monitor at 5 year intervals after baseline established
Low	0.5-1mm/yr	Monitor at 1-5 year intervals after baseline established
Moderate	1-2mm/yr	Monitor yearly. Initiate ERP
High	2-5mm/yr	Monitor yearly. Initiate ERP
Very High	>5mm/yr	Monitor yearly. Manage source
Early Warning Trigger	Rate increasing	Initiate Evaluation and Response Plan

APPENDIX 2. LEAD DATING OF HISTORICAL CORES

Lead Dating (detailed methods in Appleby and Oldfield 1992)

^{210}Pb is used to determine sedimentation rates over the last 100-150 years (from present until the start of the Industrial time) as the ^{210}Pb radionuclide has a relatively short half life of about 22 years. The "total ^{210}Pb" content of estuary sediments is derived from two sources;

- from within the sediments, and
- from the atmosphere.

Both sources begin within the earth's crust where the decay of ^{226}Ra (half-life 1622 years) occurs. Within the estuary sediments this decays to ^{222}Rn (half-life 3.83 days), which then decays to ^{210}Pb (called the "supported ^{210}Pb" content). Within the atmosphere, the decay products are the same and the resulting ^{210}Pb quickly precipitates out of the atmosphere and is deposited at the estuary surface (called the "unsupported ^{210}Pb" content). The total ^{210}Pb content is the sum of the two and is what is measured when the sediments are analysed. However, to "date" the sediments, the concentration profile of the ^{210}Pb from the atmosphere (i.e. the unsupported lead) is used. Assuming a constant supply rate from the atmosphere (and constant initial concentration), and the rate of decay of ^{210}Pb, it is relatively straightforward to then date a sediment layer based on the difference in concentration of unsupported ^{210}Pb between the surface and the chosen layer.

If a rate of sedimentation is constant, the decay process results in an exponential decrease in ^{210}Pb activity with depth that can be used to estimate sedimentation rates and therefore sediment age back about 100–150 years. The activity of ^{210}Pb samples where the curve becomes asymptotic with respect to ^{210}Pb activity is assumed to be the supported ^{210}Pb level; that is, the amount of ^{210}Pb produced from the decay of ^{222}Rn within the sediment column and not deposited from the atmosphere. Alternatively, one can use the ^{226}Ra activity to equal the supported ^{210}Pb activity as, in the absence of atmospheric ^{210}Pb fallout, ^{210}Pb will be in radioactive equilibrium with ^{226}Ra in the sediment. These supported ^{210}Pb values are subtracted from the total ^{210}Pb values obtained in the analysis, resulting in an unsupported ^{210}Pb profile (from atmospheric deposition).

The age in years since the sediment layer at depth x was deposited (t) can then be calculated by using the relationship:

$$t = 1/k.\log N(C_0/C_x)$$

where:
C_o = the unsupported activity of ^{210}Pb in the modern surface sediments,
C_x = the unsupported activity of ^{210}Pb at (uncompressed) depth x, and
k = the ^{210}Pb decay constant (0.03114 yr^{-1}).

APPENDIX 3. PARTICLE GRAIN SIZE RESULTS

Summary of particle grain size results (as a percentage of total core composition) for historic cores collected from 2 sites within Waimea Inlet, January 2011.

CORE +depth cm	MUD-COLLOID	MUD-CLAY	MUD-SILT	VERY FINE SAND	FINE SAND	MEDIUM SAND	COARSE SAND	V. COARSE SAND	GRAVEL
A0	1.3	1.9	41.3	26.8	26.1	2.4	0.0	0.0	0.1
A10	1.3	1.9	40.3	23.0	20.3	2.1	0.0	0.0	11.1
A20	1.0	1.5	31.7	31.6	27.0	3.1	2.7	1.1	0.3
A30	1.2	1.8	34.2	28.4	26.1	3.5	2.8	1.3	0.7
A40	1.2	1.8	31.7	25.2	30.7	5.1	2.1	1.0	1.2
A50	1.3	1.9	34.3	20.2	25.4	9.7	5.2	1.0	1.0
A60	2.2	3.4	55.4	16.4	13.2	4.7	3.5	0.6	0.4
A70	1.6	2.3	46.2	21.7	17.8	6.4	3.3	0.5	0.2
A80	1.6	2.4	42.9	17.5	14.9	10.0	9.0	1.7	0.0
A90	1.4	2.1	42.9	18.7	16.6	7.1	4.9	1.4	4.8
A100	0.9	1.3	26.9	27.0	29.7	6.4	2.7	0.9	4.3
B0	1.8	2.5	64.0	12.2	6.3	5.0	1.3	0.0	6.9
B10	2.5	3.6	75.2	11.8	3.7	1.8	0.5	0.0	1.1
B20	2.1	2.8	69.2	15.6	4.8	2.0	0.6	0.0	2.9
B30	2.1	2.9	72.4	14.7	4.4	1.9	0.7	0.0	0.9
B40	2.2	3.0	72.6	11.8	6.5	2.8	0.3	0.0	0.7
B50	2.1	2.9	68.4	11.9	8.8	3.1	0.1	0.0	2.7
B60	2.1	3.1	54.1	9.8	15.5	8.6	3.8	1.8	1.3
B70	2.2	3.1	60.5	8.2	12.5	9.4	2.8	0.5	0.9
B80	1.9	2.8	54.8	7.8	15.0	12.2	3.1	0.3	2.1
B85	1.0	1.5	24.8	5.4	14.3	19.1	9.8	1.3	22.9
B100	3.5	5.2	75.1	12.2	2.3	0.8	0.8	0.0	0.1

Detailed analytical output provided by the University of Waikato is presented on the following pages.

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

MASTERSIZER 2000

Department of Earth & Ocean Sciences
School of Science and Engineering
The University of Waikato
Private Bag 3105
Hamilton, New Zealand

Result Analysis Report

Sample Name:
B100

SOP Name:
Marine Sed Bryna

Measured:
Friday, 21 January 2011 1:57:04 p.m.

Sample Source & type:
Factory

Measured by:
mckinnon

Analysed:
Friday, 21 January 2011 1:57:05 p.m.

Sample bulk lot ref:
2011015/12

Result Source:
Measurement

Particle Name:
Marine Sed Bryna

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
1

Size range:
0.020 to 2000.000 um

Obscuration:
12.75 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.215 %

Result Emulation:
Off

Concentration:
0.0092 %Vol

Span :
5.042

Uniformity:
1.95

Result units:
Volume

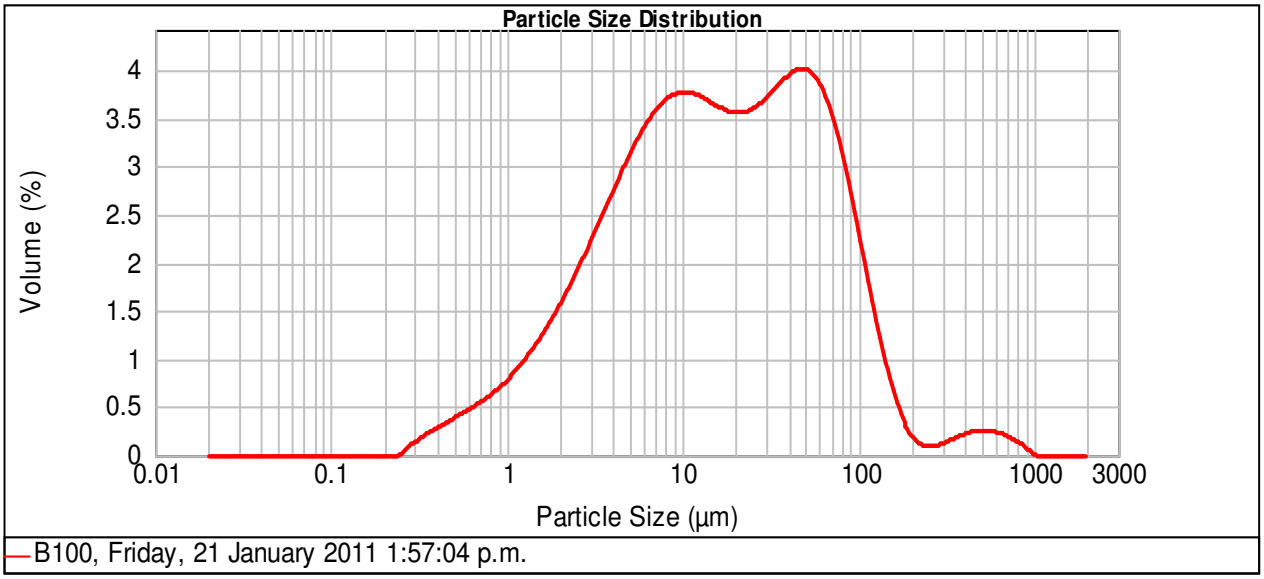
Specific Surface Area:
1.11 m²/g

Surface Weighted Mean D[3,2]:
5.395 um

Vol. Weighted Mean D[4,3]:
37.392 um

---

d(0.1): 2.261 um **d(0.5):** 15.909 um **d(0.9):** 82.471 um



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	0.980	3.46	37.000	70.13	105.000	94.09	300.000	98.51	840.000	99.93
0.060	0.00	2.000	8.68	44.000	74.60	125.000	96.08	350.000	98.66	1000.000	100.00
0.120	0.00	3.900	17.87	53.000	79.49	149.000	97.32	420.000	98.91	2000.000	100.00
0.240	0.00	7.800	32.63	63.000	83.91	177.000	97.97	500.000	99.20		
0.490	0.94	15.600	49.53	74.000	87.71	210.000	98.26	590.000	99.48		
0.700	2.02	31.000	65.72	88.000	91.25	250.000	98.40	710.000	99.75		

Operator notes:

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MASTERSIZER 2000

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School of Science and Engineering
The University of Waikato
Private Bag 3105
Hamilton, New Zealand

Result Analysis Report

Sample Name:
B85

SOP Name:
Marine Sed Bryna

Measured:
Friday, 21 January 2011 2:06:02 p.m.

Sample Source & type:
Factory

Measured by:
mckinnon

Analysed:
Friday, 21 January 2011 2:06:03 p.m.

Sample bulk lot ref:
2011015/13

Result Source:
Measurement

Particle Name:
Marine Sed Bryna

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
1

Size range:
0.020 to 2000.000 um

Obscuration:
28.32 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
1.010 %

Result Emulation:
Off

Concentration:
0.0557 %Vol

Span :
3.266

Uniformity:
1.08

Result units:
Volume

Specific Surface Area:
0.45 m²/g

Surface Weighted Mean D[3,2]:
13.338 um

Vol. Weighted Mean D[4,3]:
241.078 um

---

d(0.1): 5.769 um **d(0.5):** 178.787 um **d(0.9):** 589.632 um

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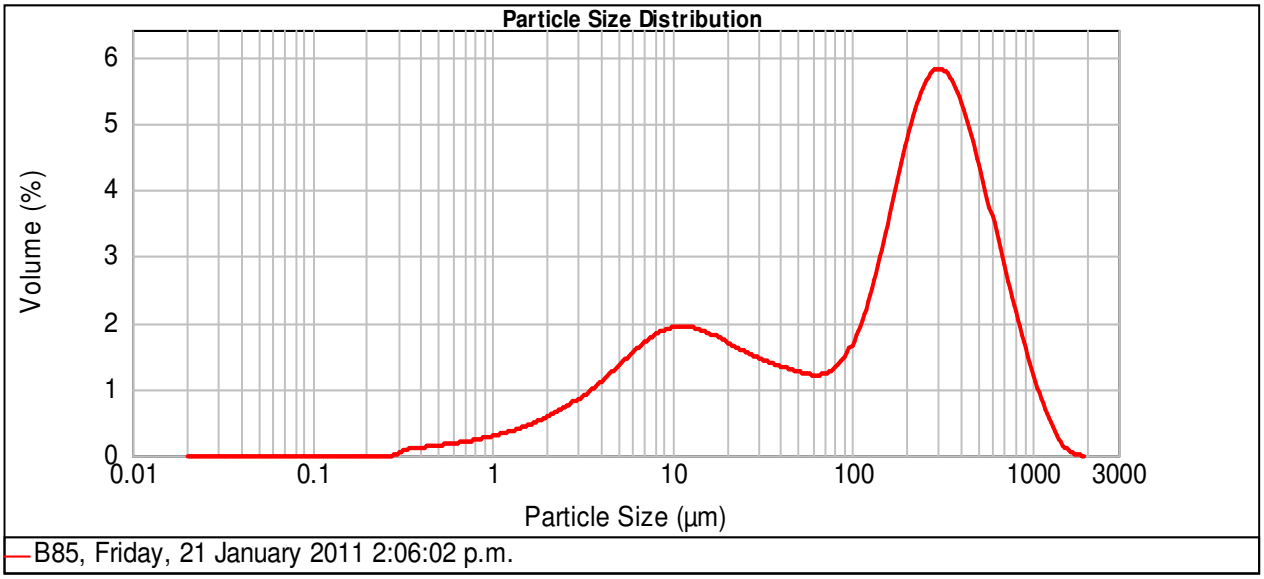

Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	0.980	1.27	37.000	30.92	105.000	39.98	300.000	67.69	840.000	96.48
0.060	0.00	2.000	3.19	44.000	32.44	125.000	42.36	350.000	73.53	1000.000	98.30
0.120	0.00	3.900	6.69	53.000	33.98	149.000	45.58	420.000	80.07	2000.000	100.00
0.240	0.00	7.800	13.27	63.000	35.37	177.000	49.73	500.000	85.61		
0.490	0.34	15.600	21.89	74.000	36.65	210.000	54.82	590.000	90.02		
0.700	0.74	31.000	29.28	88.000	38.14	250.000	60.86	710.000	93.89		

Operator notes:

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MASTERSIZER 2000

Department of Earth & Ocean Sciences
School of Science and Engineering
The University of Waikato
Private Bag 3105
Hamilton, New Zealand

Result Analysis Report

Sample Name:
B80

SOP Name:
Marine Sed Bryna

Measured:
Friday, 21 January 2011 2:14:57 p.m.

Sample Source & type:
Factory

Measured by:
mckinnon

Analysed:
Friday, 21 January 2011 2:14:58 p.m.

Sample bulk lot ref:
2011015/14

Result Source:
Measurement

Particle Name:
Marine Sed Bryna

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
1

Size range:
0.020 to 2000.000 um

Obscuration:
25.73 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.405 %

Result Emulation:
Off

Concentration:
0.0314 %Vol

Span :
10.128

Uniformity:
3.22

Result units:
Volume

Specific Surface Area:
0.714 m²/g

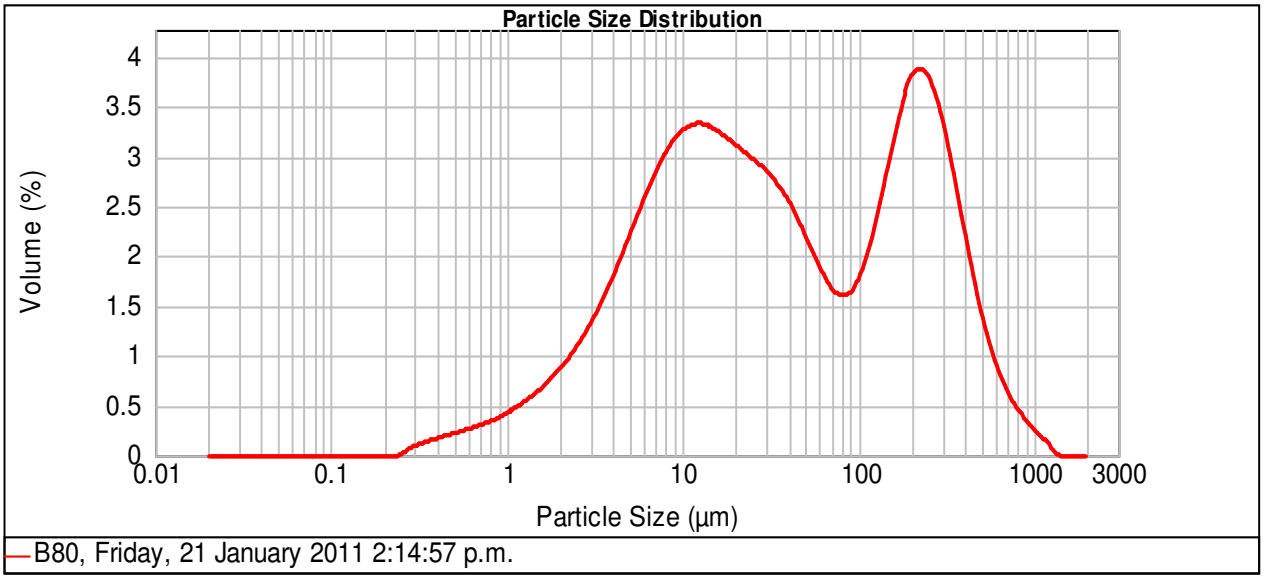
Surface Weighted Mean D[3,2]:
8.405 um

Vol. Weighted Mean D[4,3]:
112.591 um

---

d(0.1): 3.795 um **d(0.5):** 31.449 um **d(0.9):** 322.301 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	0.980	1.98	37.000	52.91	105.000	66.37	300.000	88.46	840.000	99.35
0.060	0.00	2.000	4.83	44.000	55.80	125.000	68.77	350.000	91.62	1000.000	99.74
0.120	0.00	3.900	10.31	53.000	58.56	149.000	71.83	420.000	94.55	2000.000	100.00
0.240	0.00	7.800	21.21	63.000	60.77	177.000	75.53	500.000	96.54		
0.490	0.58	15.600	35.98	74.000	62.57	210.000	79.70	590.000	97.84		
0.700	1.19	31.000	49.73	88.000	64.38	250.000	84.12	710.000	98.79		

Operator notes:

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MASTERSIZER 2000

Department of Earth & Ocean Sciences
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Result Analysis Report

Sample Name:
B70

SOP Name:
Marine Sed Bryna

Measured:
Friday, 21 January 2011 2:24:31 p.m.

Sample Source & type:
Factory

Measured by:
mckinnon

Analysed:
Friday, 21 January 2011 2:24:33 p.m.

Sample bulk lot ref:
2011015/15

Result Source:
Measurement

Particle Name:
Marine Sed Bryna

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
1

Size range:
0.020 to 2000.000 um

Obscuration:
26.46 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.293 %

Result Emulation:
Off

Concentration:
0.0298 %Vol

Span :
11.498

Uniformity:
3.56

Result units:
Volume

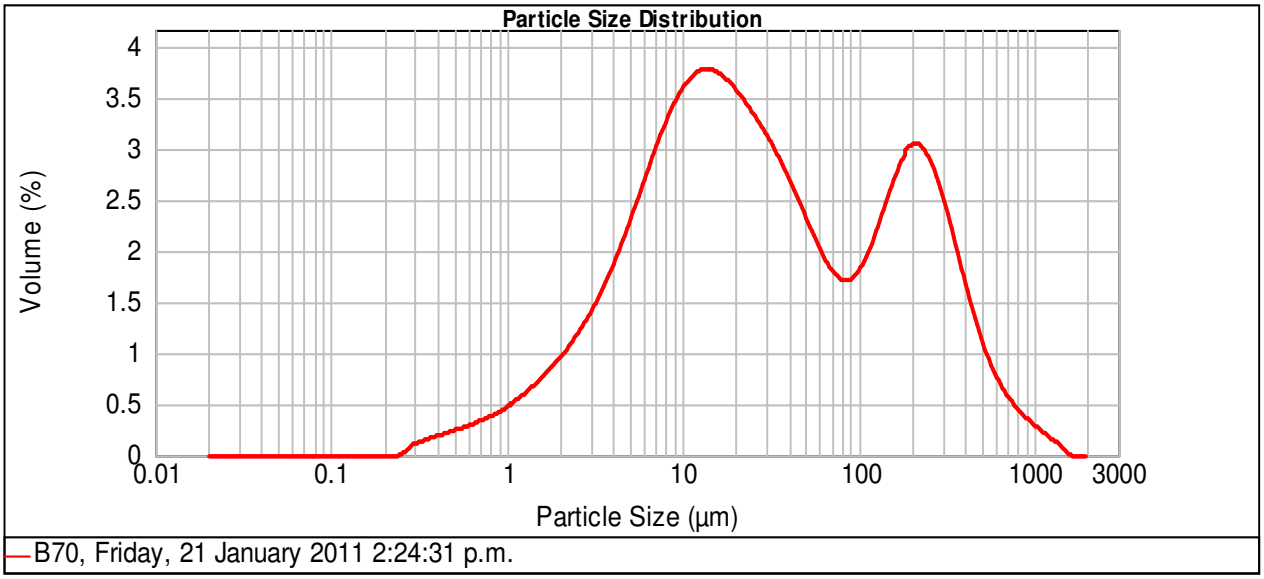
Specific Surface Area:
0.777 m²/g

Surface Weighted Mean D[3,2]:
7.719 um

Vol. Weighted Mean D[4,3]:
98.741 um

---

d(0.1): 3.513 um **d(0.5):** 24.939 um **d(0.9):** 290.255 um



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	0.980	2.20	37.000	58.04	105.000	72.31	300.000	90.56	840.000	99.14
0.060	0.00	2.000	5.37	44.000	61.11	125.000	74.61	350.000	92.95	1000.000	99.55
0.120	0.00	3.900	11.18	53.000	64.03	149.000	77.35	420.000	95.17	2000.000	100.00
0.240	0.00	7.800	22.54	63.000	66.38	177.000	80.46	500.000	96.72		
0.490	0.65	15.600	38.99	74.000	68.32	210.000	83.82	590.000	97.77		
0.700	1.32	31.000	54.60	88.000	70.27	250.000	87.26	710.000	98.60		

Operator notes:

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

MASTERSIZER 2000

Department of Earth & Ocean Sciences
School of Science and Engineering
The University of Waikato
Private Bag 3105
Hamilton, New Zealand

Result Analysis Report

Sample Name:
B60

SOP Name:
Marine Sed Bryna

Measured:
Friday, 21 January 2011 2:34:28 p.m.

Sample Source & type:
Factory

Measured by:
mckinnon

Analysed:
Friday, 21 January 2011 2:34:29 p.m.

Sample bulk lot ref:
2011015/16

Result Source:
Measurement

Particle Name:
Marine Sed Bryna

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
1

Size range:
0.020 to 2000.000 um

Obscuration:
23.12 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.418 %

Result Emulation:
Off

Concentration:
0.0263 %Vol

Span :
10.709

Uniformity:
3.94

Result units:
Volume

Specific Surface Area:
0.752 m²/g

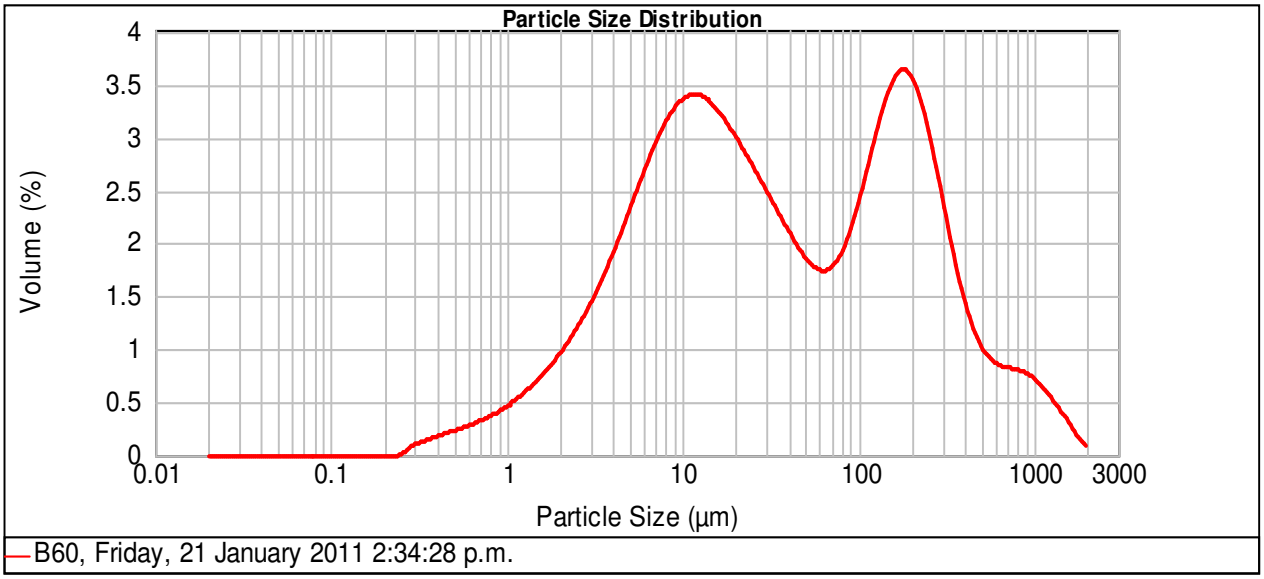
Surface Weighted Mean D[3,2]:
7.980 um

Vol. Weighted Mean D[4,3]:
127.868 um

---

d(0.1): 3.520 um **d(0.5):** 29.767 um **d(0.9):** 322.306 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	0.980	2.10	37.000	53.37	105.000	66.76	300.000	88.91	840.000	97.28
0.060	0.00	2.000	5.25	44.000	55.76	125.000	69.95	350.000	91.10	1000.000	98.16
0.120	0.00	3.900	11.19	53.000	58.07	149.000	73.71	420.000	93.01	2000.000	100.00
0.240	0.00	7.800	22.56	63.000	60.06	177.000	77.75	500.000	94.35		
0.490	0.61	15.600	37.68	74.000	61.91	210.000	81.79	590.000	95.36		
0.700	1.25	31.000	50.66	88.000	64.10	250.000	85.59	710.000	96.39		

Operator notes:

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Hamilton, New Zealand

Result Analysis Report

Sample Name:
B50

SOP Name:
Marine Sed Bryna

Measured:
Friday, 21 January 2011 2:43:23 p.m.

Sample Source & type:
Factory

Measured by:
mckinnon

Analysed:
Friday, 21 January 2011 2:43:24 p.m.

Sample bulk lot ref:
2011015/17

Result Source:
Measurement

Particle Name:
Marine Sed Bryna

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
1

Size range:
0.020 to 2000.000 um

Obscuration:
18.77 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.212 %

Result Emulation:
Off

Concentration:
0.0202 %Vol

Span :
6.047

Uniformity:
1.81

Result units:
Volume

Specific Surface Area:
0.777 m²/g

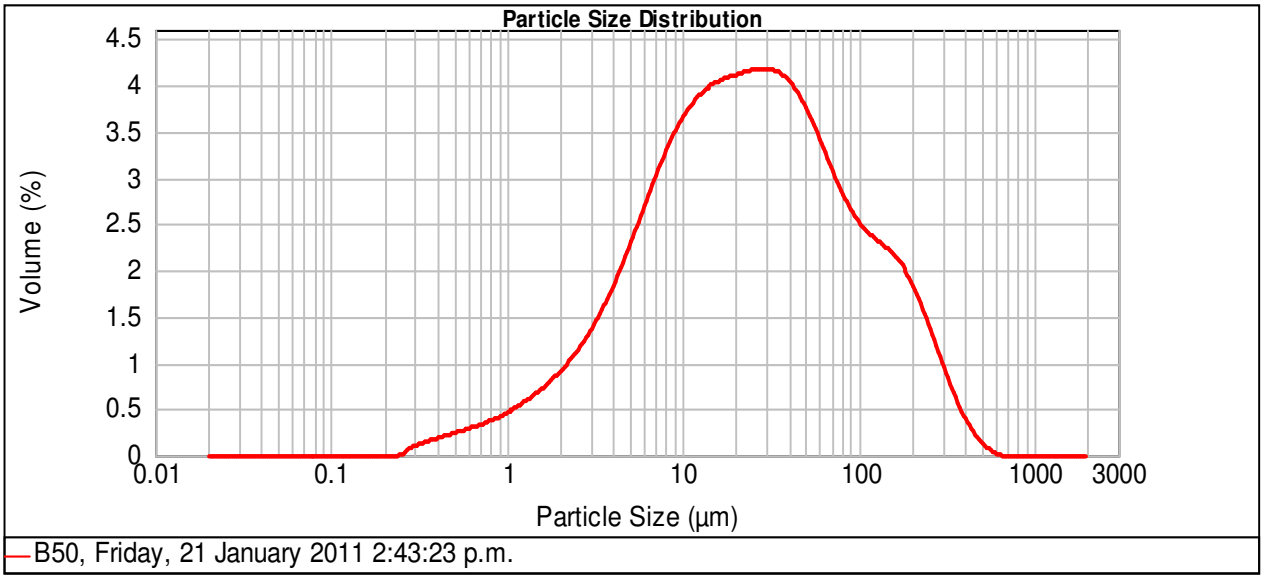
Surface Weighted Mean D[3,2]:
7.720 um

Vol. Weighted Mean D[4,3]:
52.467 um

---

d(0.1): 3.648 um **d(0.5):** 23.541 um **d(0.9):** 145.996 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	0.980	2.14	37.000	62.30	105.000	84.96	300.000	98.19	840.000	100.00
0.060	0.00	2.000	5.16	44.000	66.88	125.000	87.68	350.000	99.04	1000.000	100.00
0.120	0.00	3.900	10.75	53.000	71.53	149.000	90.30	420.000	99.64	2000.000	100.00
0.240	0.00	7.800	22.07	63.000	75.47	177.000	92.71	500.000	99.91		
0.490	0.62	15.600	38.99	74.000	78.79	210.000	94.87	590.000	100.00		
0.700	1.29	31.000	57.50	88.000	81.99	250.000	96.72	710.000	100.00		

Operator notes:

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Hamilton, New Zealand

Result Analysis Report

Sample Name:
B40

SOP Name:
Marine Sed Bryna

Measured:
Friday, 21 January 2011 2:52:15 p.m.

Sample Source & type:
Factory

Measured by:
mckinnon

Analysed:
Friday, 21 January 2011 2:52:16 p.m.

Sample bulk lot ref:
2011015/18

Result Source:
Measurement

Particle Name:
Marine Sed Bryna

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
1

Size range:
0.020 to 2000.000 um

Obscuration:
21.09 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.204 %

Result Emulation:
Off

Concentration:
0.0229 %Vol

Span :
4.905

Uniformity:
1.62

Result units:
Volume

Specific Surface Area:
0.781 m²/g

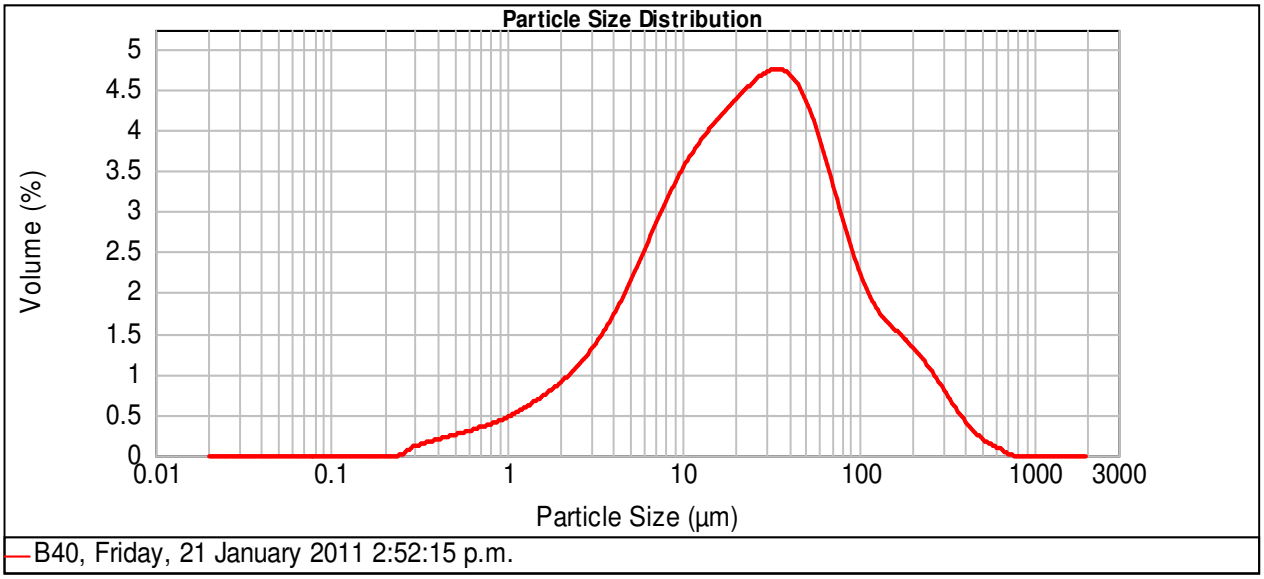
Surface Weighted Mean D[3,2]:
7.685 um

Vol. Weighted Mean D[4,3]:
49.167 um

---

d(0.1): 3.680 um **d(0.5):** 24.025 um **d(0.9):** 121.512 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	0.980	2.23	37.000	63.21	105.000	88.10	300.000	98.09	840.000	100.00
0.060	0.00	2.000	5.26	44.000	68.51	125.000	90.34	350.000	98.82	1000.000	100.00
0.120	0.00	3.900	10.61	53.000	73.90	149.000	92.29	420.000	99.41	2000.000	100.00
0.240	0.00	7.800	21.23	63.000	78.42	177.000	94.00	500.000	99.74		
0.490	0.66	15.600	37.79	74.000	82.07	210.000	95.55	590.000	99.91		
0.700	1.35	31.000	57.73	88.000	85.36	250.000	96.93	710.000	100.00		

Operator notes:

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Result Analysis Report

Sample Name:
B30

SOP Name:
Marine Sed Bryna

Measured:
Friday, 21 January 2011 3:01:27 p.m.

Sample Source & type:
Factory

Measured by:
mckinnon

Analysed:
Friday, 21 January 2011 3:01:28 p.m.

Sample bulk lot ref:
2011015/19

Result Source:
Measurement

Particle Name:
Marine Sed Bryna

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
1

Size range:
0.020 to 2000.000 um

Obscuration:
15.35 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.178 %

Result Emulation:
Off

Concentration:
0.0168 %Vol

Span :
3.809

Uniformity:
1.47

Result units:
Volume

Specific Surface Area:
0.751 m²/g

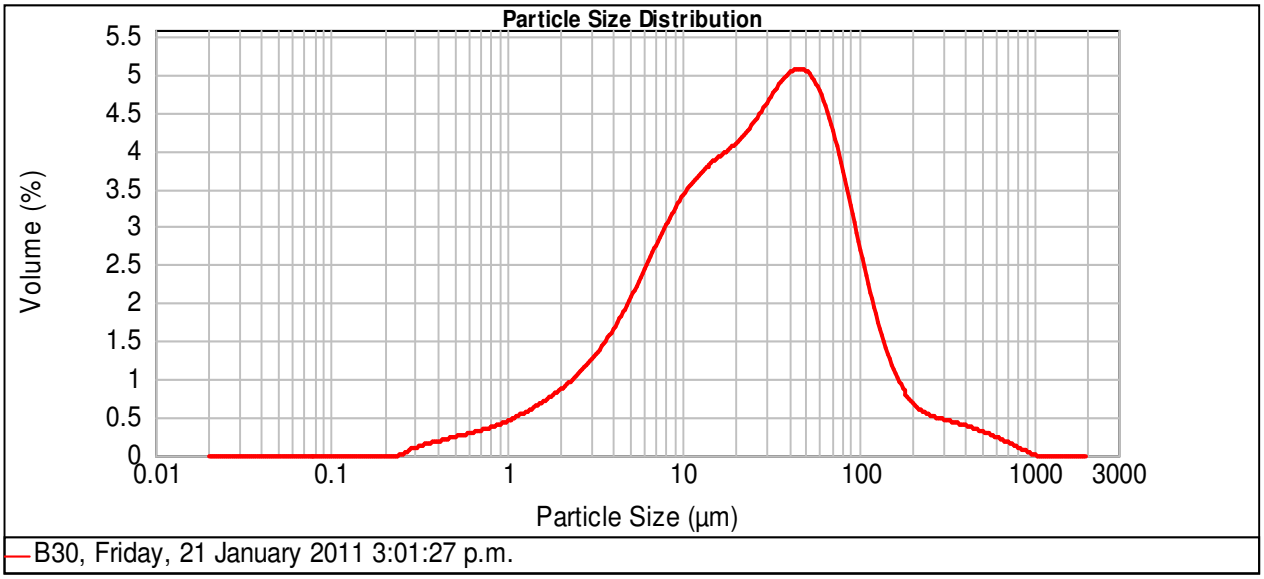
Surface Weighted Mean D[3,2]:
7.991 um

Vol. Weighted Mean D[4,3]:
49.098 um

---

d(0.1): 3.836 um **d(0.5):** 25.999 um **d(0.9):** 102.868 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	0.980	2.11	37.000	60.74	105.000	90.35	300.000	97.89	840.000	99.95
0.060	0.00	2.000	5.02	44.000	66.42	125.000	92.84	350.000	98.35	1000.000	100.00
0.120	0.00	3.900	10.17	53.000	72.57	149.000	94.59	420.000	98.84	2000.000	100.00
0.240	0.00	7.800	20.41	63.000	78.05	177.000	95.77	500.000	99.25		
0.490	0.62	15.600	36.31	74.000	82.68	210.000	96.61	590.000	99.56		
0.700	1.28	31.000	55.20	88.000	86.93	250.000	97.29	710.000	99.82		

Operator notes:

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Result Analysis Report

Sample Name:
B20

SOP Name:
Marine Sed Bryna

Measured:
Friday, 21 January 2011 3:10:29 p.m.

Sample Source & type:
Factory

Measured by:
mckinnon

Analysed:
Friday, 21 January 2011 3:10:30 p.m.

Sample bulk lot ref:
2011015/20

Result Source:
Measurement

Particle Name:
Marine Sed Bryna

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
1

Size range:
0.020 to 2000.000 um

Obscuration:
22.50 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.197 %

Result Emulation:
Off

Concentration:
0.0259 %Vol

Span :
3.588

Uniformity:
1.36

Result units:
Volume

Specific Surface Area:
0.743 m²/g

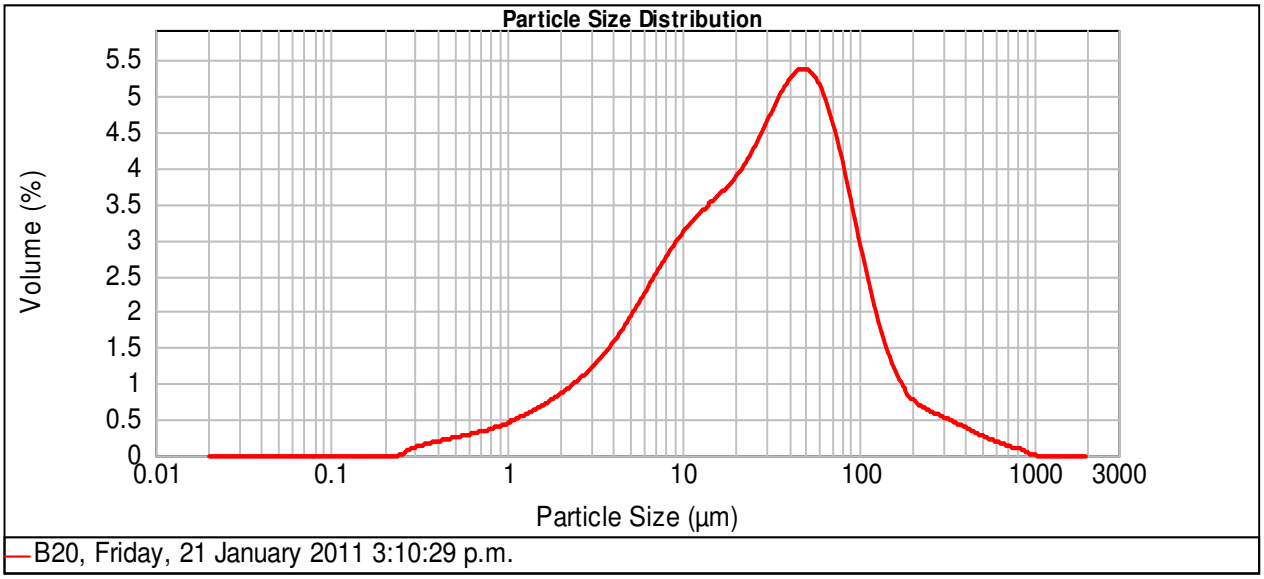
Surface Weighted Mean D[3,2]:
8.076 um

Vol. Weighted Mean D[4,3]:
50.730 um

---

d(0.1): 3.859 um **d(0.5):** 28.687 um **d(0.9):** 106.779 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	0.980	2.17	37.000	57.99	105.000	89.70	300.000	97.99	840.000	99.95
0.060	0.00	2.000	5.08	44.000	63.91	125.000	92.38	350.000	98.50	1000.000	100.00
0.120	0.00	3.900	10.10	53.000	70.45	149.000	94.27	420.000	99.00	2000.000	100.00
0.240	0.00	7.800	19.63	63.000	76.35	177.000	95.56	500.000	99.37		
0.490	0.66	15.600	34.17	74.000	81.37	210.000	96.51	590.000	99.63		
0.700	1.33	31.000	52.34	88.000	85.99	250.000	97.29	710.000	99.84		

Operator notes:

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Result Analysis Report

Sample Name:
B10

SOP Name:
Marine Sed Bryna

Measured:
Friday, 21 January 2011 3:40:45 p.m.

Sample Source & type:
Factory

Measured by:
mckinnon

Analysed:
Friday, 21 January 2011 3:40:46 p.m.

Sample bulk lot ref:
2011015/21

Result Source:
Measurement

Particle Name:
Marine Sed Bryna

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
1

Size range:
0.020 to 2000.000 um

Obscuration:
18.17 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.190 %

Result Emulation:
Off

Concentration:
0.0174 %Vol

Span :
4.058

Uniformity:
1.54

Result units:
Volume

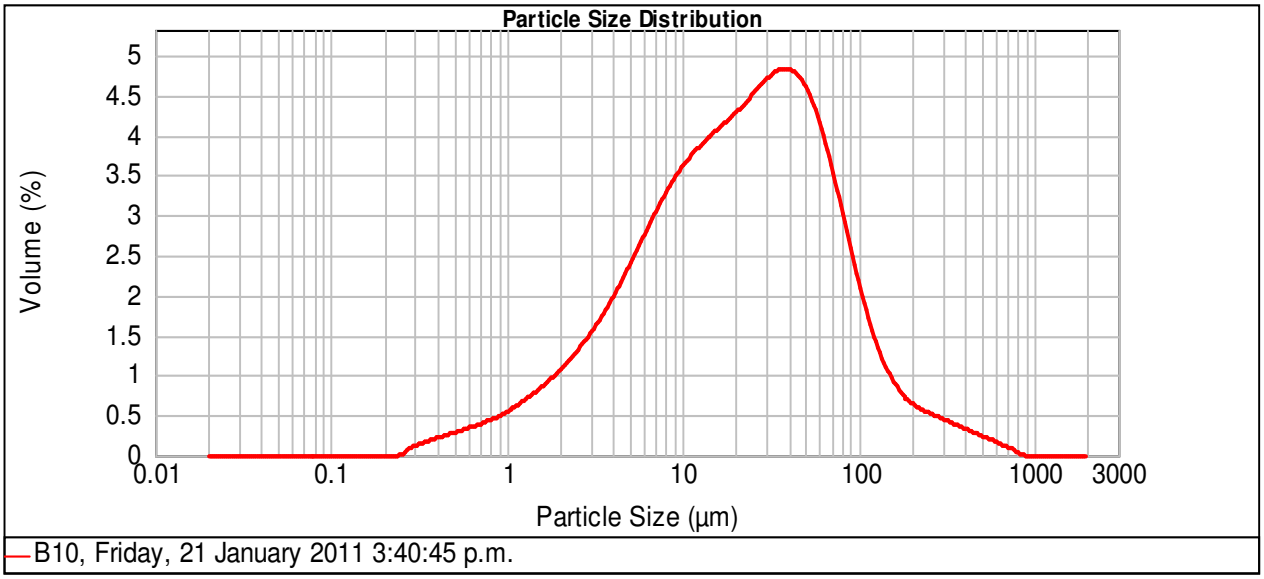
Specific Surface Area:
0.868 m²/g

Surface Weighted Mean D[3,2]:
6.915 um

Vol. Weighted Mean D[4,3]:
42.516 um

---

d(0.1): 3.150 um **d(0.5):** 21.688 um **d(0.9):** 91.162 um



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	0.980	2.53	37.000	66.13	105.000	92.07	300.000	98.35	840.000	100.00
0.060	0.00	2.000	6.11	44.000	71.59	125.000	93.97	350.000	98.78	1000.000	100.00
0.120	0.00	3.900	12.45	53.000	77.26	149.000	95.34	420.000	99.21	2000.000	100.00
0.240	0.00	7.800	24.15	63.000	82.08	177.000	96.32	500.000	99.53		
0.490	0.73	15.600	40.97	74.000	85.97	210.000	97.09	590.000	99.76		
0.700	1.51	31.000	60.59	88.000	89.40	250.000	97.75	710.000	99.93		

Operator notes:

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Hamilton, New Zealand

Result Analysis Report

Sample Name:
B0

SOP Name:
Marine Sed Bryna

Measured:
Friday, 21 January 2011 4:03:12 p.m.

Sample Source & type:
Factory

Measured by:
mckinnon

Analysed:
Friday, 21 January 2011 4:03:13 p.m.

Sample bulk lot ref:
2011015/22

Result Source:
Measurement

Particle Name:
Marine Sed Bryna

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
1

Size range:
0.020 to 2000.000 um

Obscuration:
14.67 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.223 %

Result Emulation:
Off

Concentration:
0.0173 %Vol

Span :
5.793

Uniformity:
1.83

Result units:
Volume

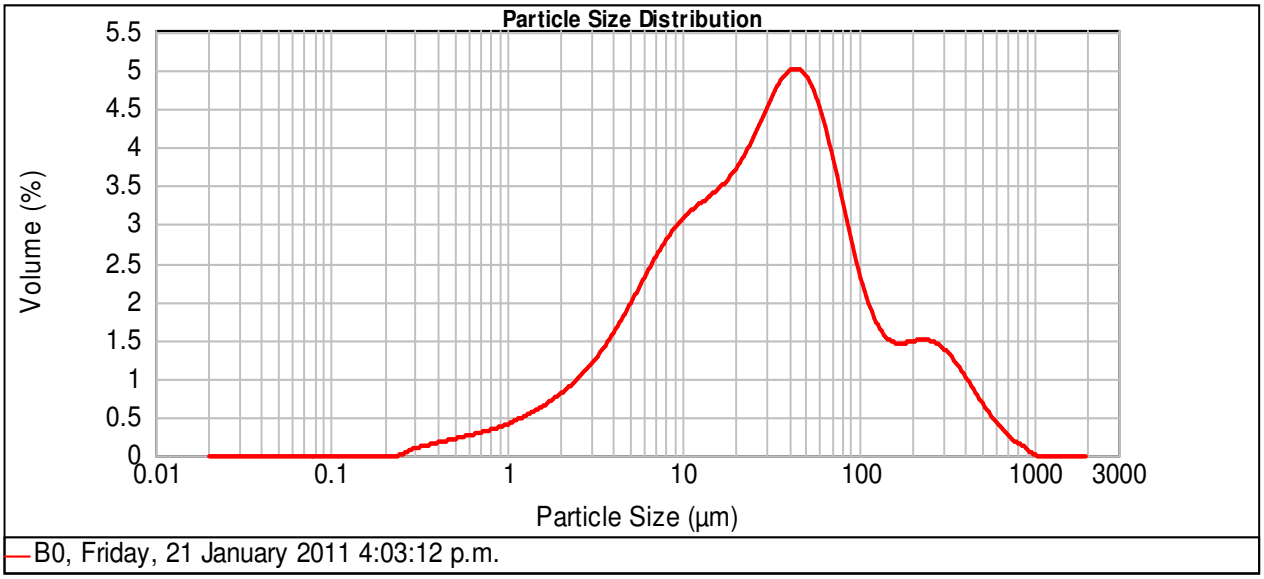
Specific Surface Area:
0.693 m²/g

Surface Weighted Mean D[3,2]:
8.664 um

Vol. Weighted Mean D[4,3]:
67.012 um

---

d(0.1): 4.123 um **d(0.5):** 30.039 um **d(0.9):** 178.138 um



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	0.980	1.90	37.000	56.42	105.000	84.26	300.000	95.03	840.000	99.92
0.060	0.00	2.000	4.55	44.000	62.07	125.000	86.47	350.000	96.37	1000.000	100.00
0.120	0.00	3.900	9.43	53.000	68.11	149.000	88.30	420.000	97.70	2000.000	100.00
0.240	0.00	7.800	19.14	63.000	73.34	177.000	89.94	500.000	98.66		
0.490	0.56	15.600	33.41	74.000	77.58	210.000	91.58	590.000	99.28		
0.700	1.15	31.000	50.93	88.000	81.32	250.000	93.29	710.000	99.72		

Operator notes:

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Te Whare Wānanga o Waikato

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The University of Waikato
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Hamilton, New Zealand

Result Analysis Report

Sample Name:
A100

SOP Name:
Marine Sed Bryna

Measured:
Friday, 21 January 2011 11:48:30 a.m.

Sample Source & type:
Factory = Paris

Measured by:
mckinnon

Analysed:
Friday, 21 January 2011 11:48:32 a.m.

Sample bulk lot ref:
2011015/1

Result Source:
Measurement

Particle Name:
Marine Sed Bryna

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
1

Size range:
0.020 to 2000.000 um

Obscuration:
17.17 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.589 %

Result Emulation:
Off

Concentration:
0.0409 %Vol

Span :
2.306

Uniformity:
0.875

Result units:
Volume

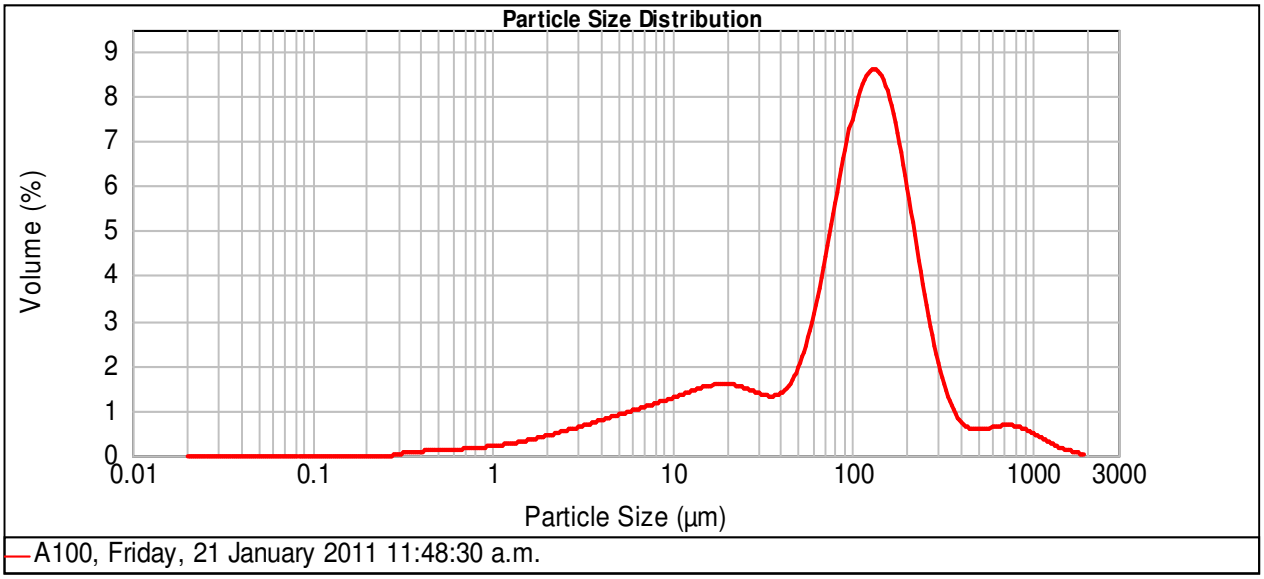
Specific Surface Area:
0.35 m²/g

Surface Weighted Mean D[3,2]:
17.153 um

Vol. Weighted Mean D[4,3]:
140.350 um

---

d(0.1): 8.678 um **d(0.5): 106.807 um** **d(0.9): 254.951 um**



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	0.980	0.92	37.000	23.60	105.000	49.12	300.000	92.91	840.000	98.38
0.060	0.00	2.000	2.31	44.000	25.17	125.000	58.56	350.000	94.52	1000.000	99.04
0.120	0.00	3.900	4.90	53.000	27.35	149.000	68.37	420.000	95.57	2000.000	100.00
0.240	0.00	7.800	9.19	63.000	30.39	177.000	77.20	500.000	96.24		
0.490	0.26	15.600	15.24	74.000	34.57	210.000	84.33	590.000	96.87		
0.700	0.55	31.000	22.07	88.000	40.86	250.000	89.54	710.000	97.66		

Operator notes:

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Te Whare Wānanga o Waikato

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The University of Waikato
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Hamilton, New Zealand

Result Analysis Report

Sample Name:
A90

SOP Name:
Marine Sed Bryna

Measured:
Friday, 21 January 2011 12:06:32 p.m.

Sample Source & type:
Factory

Measured by:
mckinnon

Analysed:
Friday, 21 January 2011 12:06:33 p.m.

Sample bulk lot ref:
2011015/2

Result Source:
Edited

Particle Name:
Marine Sed Bryna

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
1

Size range:
0.020 to 2000.000 um

Obscuration:
19.98 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.433 %

Result Emulation:
Off

Concentration:
0.0310 %Vol

Span :
5.140

Uniformity:
1.77

Result units:
Volume

Specific Surface Area:
0.542 m²/g

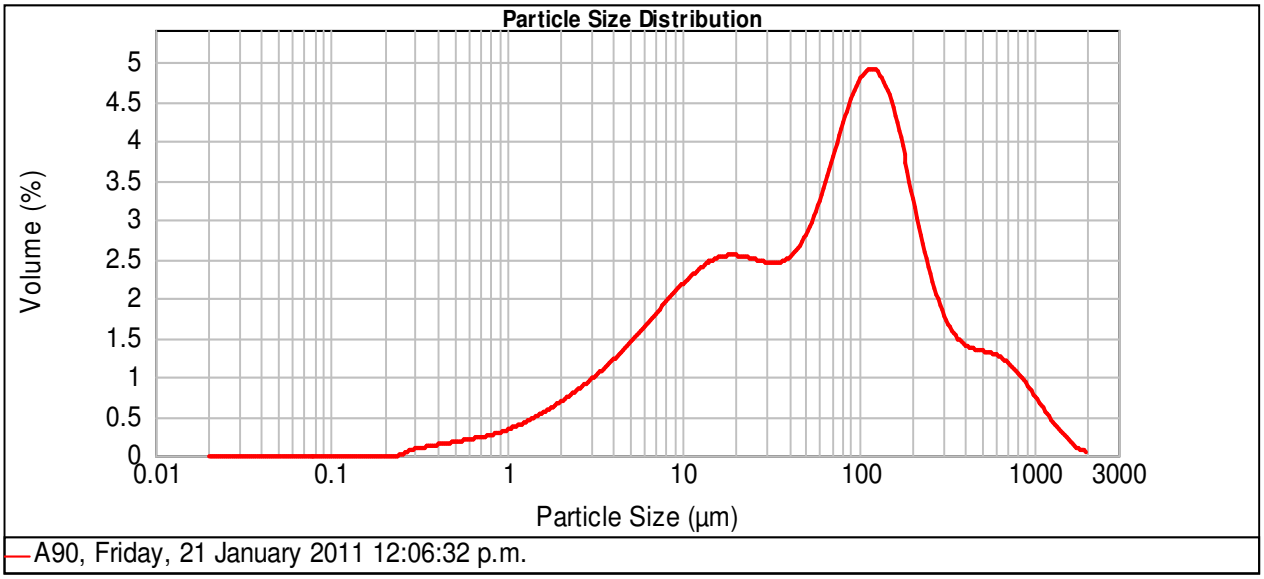
Surface Weighted Mean D[3,2]:
11.061 um

Vol. Weighted Mean D[4,3]:
139.267 um

---

d(0.1): 5.091 um **d(0.5):** 66.432 um **d(0.9):** 346.534 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	0.980	1.51	37.000	39.07	105.000	62.81	300.000	88.41	840.000	97.50
0.060	0.00	2.000	3.72	44.000	41.92	125.000	68.41	350.000	90.10	1000.000	98.51
0.120	0.00	3.900	7.71	53.000	45.25	149.000	73.89	420.000	91.83	2000.000	100.00
0.240	0.00	7.800	14.71	63.000	48.80	177.000	78.71	500.000	93.38		
0.490	0.46	15.600	24.95	74.000	52.64	210.000	82.70	590.000	94.80		
0.700	0.92	31.000	36.24	88.000	57.40	250.000	85.88	710.000	96.30		

Operator notes:

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Te Whare Wānanga o Waikato

MASTERSIZER 2000

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Private Bag 3105
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Result Analysis Report

Sample Name:
A80

SOP Name:
Marine Sed Bryna

Measured:
Friday, 21 January 2011 12:20:22 p.m.

Sample Source & type:
Factory

Measured by:
mckinnon

Analysed:
Friday, 21 January 2011 12:20:23 p.m.

Sample bulk lot ref:
2011015/3

Result Source:
Measurement

Particle Name:
Marine Sed Bryna

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
1

Size range:
0.020 to 2000.000 um

Obscuration:
19.70 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.545 %

Result Emulation:
Off

Concentration:
0.0292 %Vol

Span :
7.116

Uniformity:
2.04

Result units:
Volume

Specific Surface Area:
0.566 m²/g

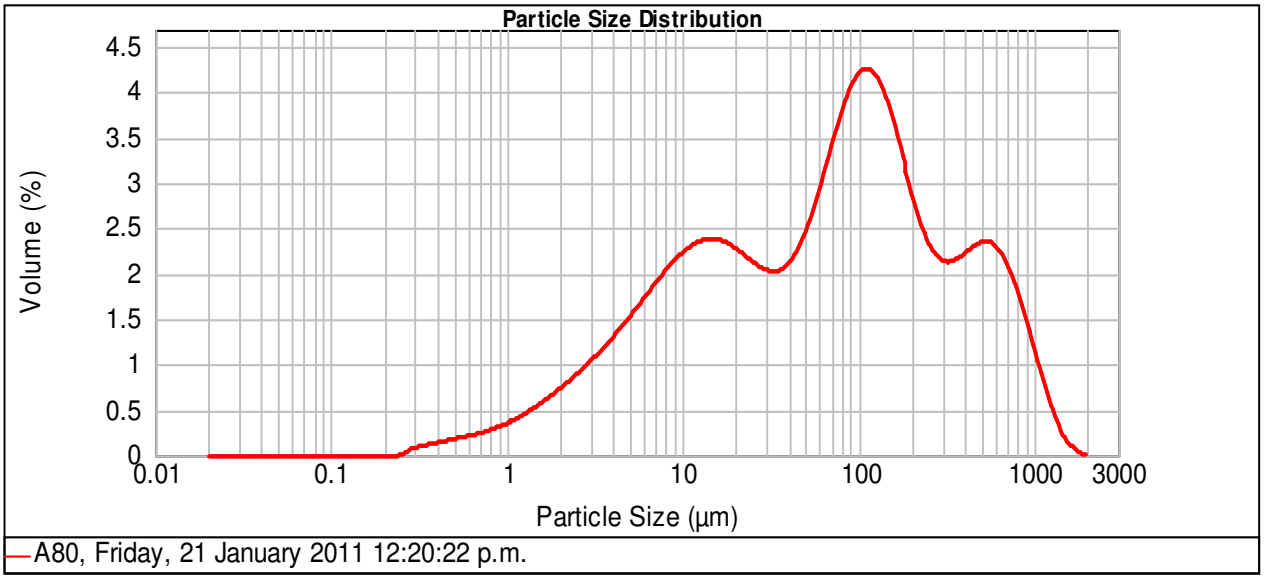
Surface Weighted Mean D[3,2]:
10.609 um

Vol. Weighted Mean D[4,3]:
170.338 um

---

d(0.1): 4.694 um **d(0.5):** 72.760 um **d(0.9):** 522.462 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	0.980	1.61	37.000	38.37	105.000	59.51	300.000	81.93	840.000	96.65
0.060	0.00	2.000	4.03	44.000	40.77	125.000	64.35	350.000	84.08	1000.000	98.28
0.120	0.00	3.900	8.34	53.000	43.69	149.000	68.97	420.000	86.69	2000.000	100.00
0.240	0.00	7.800	15.78	63.000	46.89	177.000	72.99	500.000	89.32		
0.490	0.48	15.600	26.07	74.000	50.39	210.000	76.38	590.000	91.87		
0.700	0.97	31.000	36.02	88.000	54.71	250.000	79.28	710.000	94.56		

Operator notes:

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Result Analysis Report

Sample Name:
A70

SOP Name:
Marine Sed Bryna

Measured:
Friday, 21 January 2011 12:31:10 p.m.

Sample Source & type:
Factory

Measured by:
mckinnon

Analysed:
Friday, 21 January 2011 12:31:12 p.m.

Sample bulk lot ref:
2011015/4

Result Source:
Measurement

Particle Name:
Marine Sed Bryna

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
1

Size range:
0.020 to 2000.000 um

Obscuration:
14.92 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.404 %

Result Emulation:
Off

Concentration:
0.0217 %Vol

Span :
3.984

Uniformity:
1.46

Result units:
Volume

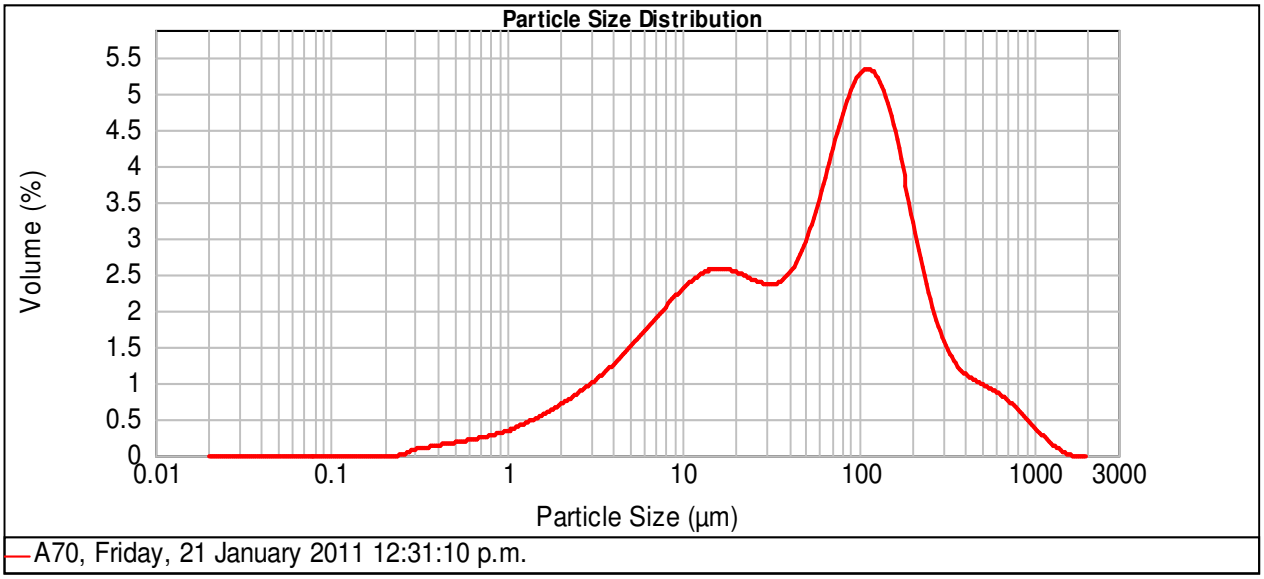
Specific Surface Area:
0.562 m²/g

Surface Weighted Mean D[3,2]:
10.673 um

Vol. Weighted Mean D[4,3]:
111.617 um

---

d(0.1): 4.900 um **d(0.5):** 62.442 um **d(0.9):** 253.690 um



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	0.980	1.57	37.000	40.01	105.000	65.84	300.000	92.11	840.000	98.95
0.060	0.00	2.000	3.88	44.000	42.86	125.000	71.93	350.000	93.58	1000.000	99.50
0.120	0.00	3.900	8.00	53.000	46.35	149.000	77.74	420.000	95.00	2000.000	100.00
0.240	0.00	7.800	15.30	63.000	50.22	177.000	82.72	500.000	96.18		
0.490	0.47	15.600	26.07	74.000	54.50	210.000	86.71	590.000	97.20		
0.700	0.95	31.000	37.26	88.000	59.83	250.000	89.78	710.000	98.21		

Operator notes:

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Result Analysis Report

Sample Name:
A60

SOP Name:
Marine Sed Bryna

Measured:
Friday, 21 January 2011 12:40:33 p.m.

Sample Source & type:
Factory

Measured by:
mckinnon

Analysed:
Friday, 21 January 2011 12:40:34 p.m.

Sample bulk lot ref:
2011015/5

Result Source:
Measurement

Particle Name:
Marine Sed Bryna

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
1

Size range:
0.020 to 2000.000 um

Obscuration:
14.13 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.344 %

Result Emulation:
Off

Concentration:
0.0148 %Vol

Span :
6.941

Uniformity:
2.67

Result units:
Volume

Specific Surface Area:
0.776 m²/g

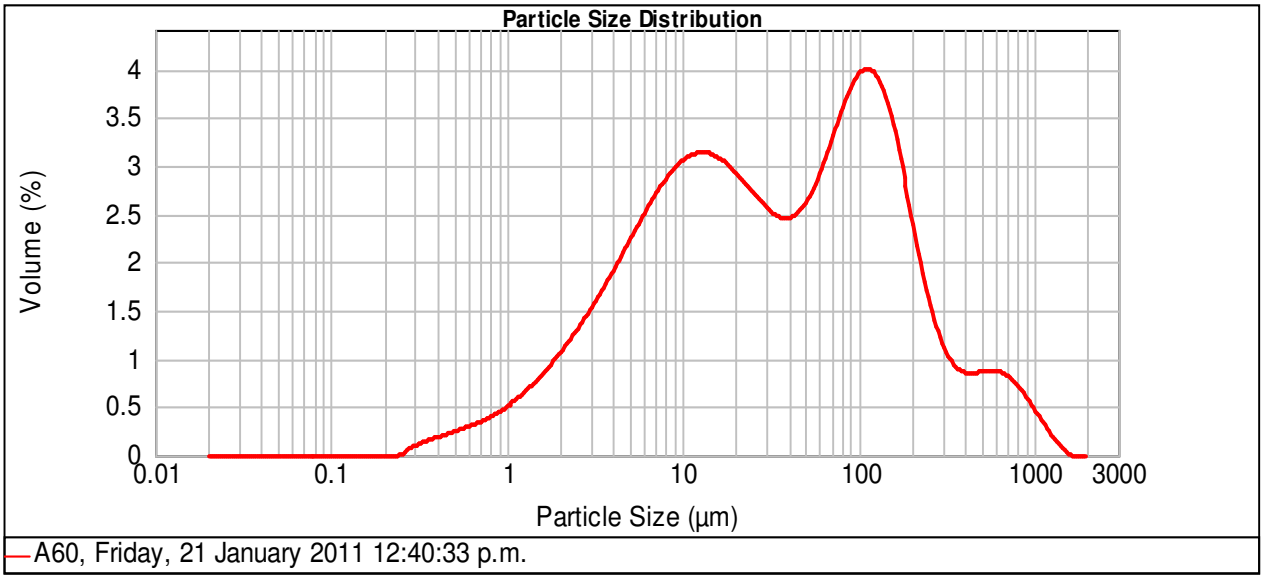
Surface Weighted Mean D[3,2]:
7.733 um

Vol. Weighted Mean D[4,3]:
97.076 um

---

d(0.1): 3.288 um **d(0.5):** 32.281 um **d(0.9):** 227.360 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	0.980	2.22	37.000	52.21	105.000	73.28	300.000	92.80	840.000	98.69
0.060	0.00	2.000	5.68	44.000	55.00	125.000	77.84	350.000	93.85	1000.000	99.35
0.120	0.00	3.900	11.95	53.000	58.13	149.000	82.19	420.000	94.90	2000.000	100.00
0.240	0.00	7.800	22.70	63.000	61.34	177.000	85.92	500.000	95.87		
0.490	0.63	15.600	36.57	74.000	64.71	210.000	88.88	590.000	96.82		
0.700	1.31	31.000	49.33	88.000	68.77	250.000	91.13	710.000	97.86		

Operator notes:

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Result Analysis Report

Sample Name:
A50

SOP Name:
Marine Sed Bryna

Measured:
Friday, 21 January 2011 1:02:02 p.m.

Sample Source & type:
Factory

Measured by:
mckinnon

Analysed:
Friday, 21 January 2011 1:02:03 p.m.

Sample bulk lot ref:
2011015/6

Result Source:
Measurement

Particle Name:
Marine Sed Bryna

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
1

Size range:
0.020 to 2000.000 um

Obscuration:
20.92 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.577 %

Result Emulation:
Off

Concentration:
0.0379 %Vol

Span :
3.409

Uniformity:
1.17

Result units:
Volume

Specific Surface Area:
0.467 m²/g

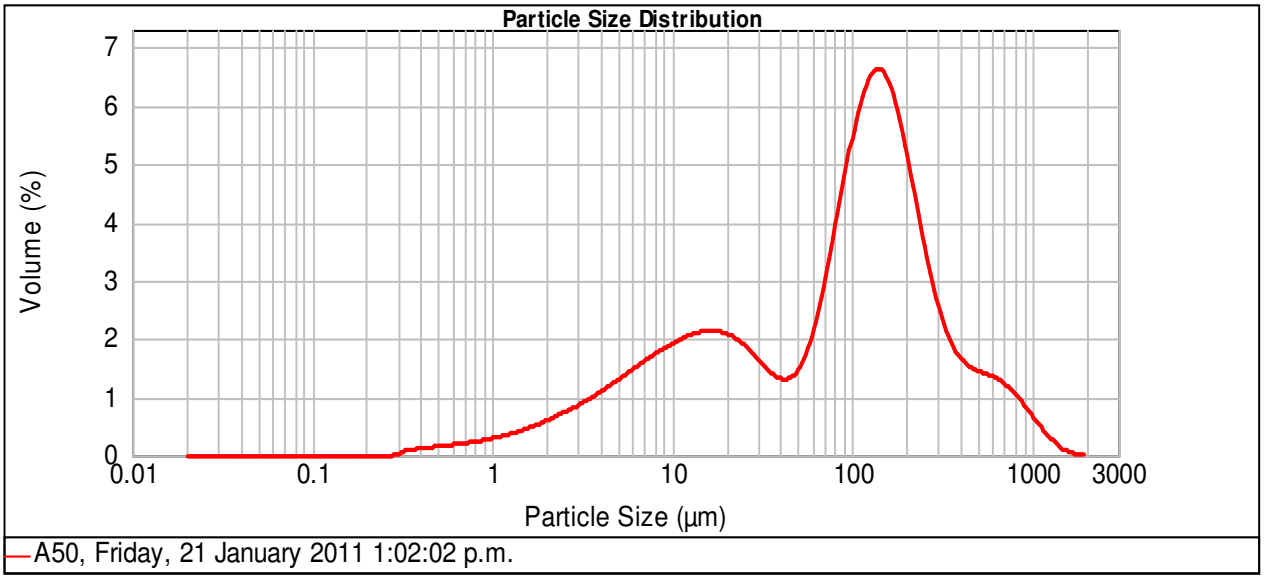
Surface Weighted Mean D[3,2]:
12.842 um

Vol. Weighted Mean D[4,3]:
152.719 um

---

d(0.1): 5.749 um **d(0.5):** 101.578 um **d(0.9):** 352.071 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	0.980	1.29	37.000	32.60	105.000	51.23	300.000	87.66	840.000	98.06
0.060	0.00	2.000	3.26	44.000	34.09	125.000	58.31	350.000	89.92	1000.000	99.00
0.120	0.00	3.900	6.82	53.000	35.80	149.000	65.92	420.000	92.02	2000.000	100.00
0.240	0.00	7.800	13.14	63.000	37.93	177.000	73.04	500.000	93.75		
0.490	0.34	15.600	22.05	74.000	40.82	210.000	79.12	590.000	95.28		
0.700	0.75	31.000	30.89	88.000	45.24	250.000	83.98	710.000	96.86		

Operator notes:

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Result Analysis Report

Sample Name:
A40

SOP Name:
Marine Sed Bryna

Measured:
Friday, 21 January 2011 1:11:08 p.m.

Sample Source & type:
Factory

Measured by:
mckinnon

Analysed:
Friday, 21 January 2011 1:11:09 p.m.

Sample bulk lot ref:
2011015/7

Result Source:
Measurement

Particle Name:
Marine Sed Bryna

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
1

Size range:
0.020 to 2000.000 um

Obscuration:
15.18 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.626 %

Result Emulation:
Off

Concentration:
0.0275 %Vol

Span :
2.232

Uniformity:
0.901

Result units:
Volume

Specific Surface Area:
0.453 m²/g

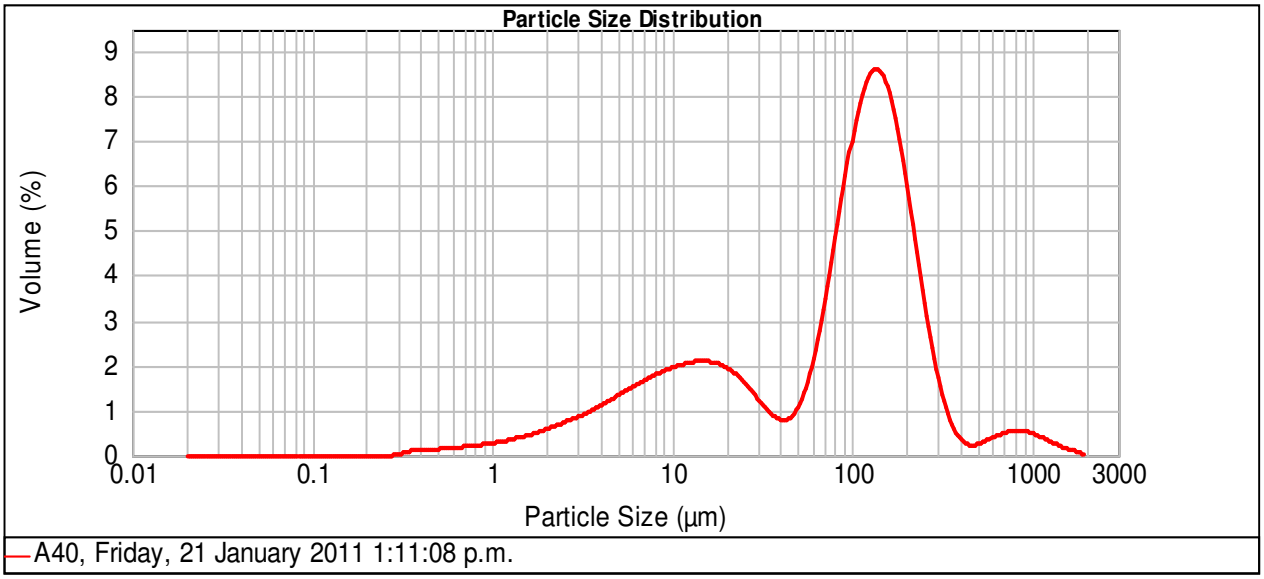
Surface Weighted Mean D[3,2]:
13.234 um

Vol. Weighted Mean D[4,3]:
128.304 um

---

d(0.1): 5.835 um **d(0.5):** 101.903 um **d(0.9):** 233.321 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	0.980	1.20	37.000	31.12	105.000	51.44	300.000	94.81	840.000	98.35
0.060	0.00	2.000	3.06	44.000	32.02	125.000	60.65	350.000	96.04	1000.000	98.96
0.120	0.00	3.900	6.60	53.000	33.20	149.000	70.49	420.000	96.62	2000.000	100.00
0.240	0.00	7.800	13.09	63.000	35.17	177.000	79.44	500.000	96.88		
0.490	0.31	15.600	22.05	74.000	38.37	210.000	86.64	590.000	97.20		
0.700	0.70	31.000	29.95	88.000	43.77	250.000	91.75	710.000	97.75		

Operator notes:

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Result Analysis Report

Sample Name:
A30

SOP Name:
Marine Sed Bryna

Measured:
Friday, 21 January 2011 1:20:25 p.m.

Sample Source & type:
Factory

Measured by:
mckinnon

Analysed:
Friday, 21 January 2011 1:20:26 p.m.

Sample bulk lot ref:
2011015/8

Result Source:
Measurement

Particle Name:
Marine Sed Bryna

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
1

Size range:
0.020 to 2000.000 um

Obscuration:
15.18 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.555 %

Result Emulation:
Off

Concentration:
0.0286 %Vol

Span :
2.377

Uniformity:
1.02

Result units:
Volume

Specific Surface Area:
0.437 m²/g

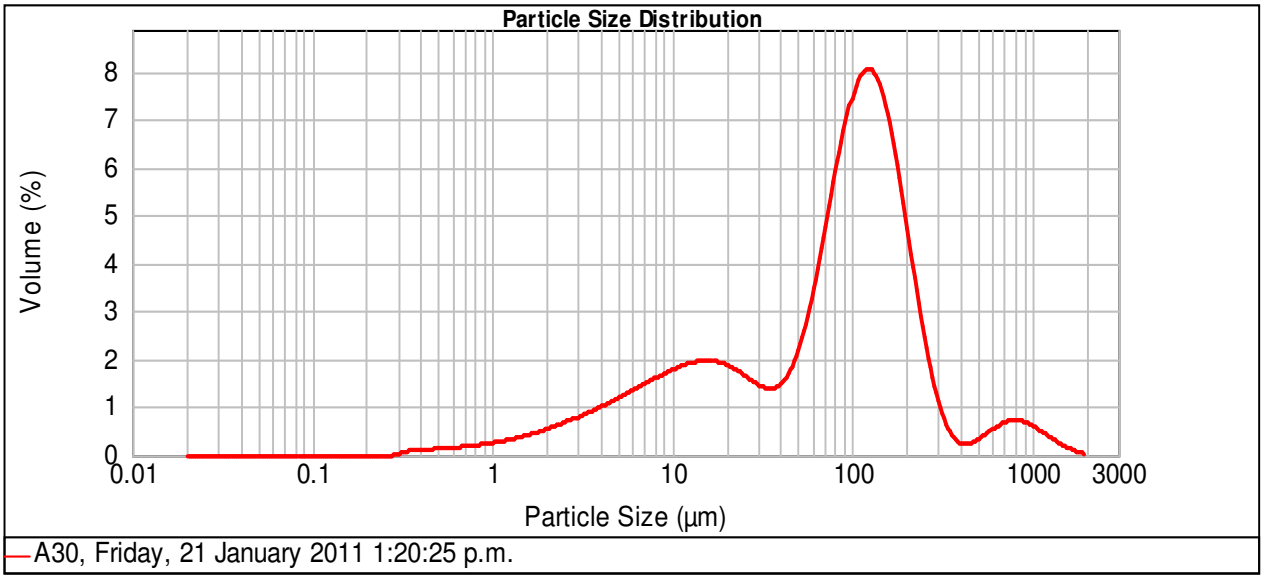
Surface Weighted Mean D[3,2]:
13.745 um

Vol. Weighted Mean D[4,3]:
127.046 um

---

d(0.1): 6.316 um **d(0.5):** 90.840 um **d(0.9):** 222.275 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	0.980	1.16	37.000	29.88	105.000	56.94	300.000	94.52	840.000	97.95
0.060	0.00	2.000	2.94	44.000	31.58	125.000	66.04	350.000	95.30	1000.000	98.73
0.120	0.00	3.900	6.24	53.000	34.02	149.000	75.04	420.000	95.67	2000.000	100.00
0.240	0.00	7.800	12.05	63.000	37.42	177.000	82.71	500.000	95.95		
0.490	0.31	15.600	20.32	74.000	41.99	210.000	88.52	590.000	96.40		
0.700	0.69	31.000	28.27	88.000	48.60	250.000	92.38	710.000	97.16		

Operator notes:

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Result Analysis Report

Sample Name:
A20

SOP Name:
Marine Sed Bryna

Measured:
Friday, 21 January 2011 1:29:44 p.m.

Sample Source & type:
Factory

Measured by:
mckinnon

Analysed:
Friday, 21 January 2011 1:29:45 p.m.

Sample bulk lot ref:
2011015/9

Result Source:
Measurement

Particle Name:
Marine Sed Bryna

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
1

Size range:
0.020 to 2000.000 um

Obscuration:
18.07 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.517 %

Result Emulation:
Off

Concentration:
0.0399 %Vol

Span :
2.219

Uniformity:
0.93

Result units:
Volume

Specific Surface Area:
0.38 m²/g

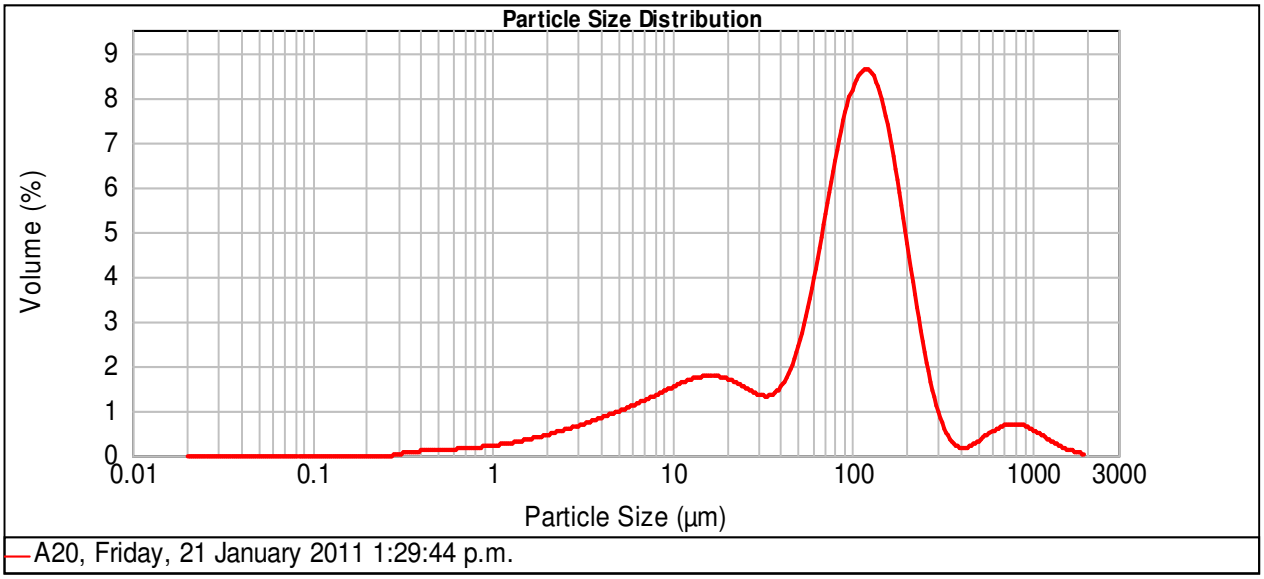
Surface Weighted Mean D[3,2]:
15.805 um

Vol. Weighted Mean D[4,3]:
126.875 um

---

d(0.1): 7.797 um **d(0.5):** 93.577 um **d(0.9):** 215.398 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	0.980	0.99	37.000	25.98	105.000	56.15	300.000	95.02	840.000	98.12
0.060	0.00	2.000	2.47	44.000	27.74	125.000	66.00	350.000	95.66	1000.000	98.86
0.120	0.00	3.900	5.22	53.000	30.44	149.000	75.54	420.000	95.91	2000.000	100.00
0.240	0.00	7.800	10.00	63.000	34.31	177.000	83.48	500.000	96.15		
0.490	0.28	15.600	17.18	74.000	39.51	210.000	89.32	590.000	96.59		
0.700	0.60	31.000	24.43	88.000	46.95	250.000	93.07	710.000	97.34		

Operator notes:

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Result Analysis Report

Sample Name:
A10

SOP Name:
Marine Sed Bryna

Measured:
Friday, 21 January 2011 1:38:55 p.m.

Sample Source & type:
Factory

Measured by:
mckinnon

Analysed:
Friday, 21 January 2011 1:38:56 p.m.

Sample bulk lot ref:
2011015/10

Result Source:
Measurement

Particle Name:
Marine Sed Bryna

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
1

Size range:
0.020 to 2000.000 um

Obscuration:
18.50 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.404 %

Result Emulation:
Off

Concentration:
0.0284 %Vol

Span :
2.676

Uniformity:
0.889

Result units:
Volume

Specific Surface Area:
0.545 m²/g

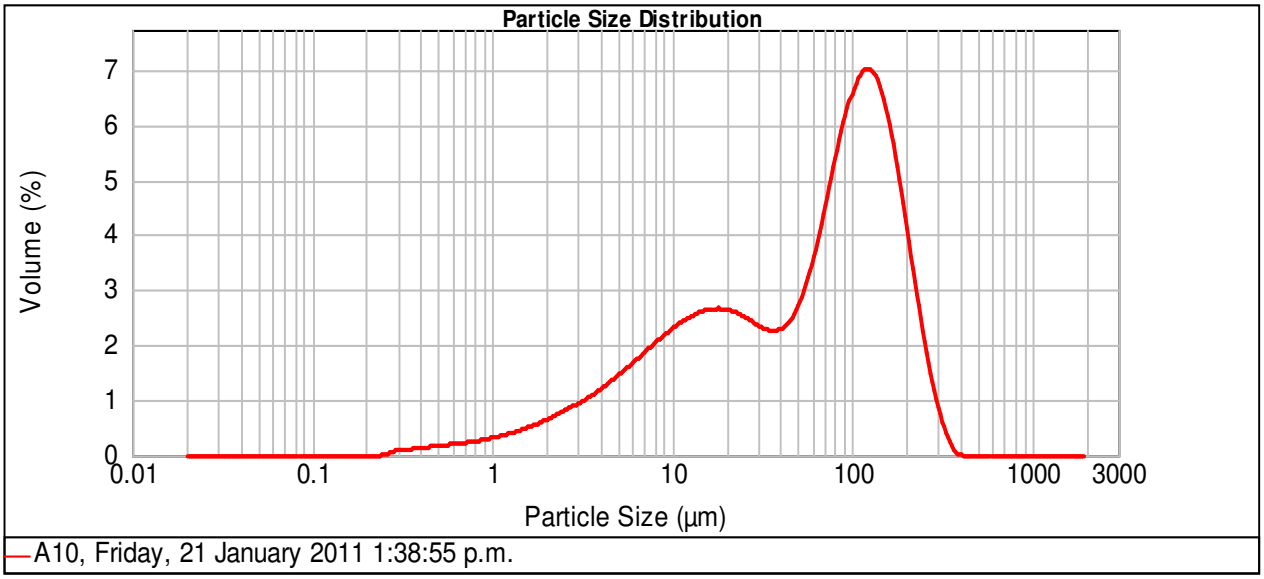
Surface Weighted Mean D[3,2]:
11.017 um

Vol. Weighted Mean D[4,3]:
79.551 um

---

d(0.1): 5.185 um **d(0.5):** 65.518 um **d(0.9):** 180.543 um

---



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	0.980	1.50	37.000	39.54	105.000	66.89	300.000	99.41	840.000	100.00
0.060	0.00	2.000	3.62	44.000	42.15	125.000	74.84	350.000	99.94	1000.000	100.00
0.120	0.00	3.900	7.51	53.000	45.31	149.000	82.67	420.000	100.00	2000.000	100.00
0.240	0.00	7.800	14.66	63.000	49.01	177.000	89.33	500.000	100.00		
0.490	0.46	15.600	25.39	74.000	53.46	210.000	94.36	590.000	100.00		
0.700	0.92	31.000	36.90	88.000	59.51	250.000	97.67	710.000	100.00		

Operator notes:

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The University of Waikato
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Result Analysis Report

Sample Name:
A0

SOP Name:
Marine Sed Bryna

Measured:
Friday, 21 January 2011 1:48:05 p.m.

Sample Source & type:
Factory

Measured by:
mckinnon

Analysed:
Friday, 21 January 2011 1:48:06 p.m.

Sample bulk lot ref:
2011015/11

Result Source:
Measurement

Particle Name:
Marine Sed Bryna

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
1

Size range:
0.020 to 2000.000 um

Obscuration:
20.27 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.525 %

Result Emulation:
Off

Concentration:
0.0341 %Vol

Span :
2.364

Uniformity:
0.783

Result units:
Volume

Specific Surface Area:
0.503 m²/g

Surface Weighted Mean D[3,2]:
11.923 um

Vol. Weighted Mean D[4,3]:
85.521 um

---

d(0.1): 5.598 um **d(0.5):** 76.774 um **d(0.9):** 187.129 um

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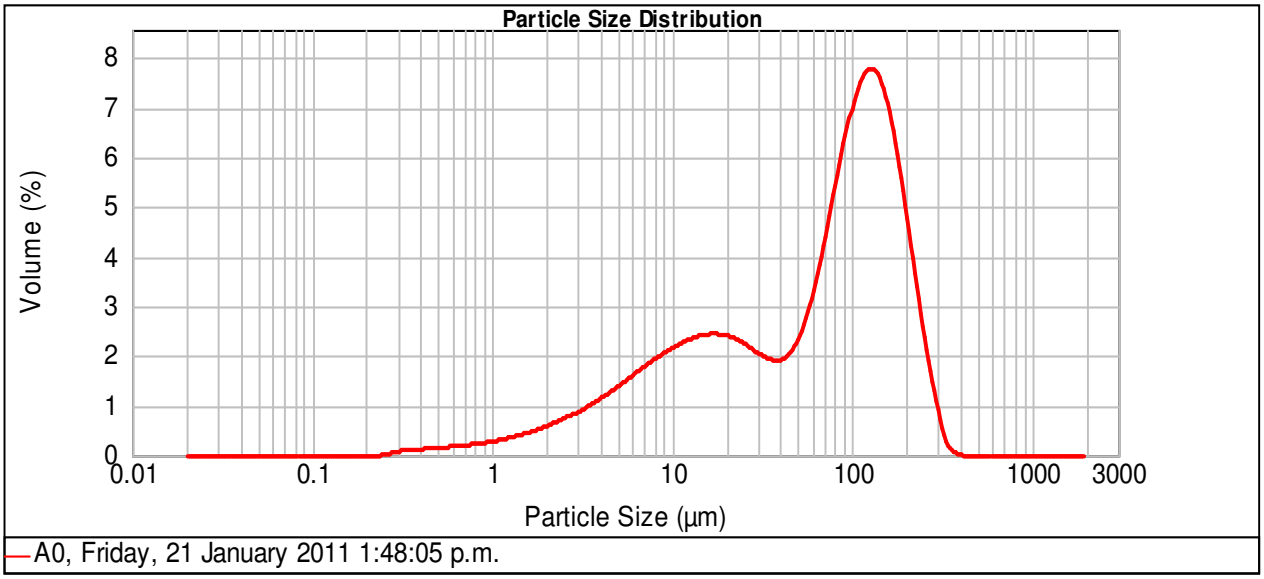

Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.050	0.00	0.980	1.35	37.000	36.39	105.000	62.72	300.000	99.54	840.000	100.00
0.060	0.00	2.000	3.25	44.000	38.58	125.000	71.41	350.000	99.96	1000.000	100.00
0.120	0.00	3.900	6.88	53.000	41.28	149.000	80.23	420.000	100.00	2000.000	100.00
0.240	0.00	7.800	13.72	63.000	44.60	177.000	87.88	500.000	100.00		
0.490	0.42	15.600	23.78	74.000	48.84	210.000	93.72	590.000	100.00		
0.700	0.83	31.000	34.14	88.000	54.94	250.000	97.56	710.000	100.00		

Operator notes: