



# **Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management (Coastal CRC) - Coastal Water Habitat Mapping Project**

# Milestone Report CG1-03 for the Coastal Geomorphology and Classification Subproject

# Sydney Harbour Sediment Sampling Results

Darren Skene and Dave Ryan

## Introduction

This Milestone Report documents the results of the analysis of sediment samples collected during the survey of Sydney Harbour in August, 2003. The samples were collected by Geoscience Australia (GA) and Defence Science and Technology Organisation (DSTO). The sediment sampling programme was undertaken as part of the coastal geomorphology and classification sub-project of the Coastal CRC - Coastal Water Habitat Mapping Project. Samples were collected to assess the physical character of the sediments and map their distribution for comparison with the geomorphology of the estuary floor using new and existing swath bathymetry data.

The analysis of the sediment samples will be used to groundtruth the areas surveyed with the Coastal CRC's Reson SeaBat 8125 multibeam sonar mapping system. Approximately one third of the targeted area was covered by the Seabat 8125 in the first survey, due to problems with the survey boat. The remaining area will be surveyed in the second Sydney Harbour survey, which is planned for September/October 2004. The sediment data will be used to assess how the physical properties of the benthos vary spatially and how they influence acoustic backscatter waveforms to classify benthic habitats. The study builds upon the existing knowledge of the geomorphology of the seabed in Sydney Harbour.

The report also discusses issues of interpretation and equipment selection for the toolkit as well as other completed work.

### Study Area

The study area is located in the outer, eastern part of Sydney Harbour in the vicinity of the Sow and Pigs reef (Figure 1). It extends from the reef to Shark Bay about 2 km to the south and is concentrated on the main part of the estuary, but extends into the adjacent bays. The area was selected to test the acoustic tools because of its known geomorphic/benthic diversity.

The bathymetry within this area is quite varied, from the bedrock reef exposed at low tide, to the deep 'hole' just south of Georges Head. Another feature of the estuary's bathymetry in the study area is the relatively flat and shallow flood tide delta which has in the past been extensively modified by dredging to allow larger ships safe passage over the shallows into the central harbour. The Western Channel (northeast-southwest) the Eastern Channel (north south) and Deviation Cut (northeast-southwest) have all been repeatedly dredged to depths of up to 15 m below sea level (bsl).



Figure 1: Study area at the eastern end of Sydney Harbour. (from geo-referenced scanned image of Hydrographic Chart Aus 201, RAN)

### Sediment Sampling and Analyses

A total of twenty one surface sediment samples were collected by GA in August 2003 (Figure 2). More samples were planned, however sea time was severely reduced due to availability of a skipper for the DSTO vessel, and mechanical problems with the vessel itself. For a full discussion of the sampling programme see the first Milestone Report (Milestone No. 1, Ryan et.al., 2003).

Samples were described in hand specimen using a binocular microscope (Table 1) and analysed for grainsize. The weight percentages of the gravel, sand and mud fractions were determined by wet sieving (Table 2), while grain size statistics for the sand and mud fractions were determined separately using laser grainsize analysis (Table 3). Percentage carbonate (CaCO<sub>3</sub>) was visually estimated as the GA equipment normally used to determine carbonate was unavailable at the time of analysis. Samples have been submitted for geochemical analysis (X-ray fluorescence spectrometry – XRF and Total Organic Carbon -TOC), but the results are not yet available.

To assist in the interpretation and provide greater coverage over the study area, additional samples collected in March 2003 by DSTO and analysed for grainsize by GA have been included (see Figure 2 for sample locations, Table 4 for the weight percentages of the gravel, sand and mud fractions and Table 5 for laser analysis of the sand and mud fractions).



**Figure 2: Combined GA and DSTO surface sediment sampling locations.** The area enclosed by the dashed line was surveyed using the Reson 8125 swath bathymetric system in May 2002.

# **Swath Bathymetry**

A swath bathymetric survey was carried out by the Coastal CRC in May 2002 over part of the study area (Figure 2) using the Reson SeaBat 8125 multibeam bathymetric system. Figure 3 shows the resultant digital elevation model (DEM) and isobaths (at 0.5 m intervals) of the estuary bed in this area. The most obvious features are the dredged areas of the southern part of the Eastern Channel and the Deviation Cut. The area was last dredged between 1926 and 1931 (McLoughlin, 2000) and the potholes left by the dredging operation are still clearly visible. The average water depth within the Cut is around 14 m with potholes being some 1 to 2 m deep. Other features within the area are the relatively flat surface of the flood tide delta south of the Sow & Pigs and the deeper areas off Laings Point (east), in southern part of Watsons Bay (southeast) and upstream into the estuary (southwest).



Figure 3: DEM from Reson's SeaBat 8125 multibeam sonar mapping system. Overlain is grouped mud percentage data (depicted using symbols of increasing size).

Subsequent to the Reson survey, a more extensive survey of central and eastern Sydney Harbour was carried out by GeoAcoustics and DSTO in March 2003 using a GeoSwath 250 kHz shallow water swath bathymetric system (Figure 4). In addition to the Eastern Channel and Deviation Cut, the Western Channel is clearly defined. It was last dredged in 1967-68 (McLoughlin, 2000) and the relatively straight sides of this channel and smoother channel floor suggest that more advanced dredging technology was employed than the previous dredging in this and other channels. Other prominent bathymetric features in the area are the Sow & Pigs reef between the channels, the deep hole south of Georges Head, and a deep channel trending north-south in the southern part of the study area.

Figure 5 shows a 3-D view of the Sow & Pigs area looking to the northwest. Bedrock reef of the Sow & Pigs is surrounded by the shallow, flat tidal delta. A higher spot, possibly a small outcrop of bedrock or a mooring block for a navigation buoy, is visible in the right foreground of the image in front of the potholed bed of the Deviation Cut. In the background are the straight lines of the edge of the dredged Western Channel.



Figure 4: DEM (2m grid) from GeoAcoustic's GeoSwath bathymetric system. *from Sydney Harbour* Common Data Set for Shallow Survey 2003. Overlain are grouped mud percentage data.



**Figure 5: 3-D view of the Sow & Pigs area** (adapted from Geoswath image in the Sydney Harbour data release: August 2003).

## **Sediment Types and their Distribution**

The study area encompasses the landward extent of the flood tide delta that has, since the latter part of the postglacial marine transgression (about 10,000 years BP) and ensuing sea level stillstand, infilled the estuary mouth and advanced upstream infilling the palaeo river channel (Thom and Roy, 1985). The principal source of sand for the flood tidal delta was marine sand from the open coast offshore of South Head. This sand was repeatedly reworked by aeolian and marine processes, and then transported into the estuary by both shoaling waves and flood tidal currents.

These tidal delta sediments predominantly comprise sand with a highly variable component of gravel sized shells and shell fragments. The sand is medium to fine grained, moderate to well sorted, subrounded to rounded, clean quartzose sand typically containing less than 2 % mud. Upstream of the delta front there is a transition area between the clean tidal delta sands and the muddy sands of the inner harbour. Here the sand becomes slightly finer and is mixed with increased quantities of terrigenous mud. The percentage of shell typically increases and the deleger areas feature muddy sand to sandy mud bottoms.

Figure 3 and Figure 4 show the percent mud (grainsize diameter  $<63\mu$ m) in the surficial sediment samples collected during both the GA and DSTO sampling programmes An inferred sediment distribution map for the study area is shown in Figure 6. The composition of the surficial sediments and their distribution is related to both the hydraulic regime and the bathymetry within this section of the estuary. Sediments with higher percentages of mud are typically associated with deeper water depths or where the hydraulic regime has little impact. Figure 4 shows the increase of mud upstream of the flood tide delta into the transition zone between the delta and the central mud basin. Mud percentages are highest in this area and are associated with the deeper part of the estuary south of Georges Head, within Watsons Bay and west of Shark Bay.

The northern part of the study area is impacted directly by ocean swells and breaking waves as well as tidal currents. The tidal delta has formed shallow banks with pre-dredging water depths averaging 5.5 m (Hunter, 1968). The dredged channels carry a major part of the tidal flows in and out of the harbour (Hamilton, 2003). The combined effects of shallow water depths and strong hydraulic movements in this area accounts for the sediments being largely clean sand with low percentages of mud (< 2%).

Morphological and sediment evidence suggests that tidal flows are stronger in the Western Channel and northern part of the Eastern Channel than the other dredged areas. The swath bathymetric image of the northern part of both channels shows a diffuse or 'smoothed' image of the dredged areas (see Figure 4) suggesting some sediment transport and deposition has taken place since these areas were dredged, infilling the potholes. Sediment samples collected in this area during previous studies do not contain mud. The central and southern part of the Western Channel floor features bedforms some 30 to 50 m long with wavelengths of 3 to 4 m (Figure 7) which is indicative of relatively strong tidal flows. In addition, sediment samples collected from the channel floor (SV58 and 61) in water depths of 15.5 m have very low percentages of mud (0.9 and 1.3 % mud respectively). Tidal flows are not as strong across the Deviation Cut and southern part of the Eastern Channel as evidenced by the clearly defined and preserved dredge potholes. The percentage mud in samples from this area is higher than in other parts of the tidal delta, ranging from 2 to 6 % within the potholes (SV63, 64), 2 % on the eastern edge of the Deviation Cut (SV 52, 53) and between 5 and 8 % in the Eastern Channel (SV6, 51, 65).



Figure 6 Inferred distribution map of surficial sediments in the Sow & Pigs area, Sydney Harbour.



Figure 7: Tidal current bedforms on the floor of the Western Channel

The area of the harbour to the south of the flood tidal delta is transitional from the clean tidal delta sands to the muddy sands and sand y muds of the inner harbour. The muds are typically composed of 60-70% silt and 30-40% clay. There is a broad correlation between the water depth and the percentage mud in the surficial sediments. As water depth increases and the effects from ocean swell and tidal flows is reduced, percentages of mud increase. Figure 8 compares the percent mud with water depth and it generally supports this assumption. In around 15 m of water, however, the percentage mud varies from 0.9% in the Western Channel (SV58) to 17% upstream of the Eastern Channel (SV66) depending on the hydraulic regime.



Figure 8: Chart showing percent mud vs water depth for August 2003 samples.

Gravel (sediment > 2 mm diameter), where it occurs within the study area, is composed almost entirely of whole shell and shell fragments. Although gravel occurs in nearly all surface sediment samples from the tidal delta, the percentages are generally < 5 % except within an area to the south of the Sow & Pigs (Figure 6). This increase is probably associated with the adjacent reef due to the effects of enhanced wave activity there (Hamilton, 2003) as well as a proliferation of shell communities on and around the reef. Although percentages of calcium carbonate are higher within the more muddy sediments than the clean tidal delta sands, gravel typically does not occur except in isolated pockets. The reasons for this are unclear.

### **Equipment Selection - Usefulness of Equipment**

### Smith-Macintyre Grab Sampler

The Smith-Macintyre grab sampler used for this survey was a large, 60kg (when weighted for marine surveys) version owned by Geoscience Australia, capable of returning samples from deep water. The grab closes on the seabed by means of a pair of powerful springs when triggered by a falling weight, and the semi-circular profile bucket travels an arc of  $180^{\circ}$  in order to scoop up a sample. The grab sampler has been extensively trialled by Geoscience Australia for other, deeper water marine surveys, and is most effective on substrates comprising sand, muddy sand, and gravels. The grab was deployed using the A-frame on the stern of the *AWB 440*; manual deployment or deployment using a smaller vessel is not

practical. The bucket of the grab sampler is able to retrieve 2-3 litres of predominantly surficial sediment at a time, although disturbance of sedimentary structures is likely. The grab is not useful for sampling muds and sandy muds, as it tends to sink too far into the substrate and collects a highly disturbed, sub-surface sample. Some "washing" of the sample occurs during retrieval, which results in the loss of a small quantity of fine material from the surface of the sample in the grab bucket. It should be noted that Smith-Macintyre grabs are superior to Van Veen grabs, in that wash-through is relatively minimal.

Of 24 Smith-Macintyre grab deployments, approximately 20% failed to retrieve a useful sample. These failures are likely to have been caused by the grab landing on the substrate at an angle and closing prior to impact with the estuary bed.

# Box Corer

The box corer used during the Sydney Harbour survey was smaller than the grab, however still needed to be deployed using the A-frame or at the minimum, a davit for safe handling. The box corer comprises a weighted stainless steel box, which penetrates the sediment without disturbing the surface or sedimentary structures. When triggered, the doors close beneath the sediment sample, and the top of the sample is protected from wash-through by a flexible rubber or silicone valve. Box corers are specifically designed for use in mud or sandy mud sediments; push cores and sub-sampling of the undisturbed sample is possible when the corer is retrieved (e.g. for macrofaunal or pore-water geochemical studies).

The box corer was used during the Sydney Harbour survey in the deeper "holes", where muddy sediment was expected. Of 5 box core deployments, 60% failed to retrieve a useful sample, probably due to the sandy/gravely nature of the substrate.

# Work still required

### Swath Bathymetry

Future work with the Reson Seabat 8125 system has been proposed for September to October 2004. In the time allotted it is intended to expand the survey already completed in the Sow and Pigs reef area.

### Backscatter to classify benthic habitats

In order to undertake a classification of the backscatter data, appropriate software is required. Project partners at Curtin University are developing these software tools. However, for the CG Subproject, 'off the shelf' software packages need to be considered if we are to meet project milestones related to backscatter classification. One option we are investigating is the QTC Multiview package.

### Sub-bottom profiling

It is proposed to conduct a sub-bottom profiling programme within the study area using either a pinger or Chirp system. This data will indicate the lateral extent and morphology of the sediment facies and the thickness of these facies. Volumes can then be computed to determine the sediment volumes within the various facies and the rate of infill of the estuary by the various facies.

#### **Issues for consideration**

#### Backscatter from Swath Bathymetry

An assessment of how the physical character of the sediments influences the acoustic backscatter wave-form properties cannot currently been made because, to date, no backscatter data from the swath survey has been provided to GA.

### Sub-bottom Profiling

Within Sydney Harbour, any actions that are likely to have a significant impact are subject to a referral, assessment, and approval process under the Department of Environment and Heritage's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). GA will need to apply for a permit for the proposed sub-bottom profiling survey. If, however, the sub-bottom profiling is to be carried out in collaboration with DSTO, then a certificate of compliance from another section of the Department of Defence could be obtained instead.

### **Other Work Completed**

Following on from the interlibrary search and compilation of a detailed bibliography of references pertaining to all aspects of the physical and chemical environments of Sydney Harbour, a draft literature review has been completed. The review covers publications on the geomorphology and sedimentary environments within Sydney Harbour, their distribution and evolution, as well as contaminants within the surficial sediments. GA is currently working with DSTO (Les Hamilton) to develop the review into a journal paper that includes a new map of surface sediment distribution in Sydney Harbour.

## References

GeoAcoustic and DSTO, 2003: DEM of central and eastern Sydney Harbour using GeoAcoustic's GeoSwath bathymetric system. *from Sydney Harbour Common Data Set for Shallow Survey 2003* 

Hamilton, L., 2003: Notes to accompany the map of surficial sediments of Sydney Harbour prepared for Shallow Survey 2003. Defence Science & Technology Organisation, Pyrmont, Australia (unpubl.).

Hunter, J., 1968: Chart of the coast between Botany Bay and Port Hacking surveyed in 1788 and 89, in *An historical journal of the transaction at Port Jackson and Norfolk Island* (facsimile edition), Libraries Board of South Australia, Adelaide, p.160 (originally published by John Stockdale, London, 1793.).

Hydrographic Service of the Royal Australian Navy, 1984: Port Jackson (eastern sheet) Inner Heads to Sydney Harbour. Aus 201.

McLoughlin, L C., 2000: Shaping Sydney Harbour: sedimentation, dredging and reclamation 1788-1990s. *Australian Geographer*, 31 (2), 183-208

Ryan, D., B. Brooke, C. Tindall & D. Skene, 2003: Coastal CRC - Coastal Water Habitat Mapping Project: Milestone Report 1 for the Coastal Geomorphology and Classification Subproject. Sydney Harbour Sediment Sampling, August 2003. 8pp.

Thom B.G. and Roy, P.S., 1985: Relative sea levels and coastal sedimentation in southeast Australia in the Holocene. *Journal of Sedimentary Petrology*, 55 (2), 257-264.

#### Table 1: Sample describtions using a binocular microscope

SampleID	Colour	Grainsize	Sorting	Round	% CaCO3	Comments	Lithology	Depositional
•				ness	in sand			Environment
SV18b	Dark fawn	vfg-cg	moderate	A-SR	30-35	Some gravel (shell fragments)	Shelly muddy sand	Mud Basin
51	Olive green	vfg-cg	moderate	SA-SR	15-20	Abundant cg shell fragments	Slightly muddy sand	Tidal delta
52	Dark fawn	vfg (-vcg)	poor	A-SR	15-20	Some whole shell to 3cm, occasional pebbles and abundant cg shell fragments	Clean shelly sand	Tidal delta
53	Dark fawn	vfg (-vcg)	well - sand poor - overall	A-SR	20-25	Abundant large shell fragments	Shelly sand	Tidal delta
54	Pale grey	vfg (-vcg)	well - sand mod - overall	SA-SR	5-10		Gravelly shelly sand	Tidal delta
55	Dark fawn	vfg (-vcg) & gravel	Poor - overall	SA-SR	15-20	vcg and gravel shell fragments	Gravelly shelly sand	Tidal delta
56	fawn	vfg-mg (-vcg)	moderate 1	A-SR	<5	Some gravel shell fragments	Clean sand	Tidal delta
57	fawn	vfg-mg	well	SA-SR	5-10	Some vcg shell fragments	Clean sand	Tidal delta
58	fawn	vfg-mg	moderate	SA-SR	5-10	Some vcg and gravel shell fragments	Slightly gravelly shelly sand	Tidal delta
59	Olive green	vfg	mod-well	A-SA	<5		Muddy sand	Mud Basin
60	Olive brown	vfg	well	A-SA	<5		Sandy mud	Mud Basin
61	fawn	vfg-mg (-vcg)	moderate	A-SR	<5	Some gravel shell fragments	Clean sand	Tidal delta
62	fawn	vfg-mg	well	SA-SR	5-10	Some vcg shell fragments	Clean sand	Tidal delta
63	Dark fawn	vfg-cg	moderate	SA-SR	5-10		Slightly muddy sand	Tidal delta
64	Dark fawn	fg-vcg	moderate	SA-SR	5-10	Some vcg and gravel shell fragments	Gravelly shelly sand	Tidal delta
65	Olive green	vfg-mg	well	A-SR	<5		Slightly muddy sand	Tidal delta
66	Olive greeny brown	vfg	well	A-SR	<5		Muddy sand	

CWHM - Coastal Geomorphology and Classification Subproject

67	fawn	vfg-mg	mod-well	A-SR	5-10	Some vcg shell fragments	Clean sand	Tidal delta
68	Olive green	vfg-fg	well	A-SA	<5		Muddy sand	Mud basin
69	Olive brown	vfg-fg	well	A-SA	<5		Muddy sand	Mud basin
70	Olive green	vfg-fg	well	A-SA	<5		Muddy sand	Mud basin

A - angular; SA - subangular, SR - subrounded, R - rounded, WR - well rounded

# Table 2: Weight percentages of GA samples

Sample	Depth				Est. CaCO3%
D	( <b>m</b> )	%Gravel	%Sand	%Mud	(sand)
18b	15	2.3	86.8	10.9	30-35
51	18	0.4	93.9	5.7	15-20
52	8.4	3.9	94.6	1.5	15-20
53	8.5	8.7	89.0	2.3	20-25
54	5.5	14.4	84.8	0.8	5-10
55	5.8	12.1	86.5	1.4	15-20
56	7.5	2.8	97.0	0.2	5-10
57	7.1	0.8	99.2	0.1	5-10
58	15.8	4.1	95.0	0.9	20-25
59	33.1	0.5	69.2	30.3	<5
60	30.7	0.0	26.7	73.3	<5
61	15.5	1.6	97.1	1.3	<5
62	10.6	0.7	99.1	0.2	5-10
63	13.5	0.6	93.5	5.9	5-10
64	12.2	10.3	87.3	2.4	<5
65	12.7	0.0	92.1	7.8	<5
66	13.3	0.1	83.3	16.5	<5
67	9.3	0.6	97.9	1.5	5-10
68	30.2	0.1	80.9	19.0	<5
69	30.3	0.1	66.5	33.3	<5
70	32.5	0.1	73.8	26.1	<5

Sample #	Vol. wtd mean	Standard Dev.	Skew	% Mud		
-					% Silt in Mud	% Clay in Mud
SV18b	12.04	17.301	2.752	10.9	59	41
SV51	14.066	18.397	2.487	5.7	68	32
Sv52	13.753	18.51	2.599	1.5	67	33
SV53	13.978	18.547	2.367	2.3	66	34
SV54	12.622	15.973	2.862	0.8	71	29
SV55	11.776	15.122	2.647	1.4	66	34
SV56	14.181	15.777	2.319	0.2	77	23
SV57	21.378	18.834	1.884	0.1	89	11
SV58	10.836	14.693	2.858	0.9	62	38
SV59	11.703	14.91	2.821	30.3	66	34
SV60	15.92	19.362	2.013	73.3	68	32
SV61	12.237	16.979	2.673	1.3	60	40
SV62	14.428	17.565	2.127	0.2	69	31
SV63	13.644	18.111	2.372	5.9	63	37
SV64	12.246	16.37	2.531	2.4	61	39
SV65	14.151	18.374	2.306	7.8	67	33
SV66	11.543	15.778	2.873	16.5	63	37
SV67	10.163	13.769	3.102	1.5	61	39
SV68	11.594	14.951	2.734	19	64	36
SV69	11.258	14.533	2.585	33.3	62	38
SV70	11.086	15.716	2.893	26.1	58	42

 Table 3: Laser analysis of mud and sand fractions – GA samples

#### Sand Fraction

**Mud Fraction** 

	Vol. wtd	Standard		
Sample #	mean	Dev.	Skew	% Sand
SV18b	349.585	214.433	1.075	86.8
SV51	390.27	369.516	1.473	93.9
Sv52	512.873	410.42	1.243	94.6
SV53	323.279	287.498	2.547	89
SV54	345.893	251.637	2.851	84.8
SV55	293.085	110.79	1.116	86.5
SV56	316.282	98.319	0.761	97
SV57	335.904	227.839	3.1	99.1
SV58	277.501	261.162	2.099	95
SV59	460.627	296.815	1.588	69.2
SV60	117.452	108.648	2.377	26.7
SV61	294.864	142.796	0.66	97.1
SV62	296.224	99.814	0.74	99.1
SV63	242.926	128.503	0.649	93.5
SV64	238.961	121.042	0.733	87.3
SV65	225.566	139.579	1.766	92.1
SV66	205.387	164.52	2.532	83.3
SV67	285.317	159.22	0.827	97.9
SV68	295.379	184.742	1.274	80.9
SV69	233.393	178.102	1.722	66.5
SV70	277.008	205.083	1.364	73.8

Table 4:	Weight	percentages of DSTO samples
Lable 4.	,, eight	percentages of Dor o sample.

Sample #	%Gravel	%Sand	%Mud	CaCO3 %Bulk
SV2	0.0	59.1	40.9	35
SV3	24.8	40.6	34.6	25
SV6	0.1	94.8	5.0	25
SV7	0.2	90.1	9.7	10
SV8	0.0	57.7	42.3	30
SV9	0.0	62.1	37.9	25
SV10	0.0	96.3	3.7	20
SV11	0.2	96.0	3.8	25
SV12	1.6	95.2	3.2	20
SV14	0.6	81.6	17.8	40
SV15	0.1	87.3	12.6	30
SV16	3.3	34.9	61.9	30
SV17	3.0	91.4	5.6	10
SV19	12.8	79.5	7.8	60
SV20	2.6	95.9	1.5	10
SV21	3.7	95.2	1.1	10
SV22	2.3	97.7	0.0	10
SV23	0.3	33.3	66.4	25

<b>Mud Fraction</b>	L					
Sample #	Vol wtd	Standard	Skow	% Mud		
Sample #	mean	Dev.	SKew	Muu	% Silt in mud	% Clay in mud
SV2	10.394	10.788	2.663	40.9	71.1	28.9
SV3	11.236	11.861	2.727	34.6	74.2	25.8
SV6	13.985	16.739	2.491	5.0	75.5	24.5
SV7	8.4	8.946	3.426	9.7	66.2	33.8
SV8	11.108	11.37	2.172	42.3	71.3	28.7
SV9	11.128	11.568	2.139	37.9	71.4	28.6
SV10	14.496	17.867	2.271	3.7	72.6	27.4
SV11	8.4	8.772	3.116	3.8	66	34
SV12	10.519	13.954	2.886	3.2	62.4	37.6
SV14	10.305	12.801	2.668	17.8	62.8	37.2
SV15	8.949	9.122	2.266	12.6	66	34
SV16	9.39	11.287	2.843	61.9	63.9	36.1
SV17	9.285	12.492	4.188	5.6	63.5	36.5
SV19	8.894	10.991	3.252	7.8	61.9	38.1
SV20	9.199	9.909	3.74	1.5	69.3	30.7
SV21	21.741	21.831	1.826	1.1	86.2	13.8
SV22	12.81	13.388	3.306	0.0	80.7	19.3
SV23	14.569	17.177	2.104	66.4	71.7	28.3

#### Table 5: Laser analysis of mud and sand fractions – DSTO samples

#### Sand fraction

	Vol wtd	Standard		%
Sample #	mean	Dev.	Skew	Sand
SV2	108.417	105.229	2.418	59.1
SV3	267.742	224.052	1.307	40.6
SV6	407.99	238.712	0.522	94.8
SV7	383.657	202.556	0.536	90.1
SV8	123.537	123.354	2.015	57.7
SV9	221.908	171.387	1.072	62.1
SV10	321.212	207.645	0.872	96.3
SV11	307.115	190.238	1.349	96.0
SV12	334.699	192.558	0.863	95.2
SV14	209.733	162.249	1.623	81.6
SV15	353.53	141.01	0.194	87.3
SV16	361.387	423.825	1.476	34.9
SV17	322.705	176.737	0.702	91.4
SV19	376.438	237.523	1.125	79.5
SV20	390.048	185.812	0.672	95.9
SV21	296.547	114.471	0.893	95.2
SV22	438.842	228.037	1.201	97.7
SV23	69.926	85.543	2.659	33.3