Don Sahong Hydropower Project

Sediment Sampling Campaign

25 July 2014 (Revision C)

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EXECUTIVE SUMMARY

This document presents a summary of the sediment sampling campaign in the Don Sahong area carried out in 2012-2013. Summaries of sampling objectives, methodologies and results are included. The collection and analysis of samples was carried out by AdTech Management, who prepared individual technical reports for each visit.

Previous studies during development of the Don Sahong Hydropower Project (DSHPP) have identified that the available sediment records are limited. Project developer Mega First Corporation Berhad (MFCB) initiated a site sediment sampling campaign in 2012, involving multiple visits collecting sediment samples across different river flow conditions.

The objectives of the sediment data collection campaign were to obtain measurements across the range of Mekong flow conditions of:

- Suspended sediment concentration
- Suspended sediment particle size distribution
- Bedload transport rates
- Bedload particle size distribution

The sampling objectives and methodologies were carefully planned to provide data that were comparable to other data collected in the region, and would be directly useful for project development and operational planning, and assessment of environmental effects. The methodologies adopted for sampling and analysis were based on published international standards. Data were recorded on MRC data reporting forms, to ensure standardisation of results and promote data sharing.

Six data collection visits were completed, concentrating on the wet season when almost all sediment transport occurs. During each visit, sediment samples were collected at multiple vertical points across each of six cross-sections.

CONTENTS

1 INTRODUCTION

Mega First Corporation Berhad (MFCB) has engaged SMEC New Zealand Ltd (SMEC) to provide advisory services in relation to development of the Don Sahong Hydropower Project (DSHPP). DSHPP is a proposed run-of-river hydropower scheme on the Hou Sahong branch of the Mekong River in Lao PDR.

The Mekong River is known to carry a significant suspended sediment load. An accurate understanding of the quantities and grain sizes of transported sediment is important for design of the scheme (e.g. turbine specification), assessment of environmental effects (e.g. changes to the sediment balance of the river), and operational planning (e.g. sedimentation potential and any requirements for sediment management).

DSHPP Reference Design studies included an investigation of available sediment data and an assessment of sedimentation[1]. The study identified that the closest site at which suspended sediment data have been recorded is at Pakse, and assessments were based on interpretation of these data. It was recognised, however, that sediment records were limited, having a wide range of uncertainty when used for project planning purposes.

MFCB initiated a site sediment sampling campaign in 2012, involving multiple visits collecting sediment samples across different river flow conditions. The sampling objectives and methodologies were carefully planned to provide data that were comparable to other data collected in the region, and would be directly useful for project development and operational planning, and assessment of environmental effects.

This document presents a summary of the sampling objectives, methodologies and results. The collection and analysis of samples was carried out by AdTech Management, who has produced individual technical reports for each visit.

[1] AECOM, DSHPP Design Studies – Hydrology, Hydraulics and Sedimentation Studies Report, October 2011

2 DATA COLLECTION METHODOLOGY

2.1 Objectives

The objectives of the sediment data collection campaign were to obtain measurements across the range of Mekong flow conditions of:

- Suspended sediment concentration
- Suspended sediment particle size distribution
- Bedload transport rates
- Bedload particle size distribution

Sampling was carried out at six cross sections around the project area, including:

- Cross sections 1 & 2, upstream of Hou Sahong
- Cross sections 3 & 4, within Hou Sahong
- Cross sections 5 & 6, downstream of Hou Sahong inlet

These locations were selected to provide direct measurement of transported sediment at the inlet to the proposed scheme, and allow investigation of any local spatial variation in transport rates and the composition of transported sediments.

Figure 1: Sediment sampling cross section locations

2.2 Methodology

Sediment sampling methodologies were specified following consultation with the MRC, ensuring that the data collected is comparable with other data collected in the region.

The exact locations and methods used were mutually agreed between the sampling contractor AdTech Management and SMEC's hydraulic engineer during a preliminary site visit.

2.2.1 Sampling

Suspended sediment sampling was based on the requirements of ISO 4363:2002(E), specifically:

- At each cross-section, samples shall be collected at multiple verticals, based on the equal-discharge-increment (EDI) method.
- Samples shall be collected at not less than 5 verticals at each cross-section.
- At each vertical, samples shall be collected using the selected-point method, with the number of points sampled depending on local channel depth (*Table 1*).
- Samples shall be collected with a point-integrating isokinetic sampler conforming to the requirements of ISO 3716

Table 1: Number and depth of sampling points at each vertical, depending on local channel depth

Depth, *h*	Method	Relative depth of points (from water surface)
< 2m	two-point	0.2*h*, 0.8*h*
2m < h <6m	three-point	0.2*h*, 0.6*h*, 0.8*h*
> 6m	five-point	near surface, 0.2*h*, 0.6*h*, 0.8*h*, near riverbed

Bedload sediment sampling was carried out using a Helley-Smith type bedload sampler with a 0.2 mm aperture mesh. Bedload samples were taken at the same cross-sections and generally at the same verticals as the suspended sediment samples.

2.2.2 Sample Analysis

Suspended sediment concentrations were determined following ASTM D3977-97 Standard test method for determining sediment concentration in water samples.

Suspended sediment particle size distribution was analysed in a laboratory using a laser diffraction system, following ISO 13320:2009. Samples had remained in storage at site for some months due to transport difficulties, and so were thoroughly agitated before analysis.

Particle size distribution of bedload samples was determined by the sieving method, following ISO 4365:2005.

2.3 Data Collection Programme

Six sediment sampling trips were planned for and successfully completed between December 2012 and October 2013. The sampling dates together with Mekong discharge are shown in the figure below.

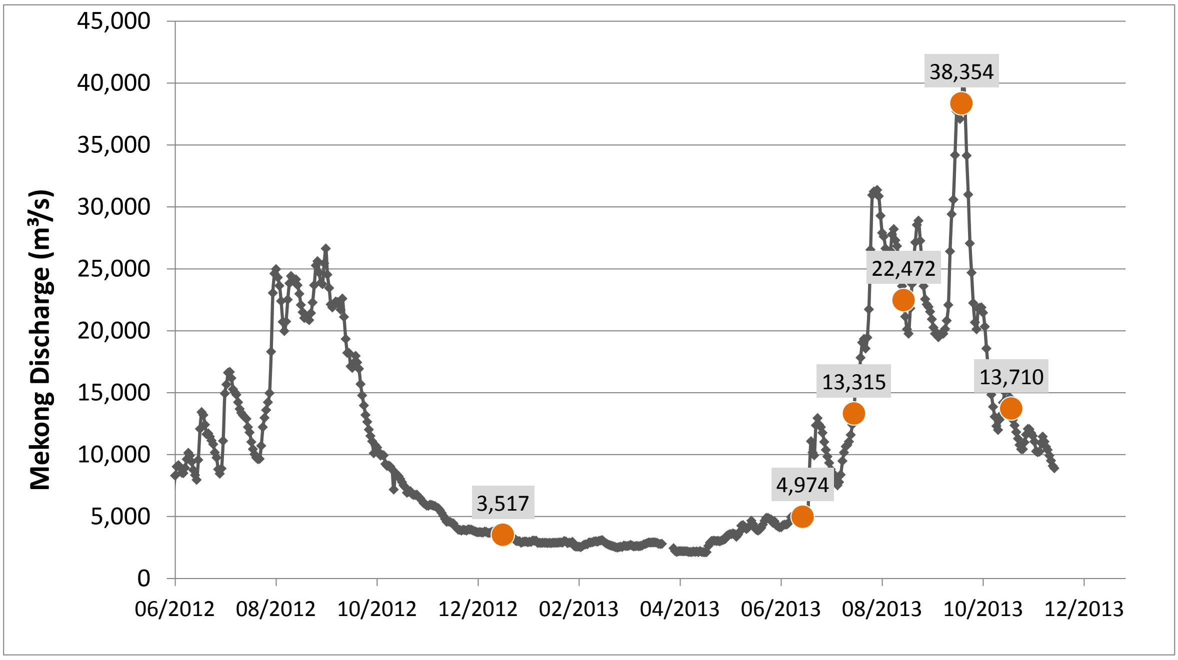

Figure 2: Dates of six sediment sampling visits, shown with Mekong at Pakse discharge

The timing of these visits was concentrated on the wet season, with the knowledge (verified during the first visit) that there is an insignificant sediment load during the dry season. The visits covered the range of mid to wet season Mekong flow conditions, including both rising and falling limbs of the season.

Data were recorded on MRC data reporting forms[2], to ensure standardisation of results and promote data sharing. These data forms are included as appendices to the individual technical reports prepared for each sampling trip.

[2] E.g. Terms of Reference for International Consultant for the Evaluation and Analysis of Sediment Data, MRC, 2012

3 SUMMARY RESULTS

3.1 Suspended Sediment

As a summary of sampling results, the average concentration and median grain size of suspended sediment samples at each cross-section are presented below. A more detailed break-down of the data is presented in the technical report prepared for each visit.

Table 2: Number of samples, average suspended sediment concentration, and median suspended grain size at six sampled cross-sections

Trip #1, December 2012							
Cross section	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**All**
Number of samples	20	20	12	16	25	20	**113**
Suspended Sediment Concentration (SSC)	7 mg/L	13 mg/L	19 mg/L	42 mg/L	6 mg/L	12 mg/L	**16 mg/L**
Median suspended grain size (d_{50})	12 μm	13 μm	10 μm	14 μm	14 μm	14 μm	**12 μm**
Trip #2, June 2013							
Cross section	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**All**
Number of samples	21	19	13	10	19	20	**102**
Suspended Sediment Concentration (SSC)	35 mg/L	35 mg/L	40 mg/L	49 mg/L	35 mg/L	44 mg/L	**40 mg/L**
Median suspended grain size (d_{50})	37 μm	40 μm	26 μm	21 μm	39 μm	43 μm	**34 μm**
Trip #3, July 2013							
Cross section	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**All**
Number of samples	23	25	15	15	23	22	**123**
Suspended Sediment Concentration (SSC)	110 mg/L	162 mg/L	126 mg/L	114 mg/L	114 mg/L	128 mg/L	**126 mg/L**
Median suspended grain size (d_{50})	8 μm	7 μm	7 μm	7 μm	7 μm	7 μm	**7 μm**

Trip #4, August 2013							
Cross section	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**All**
Number of samples	25	25	15	15	19	26	**125**
Suspended Sediment Concentration (SSC)	336 mg/L	467 mg/L	324 mg/L	407 mg/L	373 mg/L	341 mg/L	**375 mg/L**
Median suspended grain size (d_{50})	8 µm	6 µm	8 µm	7 µm	7 µm	7 µm	**7 µm**
Trip #5, September 2013							
Cross section	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**All**
Number of samples	0	0	15	15	21		**51**
Suspended Sediment Concentration (SSC)			380 mg/L	332 mg/L	365 mg/L		**359 mg/L**
Median suspended grain size (d_{50})			8 µm	8 µm	8 µm		**8 µm**
Trip #6, October 2013							
Cross section	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**All**
Number of samples	23	21	15	15	21	0	**123**
Suspended Sediment Concentration (SSC)	63 mg/L	43 mg/L	98 mg/L	73 mg/L	47 mg/L		**65 mg/L**
Median suspended grain size (d_{50})	10 µm	10 µm	9 µm	9 µm	9 µm		**9 µm**

The suspended sediment concentration (SSC) is seen to increase from visit #1 to #4 as the Mekong River discharge similarly increased (see Figure 2). Samples from Visit #5, during the highest flow condition, exhibited a similar SSC to Visit #4. On the receding flood limb, SSC from visit #6 was greatly reduced, to around half of Visit #3 which was for a similar Mekong flow rate.

Average suspended sediment concentration is plotted against Mekong River discharge in Figure 3.

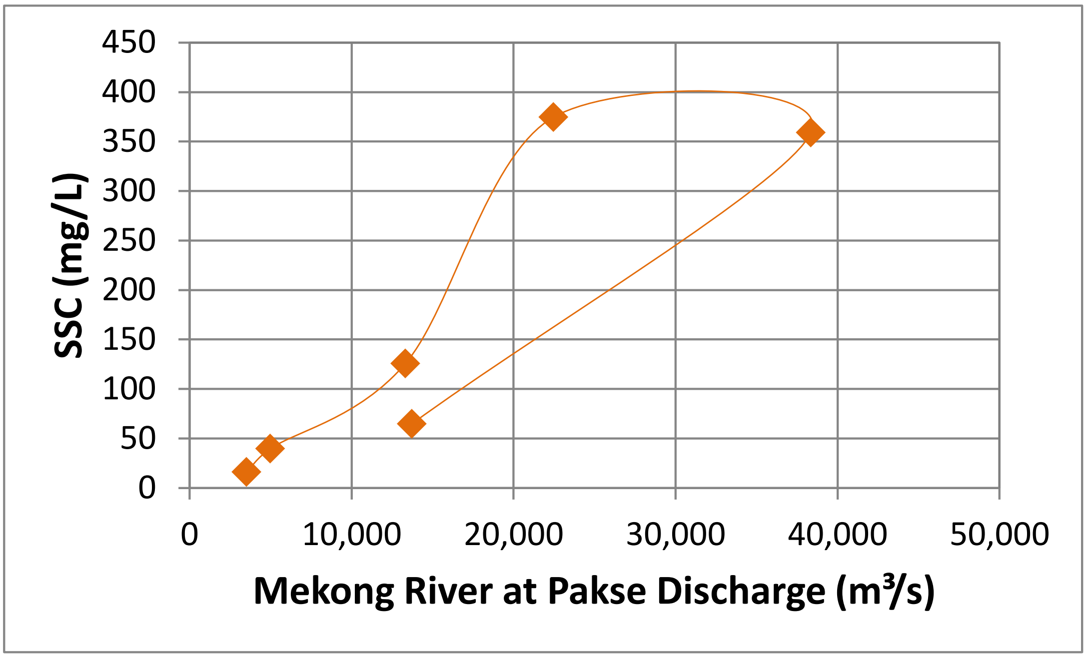

Figure 3: Average suspended sediment concentration sampled for each visit, compared with Mekong River at Pakse discharge. Line shows timing or visits.

There is variability in SSC between the sampling locations, as seen in Table 2, although there is no clear pattern to the differences. The differences are likely due to localised differences in SSC in relation to the discrete measurement points and thus represent sampling variability as opposed to true differences in average SSC of the cross-sections.

Particle size distribution curves of the suspended sediment, averaged across all sections for each visit and comparing distributions for the different times of the season are shown in Figure 4.

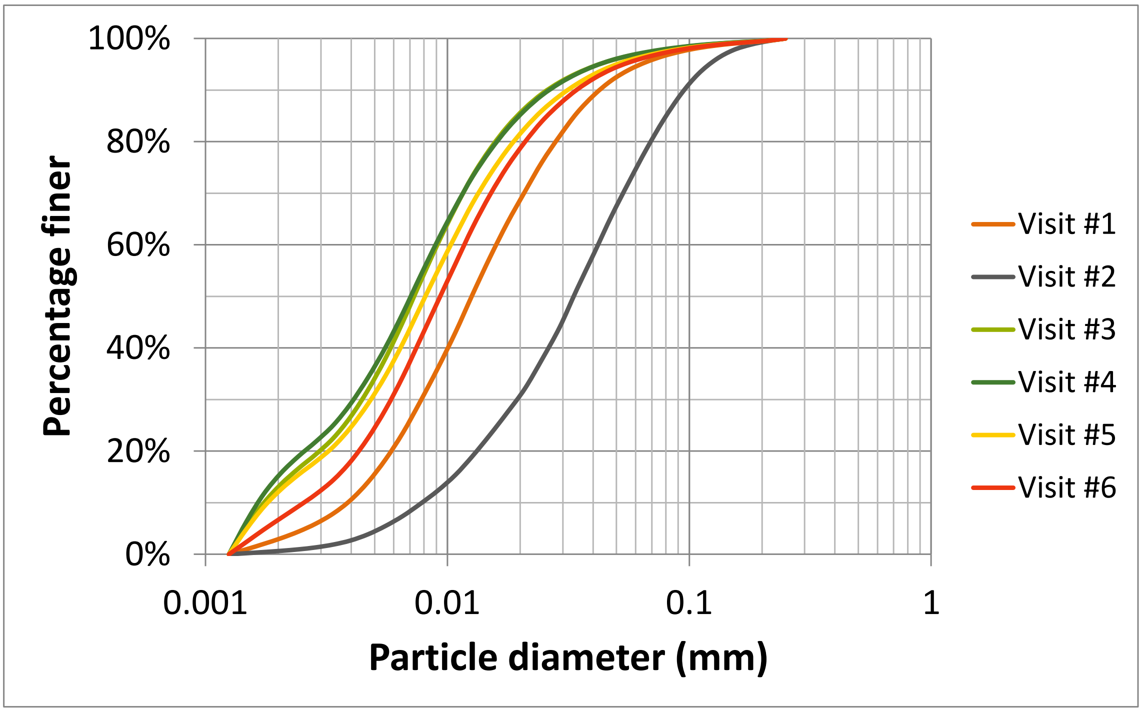

Figure 4: Particle size distribution of suspended sediment samples, averaged across all cross sections for each visit

The suspended grain size is seen to be significantly coarser in Visit #2, at the end of the dry season. The grain size distribution is very similar throughout the rising and peak wet season (Visits #3 to 5), becoming coarser as the wet season recedes (Visit #6, Visit #1).

The wet season samples of Visits #3 to #5 exhibit a bimodal distribution, with a significant proportion of clay-sized particles (around 2μm).

Similar sets of particle size distribution curves for each individual visit, comparing samples from the different cross sections, are provided in Appendix A. At each visit the particle size distributions are generally similar for all cross sections. An exception is Visit #2, for which CS3 and CS4 have finer suspended sediments than the other cross sections.

3.2 Bed load

The riverbed in the project area was found to be 'craggy' rock, with a very uneven and irregular profile. This general profile type can be observed in channels such as the Hou Sahong and Hou Xang Pheuak when areas of their channel beds are exposed in the dry season. Only very small amounts of bed load were captured, likely due to a combination of:

- spatial (cross-channel) as well as temporal variation in bed load transport, meaning sampling at distinct verticals for a finite time may miss higher rates of transport,
- difficulty in achieving a flat 'fit' between the sampler bottom and the bed given the craggy nature of the bed, and

Attempts to overcome these difficulties by taking samples at additional locations where the bed was perceived to be more regular did not significantly improve the sampling. Furthermore, at locations where reasonable volumes of bed load were captured, samples were limited to 100g, further restricting the accuracy of results.

Sampled bed load transport rates are shown in Table 3. For Visit #1, samples from all verticals were combined for each cross-section, due to the very small volumes of material collected. For other visits, the average rate across all verticals of each given cross-section is presented, along with the average rate from all cross-sections.

Table 3: Sampled bed load transport rates, Visits #1-#3 at 6 cross-sections

Trip	CS1	CS2	CS3	CS4	CS5	CS6	Average
#1 Dec 2012	0.057 g/s per metre	0.015 g/s per metre	0.025 g/s per metre	0.015 g/s per metre	0.006 g/s per metre	0.089 g/s per metre	**0.035 g/s per metre**
#2 June 2013	0.018 g/s per metre	0.016 g/s per metre	0.028 g/s per metre	0.17 g/s per metre	0.010 g/s per metre	0.049 g/s per metre	**0.042 g/s per metre**
#3 July 2013	0.042 g/s per metre	0.30 g/s per metre	0.93 g/s per metre	0.085 g/s per metre	0.23 g/s per metre	0.40 g/s per metre	**0.33 g/s per metre**
#4 Aug 2013	0.15 g/s per metre	0.33 g/s per metre	2.80 g/s per metre	2.14 g/s per metre	0.51 g/s per metre	0.63 g/s per metre	**1.09 g/s per metre**

Trip	CS1	CS2	CS3	CS4	CS5	CS6	Average
#5 Sept 2013			0.98 g/s per metre	0.77 g/s per metre	1.10 g/s per metre		**0.95 g/s per metre**
#6 Oct 2013	0.42 g/s per metre	0.58 g/s per metre	0.22 g/s per metre	0.50 g/s per metre	0.92 g/s per metre		**0.525 g/s per metre**

It is considered that the volumes of sediment collected by the bed load sampler do not adequately represent the transported sediment volume, and bed load transport rates cannot be practically determined from samples collected in the project area.

The bed load samples provide information on the distribution of particle sizes transported near-bed. Particle size distribution curves of the bed load, averaged across all sections for each visit and comparing distributions for the different times of the season are shown in Figure 5.

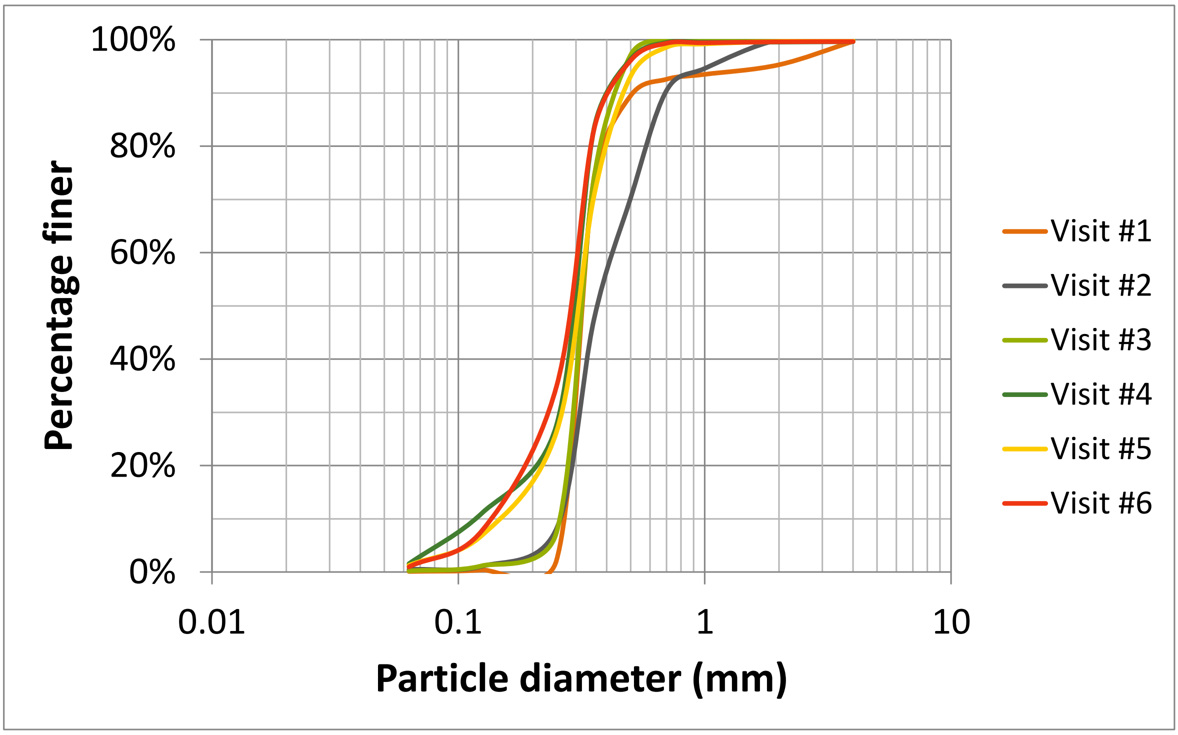

Figure 5: Particle size distribution of bed load samples, averaged across all cross sections for each visit

For all visits the median diameter (d_{50}) of sediment collected in the bed load sampler was around 0.3mm, with Visit #2 being slightly coarser. Samples from Visits #4 to #6, at the peak and receding limb of the wet season, included more fine sands (around 0.2mm).

Similar sets of particle size distribution curves for each individual visit, comparing samples from the different cross sections, are provided in Appendix B. There is no clear trend with regard to differences between cross sections. Individual cross section PSD curves from Visits #1 and #2 show significant variability due to the small volumes of bed load sampled.

4 REFERENCES

AdTech Management, Technical Report: Mekong River Sediment Sampling, Thakho, Champasak, Lao PDR 16-22 December 2012, May 2013

AdTech Management, Technical Report: Mekong River Sediment Sampling, Thakho, Champasak, Lao PDR 7-20 June 2013, November 2013

AdTech Management, Technical Report: Mekong River Sediment Sampling, Thakho, Champasak, Lao PDR 17-21 July 2013, January 2014

AdTech Management, Technical Report: Mekong River Sediment Sampling, Thakho, Champasak, Lao PDR 14-21 August 2013, May 2014

AdTech Management, Technical Report: Mekong River Sediment Sampling, Thakho, Champasak, Lao PDR 18-25 September 2013, July 2014

AdTech Management, Technical Report: Mekong River Sediment Sampling, Thakho, Champasak, Lao PDR 23-30 October 2013, July 2014

ASTM D3977-97 Standard test method for determining sediment concentration in water samples

ISO 3716:2006 Hydrometry – Functional requirements and characteristics of suspended sediment samplers

ISO 4363:2002 Measurement of liquid flow in open channels – (E) Methods for measurement of characteristics of suspended sediment

ISO 4365:2005 Liquid flow in open channels – Sediment in streams and canals – Determination of concentration, particle size distribution and relative density

ISO 13320:2009 Particle size analysis – Laser diffraction methods

MRC, Terms of Reference for International Consultant for the Evaluation and Analysis of Sediment Data, Annex 1: ToR for discharge and sediment transport measurements available: http://www.mrcmekong.org/assets/Employment-Tenders/TOR-consultanr-for-Evaluate-Sediment-data-Annex1-final-19122011.pdf

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APPENDIX A: PARTICLE SIZE DISTRIBUTION CURVES (SUSPENDED SEDIMENT)

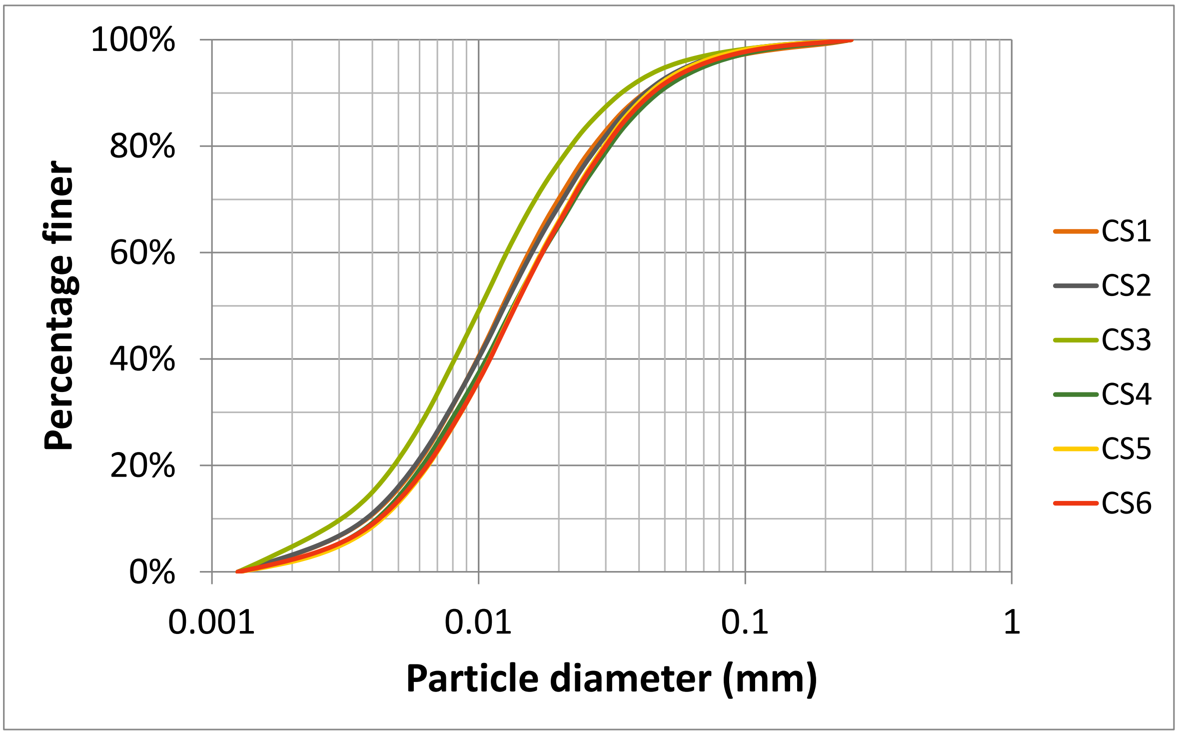

Figure A-1: Particle size distribution of suspended sediment samples, Visit #1, December 2012

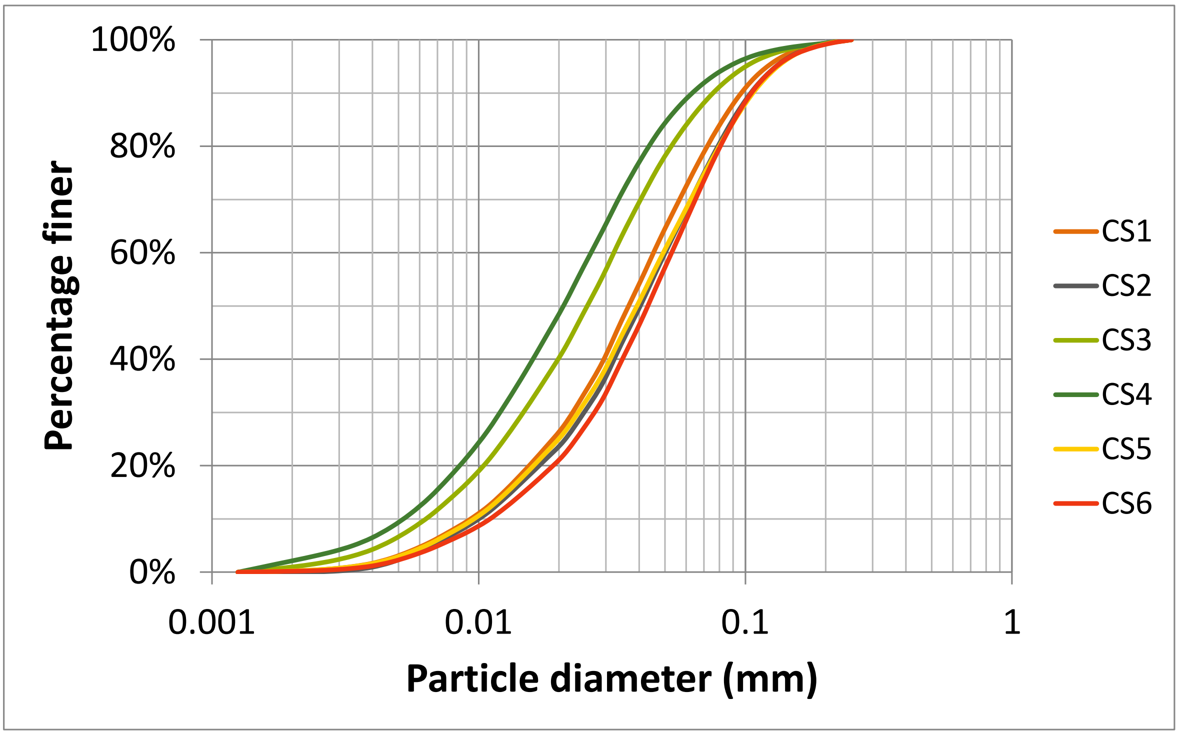

Figure A-2: Particle size distribution of suspended sediment samples, Visit #2, June 2013

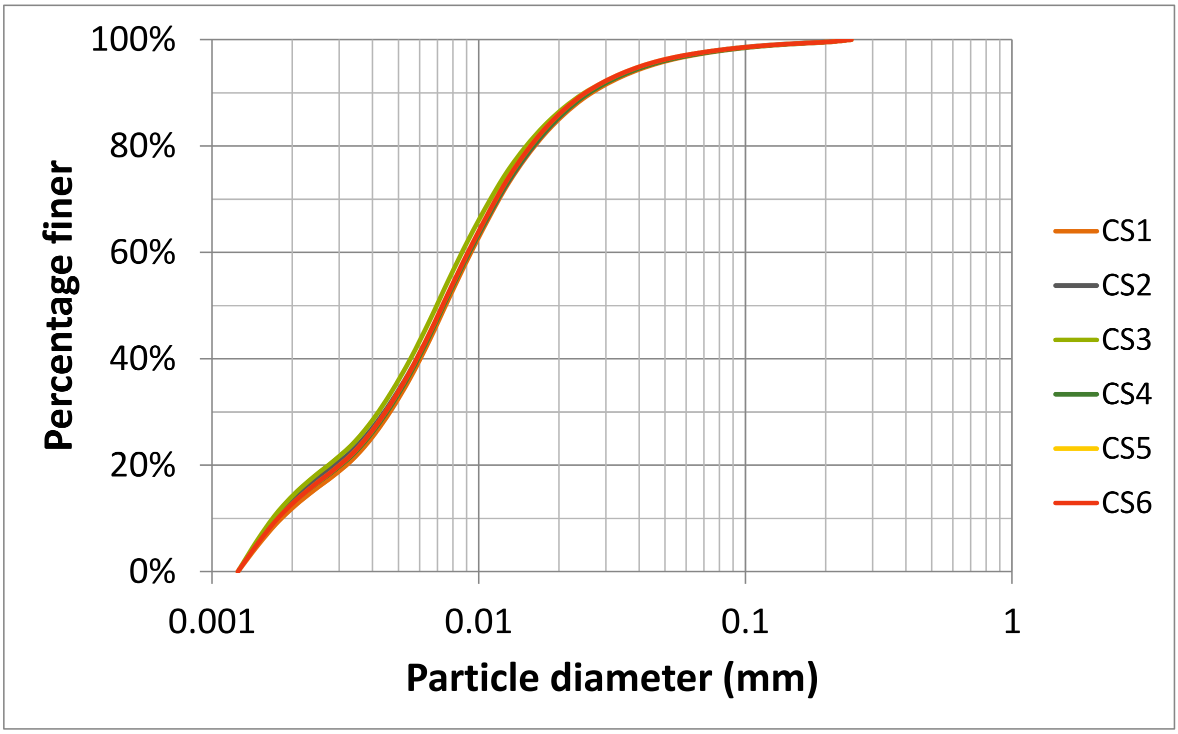

Figure A-3: Particle size distribution of suspended sediment samples, Visit #3, July 2013

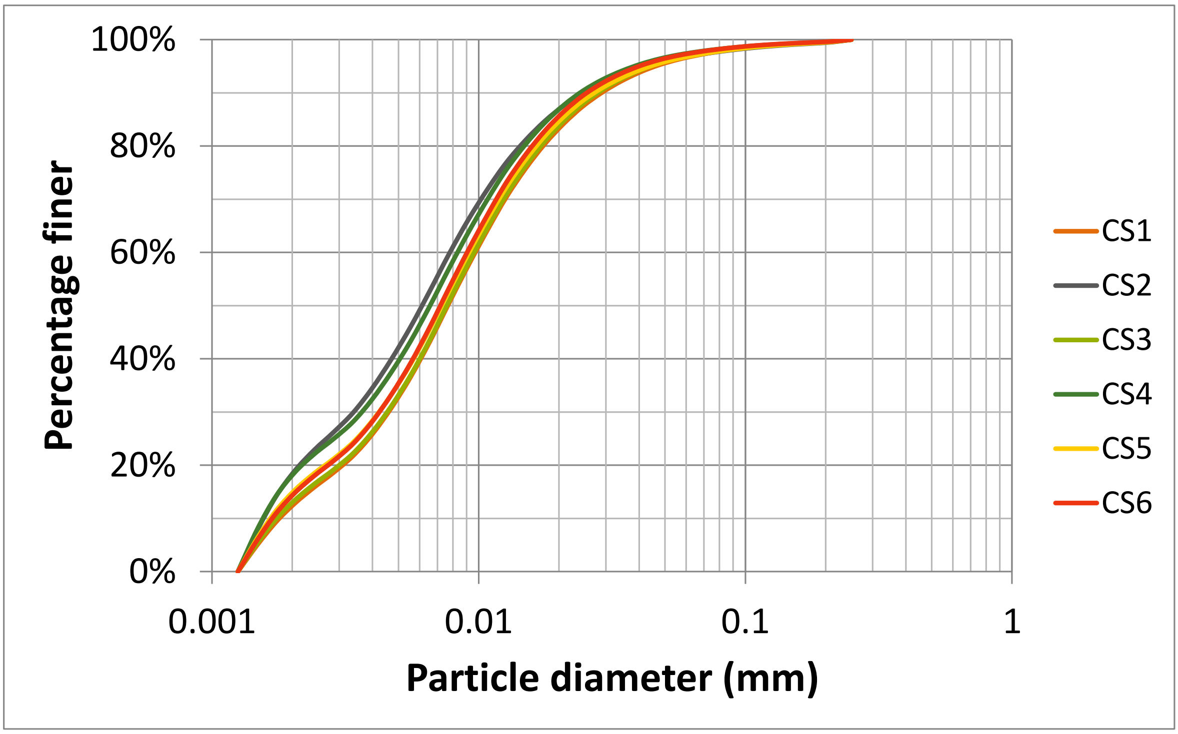

Figure A-4: Particle size distribution of suspended sediment samples, Visit #4, August 2013

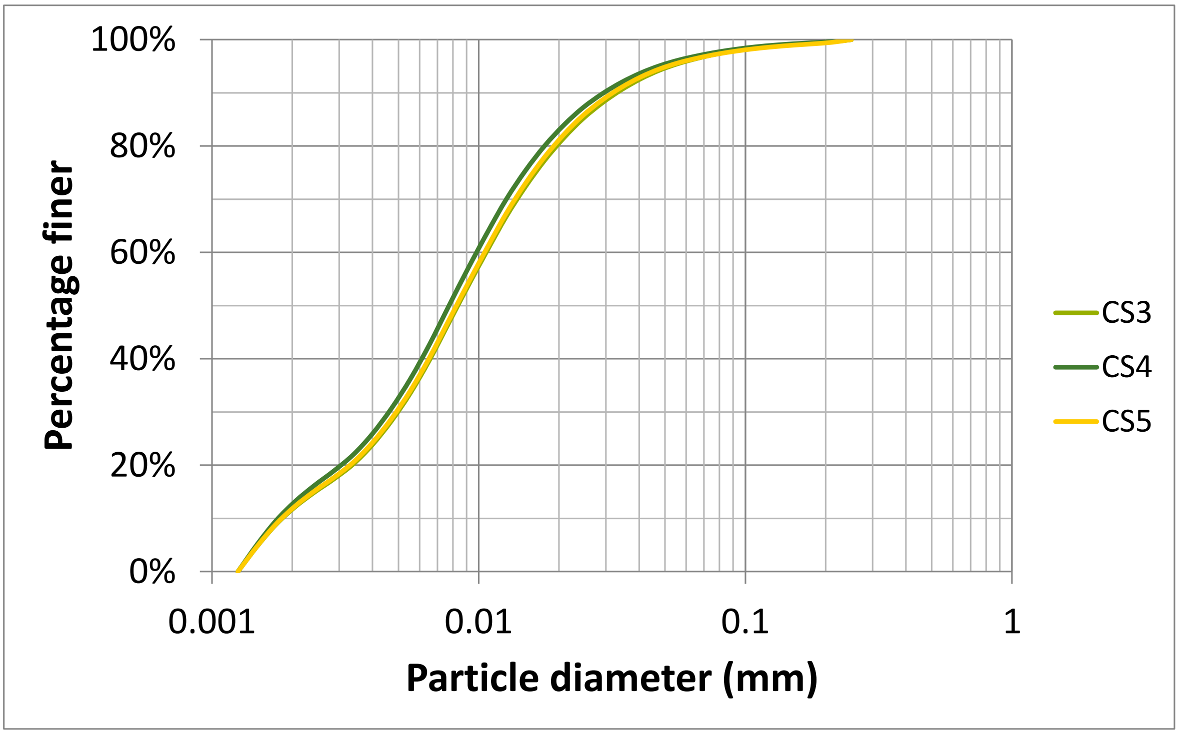

Figure A-5: Particle size distribution of suspended sediment samples, Visit #5, September 2013

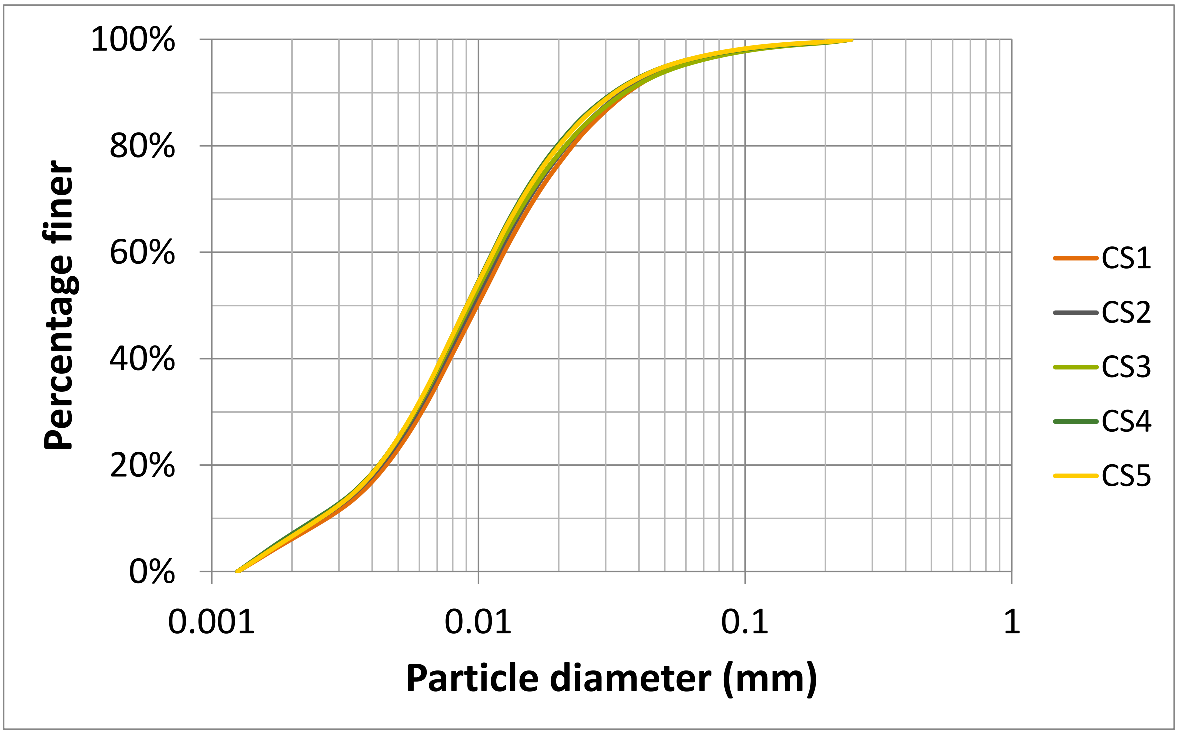

Figure A-6: Particle size distribution of suspended sediment samples, Visit #6, October 2013

APPENDIX B: PARTICLE SIZE DISTRIBUTION CURVES (BED LOAD)

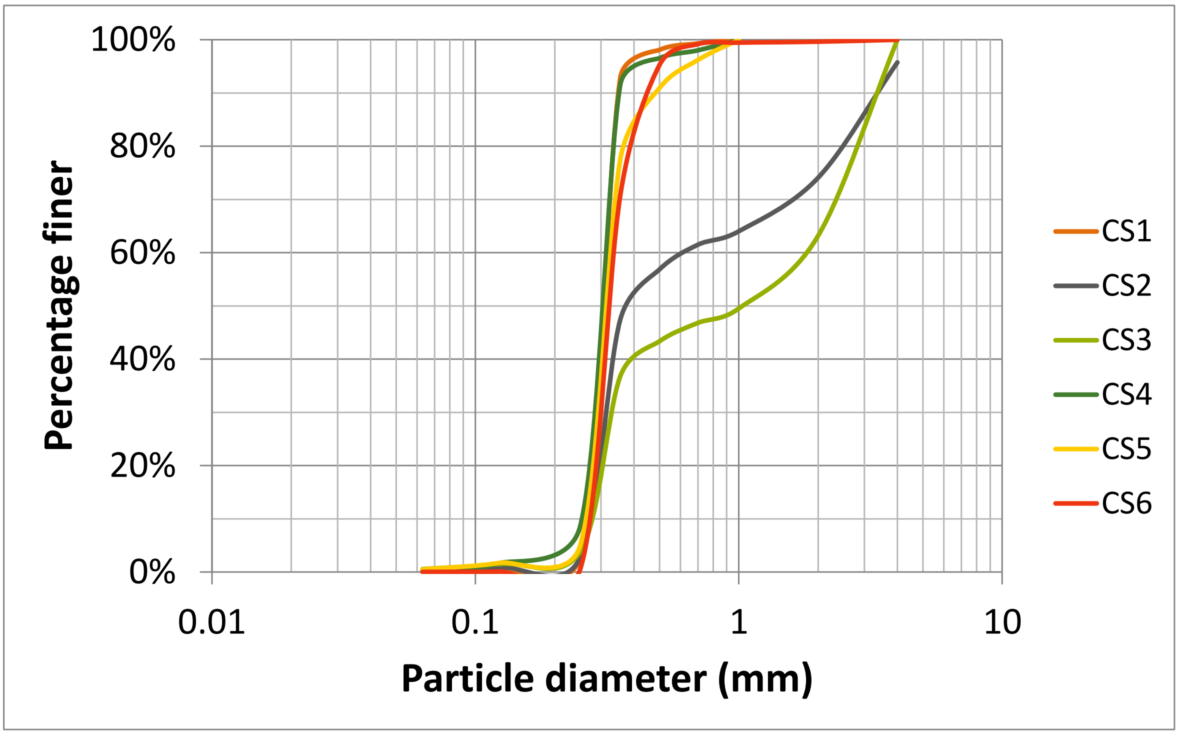

Figure B-1: Particle size distribution of bed load samples, Visit #1, December 2012

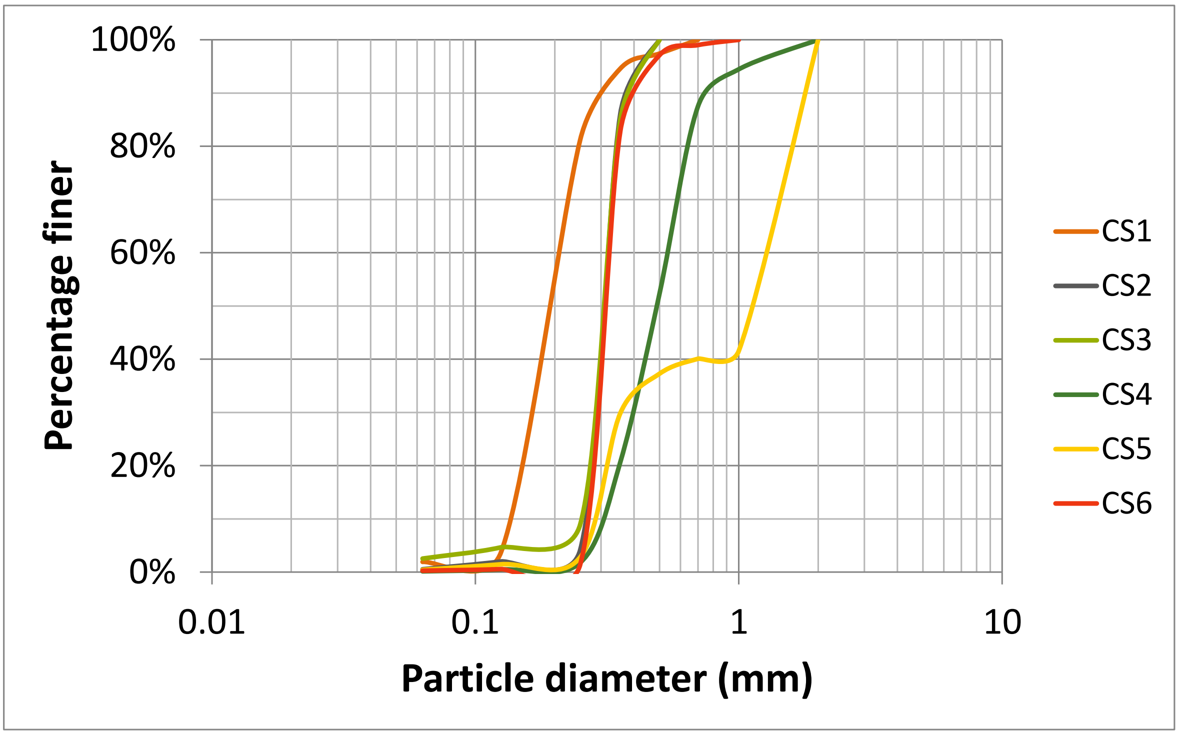

Figure B-2: Particle size distribution of bed load samples, Visit #2, June 2013

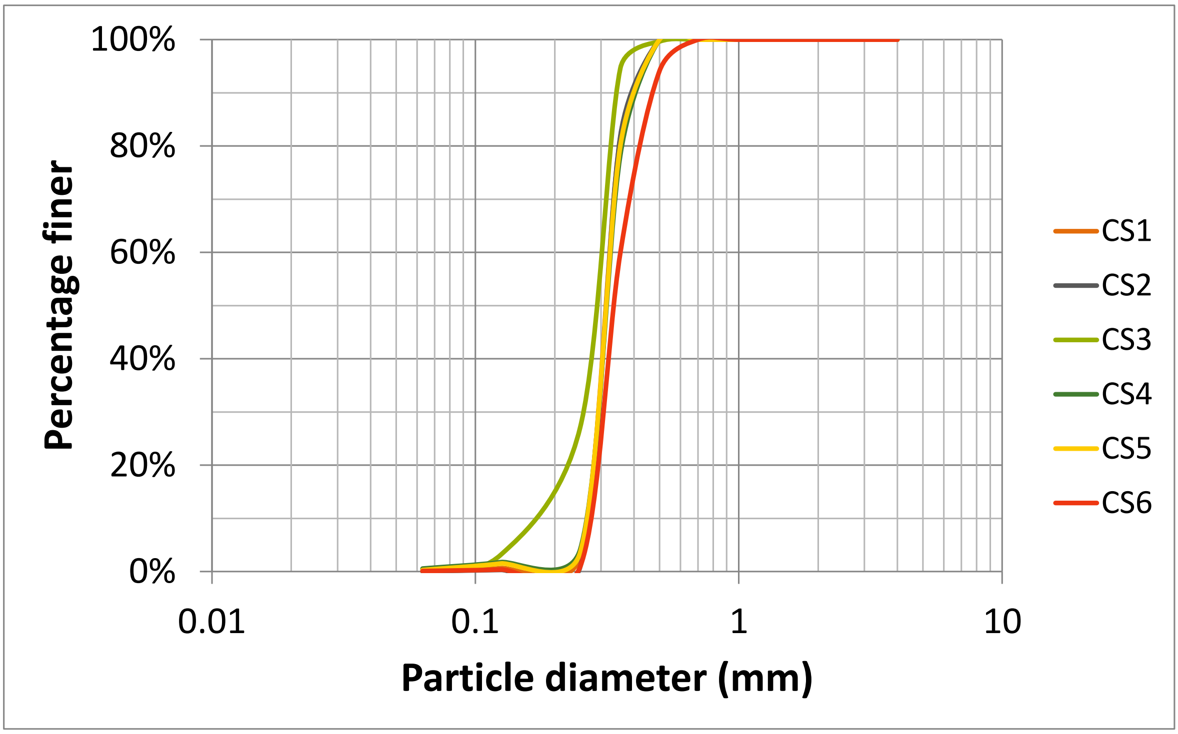

Figure B-3: Particle size distribution of bed load samples, Visit #3, July 2013

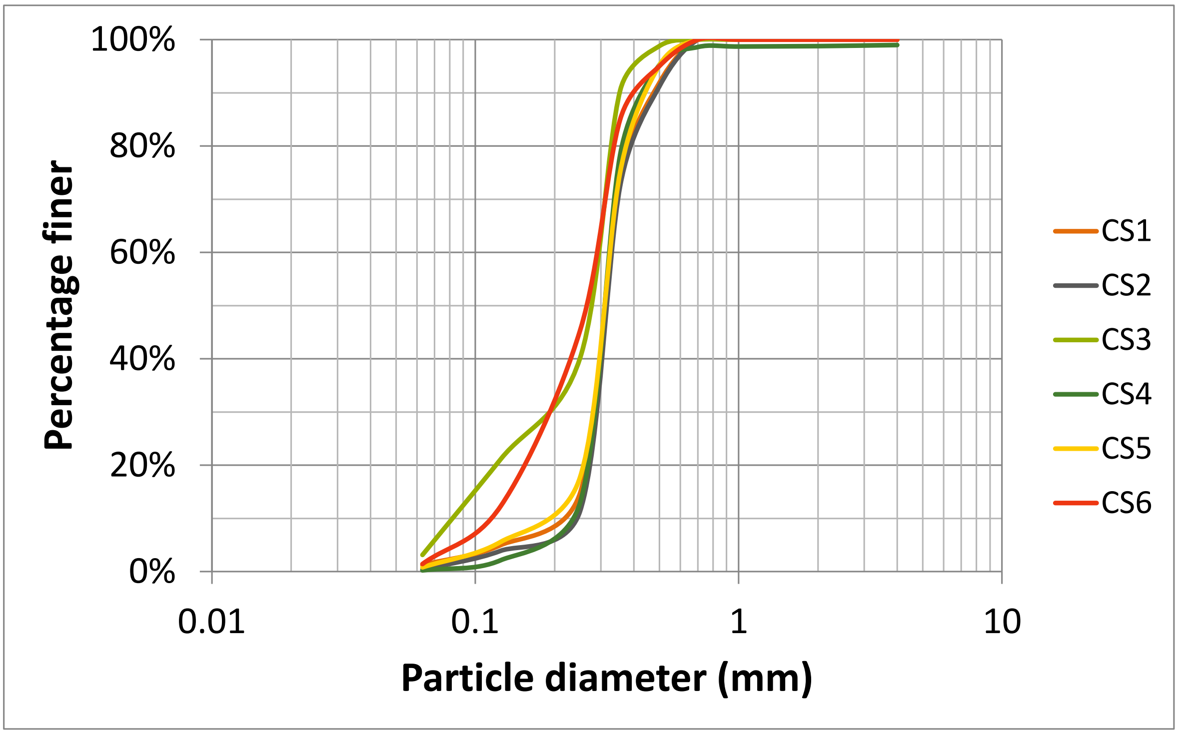

Figure B-4: Particle size distribution of bed load samples, Visit #4, August 2013

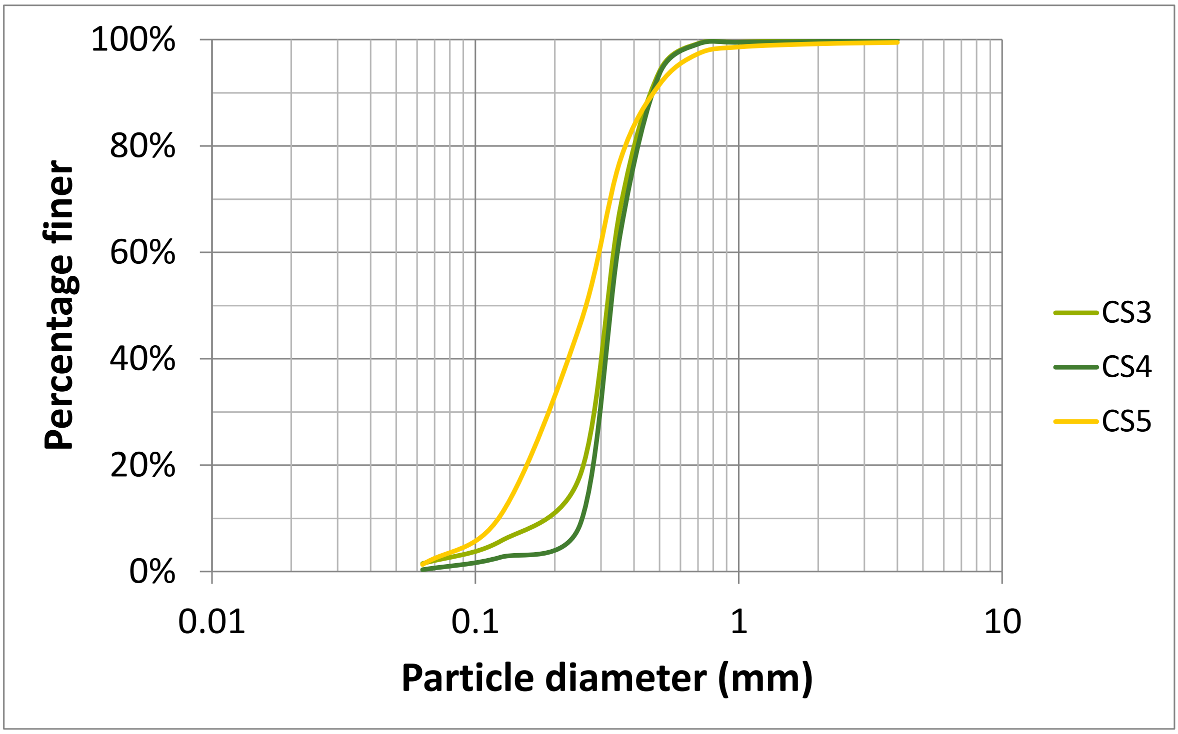

Figure B-5: Particle size distribution of bed load samples, Visit #5, September 2013

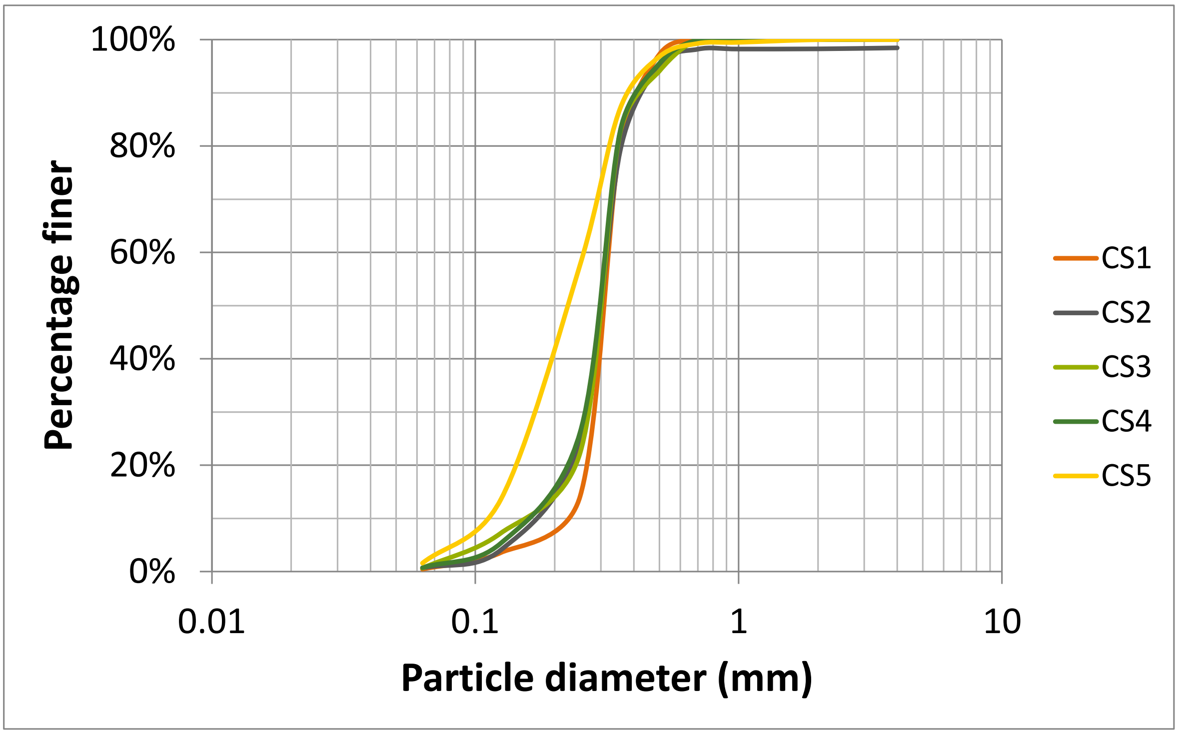

Figure B-6: Particle size distribution of bed load samples, Visit #6, October 2013