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ESTIMATION BED RIVER MORPHOLOGY USING S-PLUS

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Estimation of river-bed morphology using S-PLUS

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ABSTRACT

River-bed morphology is a product of sediment material that is transported by streams. The hydrology and morphology are interpreted to be control the form of river channel. This research is focussed of river-bed morphologic changes that influenced by tailing impoundment in Ajkwa lowland, Timika, Papua. The river transects data give variation in surface profiles of Modified Ajkwa Depositional Area (ModADA). Hence, maps based on shape of change in the river-bed morphology are evaluated. The significant criteria of selected observation based on channel form in straight to get variation in bed forms per annual discharge. Rapid and frequent variation in Q tend to increase the magnitude of the alternating patterns of erosion and deposition that seem to be a necessary part of braiding mechanics. Combination of discharge and sediment load include tailing drops in highland refer the relationship of river-bed morphology and hydraulic efficiency can de made quantitatively. Computation and estimation of bed river morphology using S-PLUS for Windows, that is an object-oriented programming and visualization environment.

Kata-kata kunci : ModADA, river bed morphology, discharge, tailing impoundment

1. INTRODUCTION

1.1. Background

Since PT Freeport Indonesia have been mining, the tailing is increasing from 7.275 ton/day in 1973 to 310,040 ton/day in 1988 and 223,100 ton/day currently. This tailing is deposited at ModADA (Modified Ajkwa Deposition Area) that is modified and managed area. ModADA area is around 235 km^2 which is divided by west levee and east levee. The tailing is delivered using river flow from mining area in highland into ModADA in lowland area (Fig. 1).

The river is use to deliver tailing is the biggest depocenter (center for deposition of tailing) in Papua. Due to high rainfall in highland, the rate of erosion is high especially around mining area.

Due to this condition, it needed effort to conserve environment along the river. One of them is developed lateral construction such as levee in ModADA as mention before. These levees would be increased to conserve management system and increase capacity of tailing deposition including inspection, monitoring and other construction work. In design of increasing of levees and tailing deposition, many aspect must have decided and important such as prediction of sedimentation pattern. It is important because of tailing deposition could be transported until sea and decreasing the environmental quality at the lowland area.

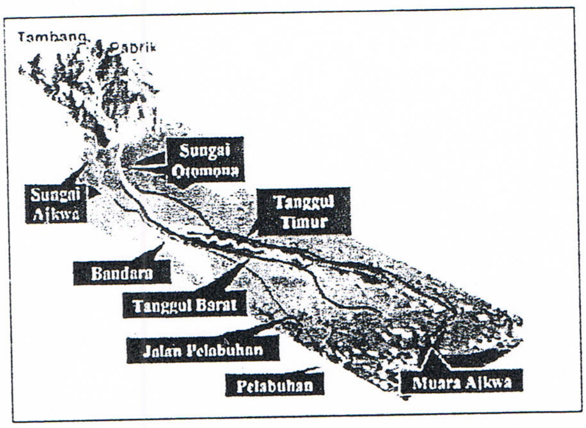

Figure 1. Location of yModADA

Flow along the river contains material from erosion which related to cohesion factor, rate of sedimentation and geometric configuration is assumed as bed river morphology. Those factors made sedimentation pattern along the river. One factor which controlled and influenced in sedimentation pattern is bed river morphology that is focused in this research.

1.2. Objectives

Objective of this research is to estimated bed river morphology to predict sedimentation pattern in ModADA due to estimation of changing physical environment at Ajkwa Lowland Area.

This preliminary study could be use for management tailing in ModADA by levee planning and gabion management as alternative to decreasing negative impact of tailing deposition.

2. SEDIMENTATION AND STATISTICAL APPROACH

2.1. Definition

Sediment is material which created by physical and chemical of rock, have variation in shape and size. Loose particle is moving cause wind, water, gravitation, wave and others, if flows by water called fluvial or sediment transport.

Sediment transport is moving of place and granular sediment material (on cohesive) on flowing water and the same direction with that flow. Based on moveable in bed load on the river could divided on three type as follows:

1. Bed load transport
2. Saltation load transport
3. Suspended load transport

2.2. Sediment properties

In process sediment transport is not only depend on properties of flow but also properties sediment itself. Properties of sediment contain particle properties and all properties of sediment. The properties are using in calculation of sediment transport as follows:

a. Grain size
b. Mass
c. Porosity
d. Shape
e. Falling velocity

2.3. Bed river morphology

Bed river morphology is all shape which found on bed river as irregular collection result of particle. Some definition also use such as bed geometry, roughness of bed, bed shape, flow regime, base phase and material base shape.

If material of bed river is move at low discharge condition would be made configuration of river bed as sediment footprint. River bed is shown as a result of moving previous material. After that move, the river bed as result with related to resistance material to water flow that the flow influenced with variability of configuration bed river and geometry of channel (Figure 2). Bed river morphology as follows:

1. Plane bed
2. Ripples
3. Bars
4. Dunes
5. Transition
6. Anti dunes
7. Chutes and pools

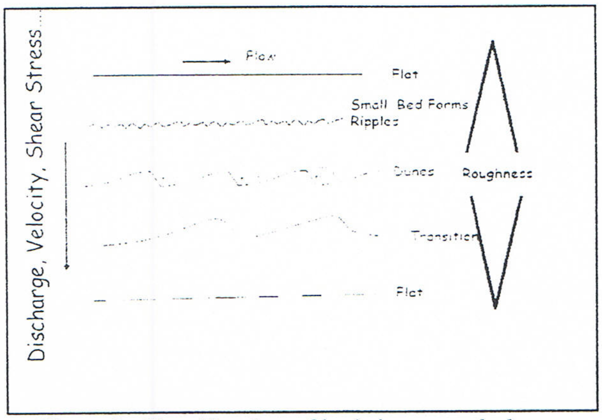

Figure 2. Classification of bed river morphology (Source: Shimizu, 2009)

Table 1. Change of flow resistance influenced by roughness of bed river as impact of increasing one parameter

Parameter	*Plane*	*Ripple*	*Dunes*	*Antidune*	*Chute & Ripple*
$C/\sqrt{g}$	15-23	6-7-12	8-12-15	10-20	9-16
n	0.012-0.016	0.018-0.035	0.018-0.035	0.012-0.028	0.015-0.031
Depth	Decrease	Decrease	Increase, D50 > 0.3 mm Decrease, D50 < 0.3 mm Decrease, D50 > 0.3 mm	Increase Limited depth Decrease	Unknown
Slope	Not change	Increase, Not change, depth	Increase, w>0.2 fps Increase, w<0.2 fps Decrease, w<0.2	Increase	Unknown
Fall Velocity	Increase	Not change	Not change	Increase	Unknown

(Source: Simon and Senturk, 1977)

Table 2. Flow characteristic on ripple

No	Karakteristik Aliran pada Dasar Ripple
1.	D50 < 0.0006 m
2.	Water level: horizontal
3.	Sediment as bed load, no suspension material
4.	Resistant to flow and inverse to river flow
5.	Shape geometry is triangular with normal orientation to flow or three dimension in horizontal plane

(Source: Simon and Senturk, 1977)

Table 3. Flow characteristic on dunes

No	Karakteristik Aliran pada Dasar Dunes
1.	0.6 < D50 < 0.15 mm
2.	Water level: irregular
3.	Suspension material
4.	D50 > 0.3 mm resistant to flow, paralel with river flow D50 < 0.3 mm resistant to flow and inverse D50 > 0.6 mm resistant to flow and inverse
5.	$8 < \frac{C}{\sqrt{g}} < 12 - 15$
6.	Shape geometry is triangular

(Source: Simon and Senturk, 19777)

2.4. Variability of Sediment

Variability sediment on regime flow could be shown as mean, varian, standard deviation, variogram and auto-correlation.

2.4.1 Mean

Mean is average or center value from sum of variable, which calculate as follows

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad \text{...} (1)$$

2.4.2. Variance

Variance as determined value to population and calculate as:

$$s^2 = \frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x}) \qquad \text{.....................} (2)$$

Where $x_1, x_2, \ldots, x_n$ is n sample observation and and x is mean.

2.4.3. Standard Deviation

Standard deviation is boundary in observation data which use generally and square of variance

2.4.4. Variogram

Let V(u) is series data (Xt) as:

$$V(u) = E\left[\frac{1}{2}\{x_t - x_{t-u}\}^2\right] \qquad \text{...........} (3)$$

Variogram is alternative covariance function to show real value in irregular data.

2.4.5. Autocorrelation

Autocorrelation is relationship variable in one population as shown in a function. One of type autocorrelation is spatial autocorrelation that show relationship between one value to other in different range. Autocorrelation is function of k, $\gamma(k)$, and defined as follows:

$$\gamma(k) = \frac{E(Xt - \mu)(X_{t+k} - \mu)}{E(Xt - \mu)^2} \qquad \text{..........} (4)$$

Where, Xt, t = 0, ±1, ±2.., as value of data series and μ is mean of data series and E is estimation point. The relationship in statistics as follows:

$$\bar{\gamma}(k) = \frac{\sum_{i=1}^{n-k} (x_i - \bar{x})(x_{i+k} - \bar{x})}{\sum_{i=1}^{n} (x_i - \bar{x})^2} \qquad \text{....} (5)$$

Where $\bar{x}$ is mean of observation data for $x_1, x_2, \ldots, x_n$. The variable value of autocorrelation which inverse to velocity is called autocorrelation function or correlogram and use as tool to analyse a good model.

2.4.6. T-test

T-test is one of significance test to predict hypothesis in population. This test is using to check relationship between population and mean value that is called as single t-test on sample. Other version is using for two of population as called as t-test independent and defined as follows:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{s\sqrt{\frac{1}{n1} + \frac{1}{n2}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where x_1 and x_2 is mean value to sample size n_1 and n_2 that take from each population and s^2 is general estimation which defined:

$$s^2 = \frac{(n_1 - 1)s_1^{\ 2} + (n_2 - 1)s_2^{\ 2}}{n_1 + n_2 - 2} \quad \ldots\ldots\ldots (7)$$

2.4.7. Program S-Plus

S-Plus is one computer program language with statistical design both standard and non-standard. S-Plus is using one type equation that is shown relationship between variable as simple parameter. In this study, S-Plus is using for test data. model selection and preview results, and simplified model to be used.

3. METHODOLOGY

The step of this research as follows:

1. Recapitulation, collection and analysis field data using Excel.
2. Calculation mean, variance, standard deviation, auto-correlation and variogram using S-Plus
3. Analysis of sediment characteristic in each section of ModADA
4. Estimation of bed river morphology to be used in sedimentation pattern in ModADA.

4. RESULT AND DISCUSSION

The data used in this research are collected in ModADA PT Freeport Indonesia, since 1997 until now. That raw data is analysis using Excel and S-Plus to figure out mean, variance, standard deviation, variogram and auto-correlation. This analysis is used to be define sediment characteristic in each section to estimate the sediment pattern at MOdADA in next step.

4.1. Sampling method and cross section

The samples is collected using sediment traps. Sampling is done in each point at MA section along the ModADA as shown in Figure 3 to 5 from upstream to downstream, respectively.

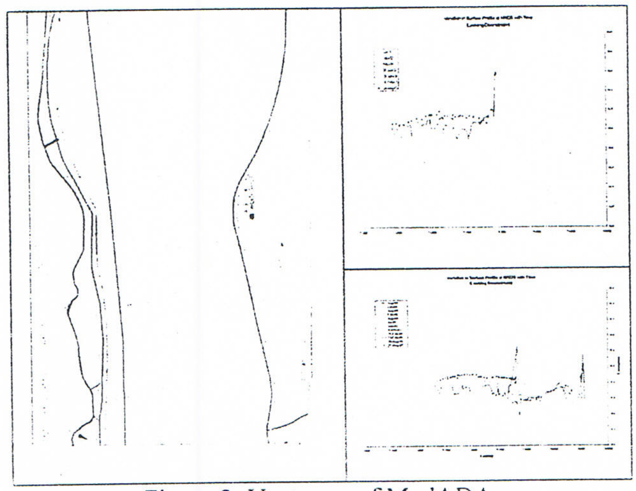

Figure 3. Upstream of ModADA
(Source: PT. Freepot Indonesia, 2007)

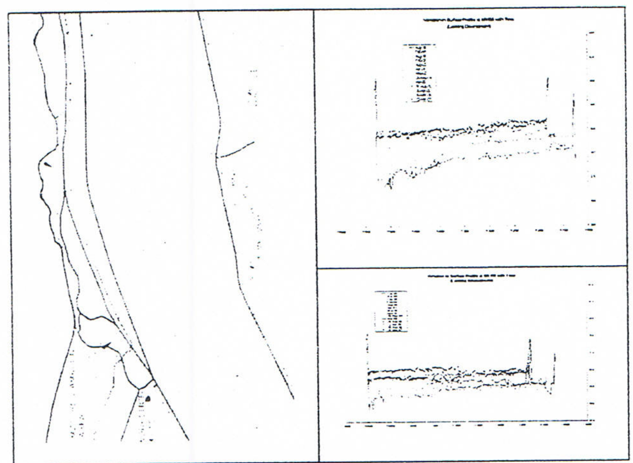

Figure 4. Middle-stream of ModADA
(Source: PT. Freepot Indonesia, 2007)

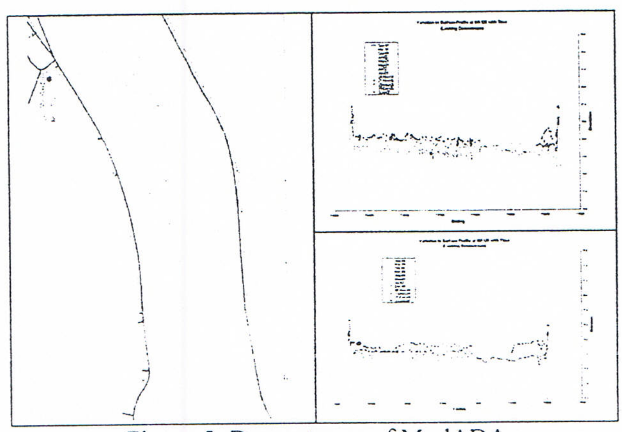

Figure 5. Downstream of ModADA
(Source: PT. Freepot Indonesia, 2007)

The sediment sampling procedure is shown in Figure 6.

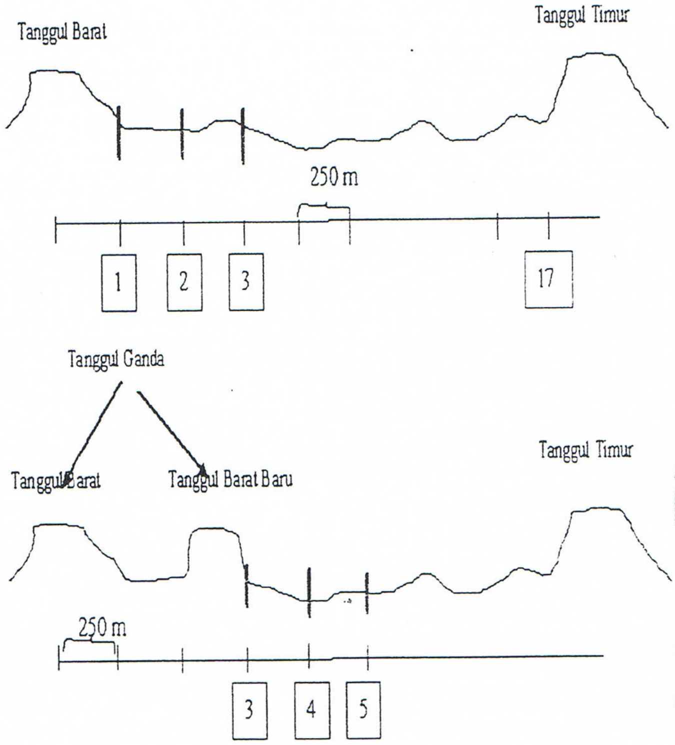

Figure 6. Sampling procedure

4.2. Collection and analysis data

The procedure of collection and analysis data as follow:

First step in data analysis is recapitulation and grouping data based on grain size in each ModADA section by D_{50} of sediment grain size with Excel.

The second step is determination of sediment characteristic such as mean, variance, standard deviation and variogram using S-Plus.

The third step is plotting data as tabulation and graphic.

The fourth step is grouping data in each section and each year, one example is shown in Figure 7.

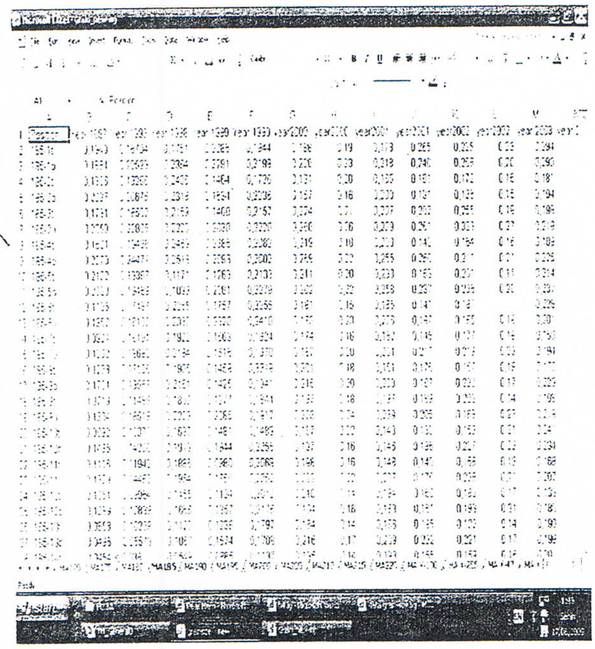

Figure 7. Recapitutalion in each MA Section

In Figure 8 is shown one example of calculation data using S-Plus after converted to Excel.

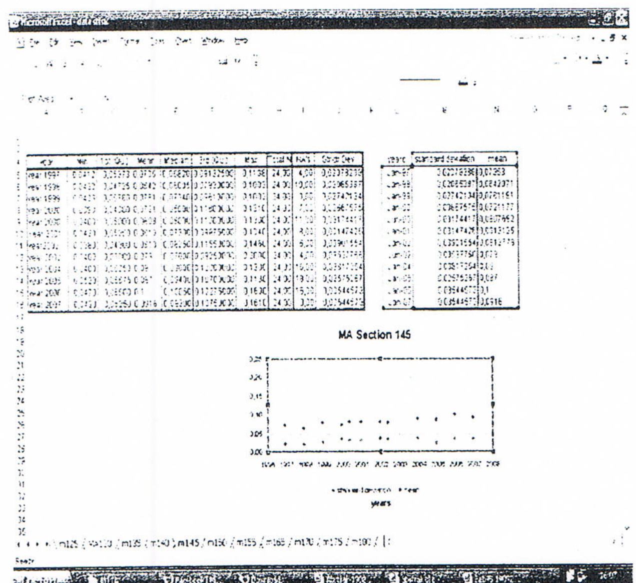

Figure 8. Processing of statistical numeric

4.3. Sediment properties: mean, variance, SD and variogram

Determination of sediment properties is using grain size D_{50} like as mean, variance and standard deviation as shown in Table 4. from upstream to downstream, respectively.

Table 4. Recapitulation Numerical Statistic data at MA Section 220

Years	Min	1st (Qu.)	Mean	Median	3rd (Qu.)	Max	Total N	NA's	Std Dev.
1997	0.0409	0.1271	0,14247	0.1455	0.1605	0.2073	28,00	19,00	0.04841684
1998	0.0506	0.1204	0,14347	0.1336	0.1647	0.2640	28,00	19,00	0.05953451
1999	0.043	0.08355	0,123	0.1085	0.14645	0.2326	28,00	17,00	0.0597143
2000	0.1090	0.12525	0,1865	0.1805	0.2480	0.2760	28,00	18,00	0.06477182
2000	0.1100	0.1675	0.20429	0.2200	0.2475	0.260	28,00	14,00	0.05139804
2001	0.066	0.14575	0,1761	0.1595	0.2225	0.276	28,00	8,00	0.0521404
2002	0.0450	0.15025	0,19181	0.2135	0.23675	0.283	28,00	2,00	0.06923584
2002	0.0600	0.1500	0,18269	0.1900	0.23750	0.2600	28,00	2,00	0.05970311
2003	0.0520	0.1420	0,18269	0.1950	0.2250	0.3070	28,00	0,00	0.06523595
2004	0.0400	0.1250	0,1875	0.2150	0.2400	0.3600	28,00	0,00	0.08694933
2005	0.0580	0.1250	0,1939	0.1910	0.2705	0.3360	28,00	8,00	0.09247867
2006	0.0980	0.1390	0.164	0.1620	0.18425	0.2530	28,00	10,00	0.03679354
2006	0.0900	0.1300	0,16889	0.1650	0.2075	0.2400	28,00	10,00	0.04522999
2007	0.1000	0.1600	0,19	0.1950	0.235	0.250	28,00	14,00	0.04673987
2007	0.0430	0.17225	0,18572	0.1960	0.2200	0.2760	28,00	10,00	0.05993311

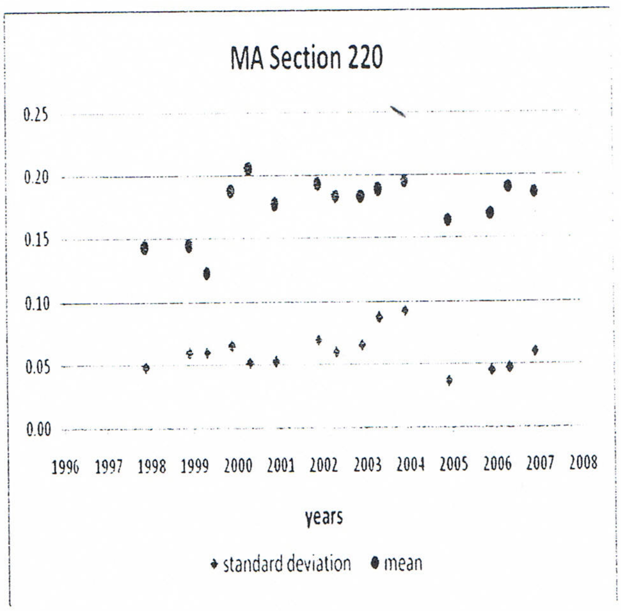

Figure 9. Grain size analysis D_{50} at MA Section 220

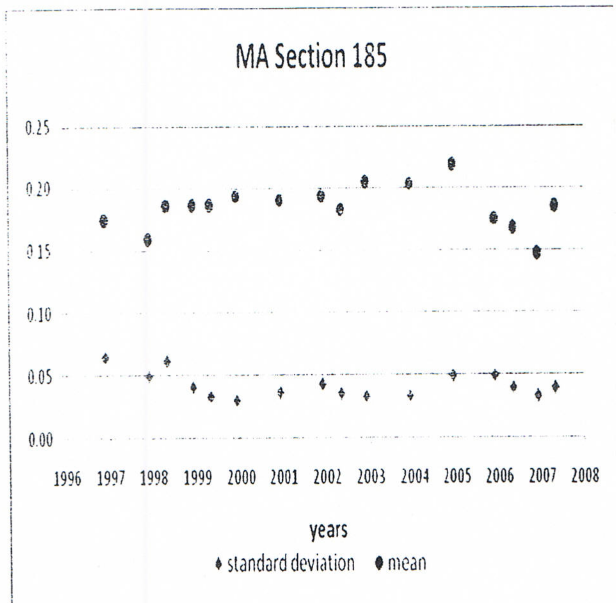

Figure 10. Grain size analysis D_{50} at MA Section 185

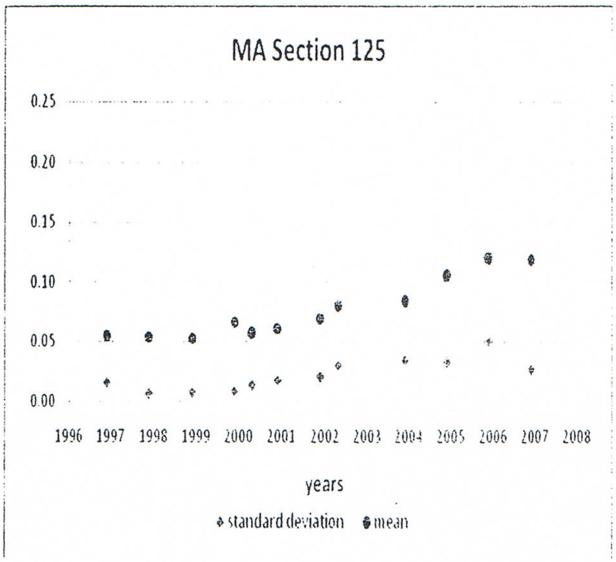

Figure 11. Grain size analysis D_{50} at MA Section 125

As shown in Figure 9 to 11 is shown that grain size is decreasing from upstream to downstream or fine material would be deposit at downstream area of ModADA. Based on standard deviation, it shown that regular value found in upstream which mean deposition area is more stable than downstream.

4.5. Analysis

Mean value of grain size distribution D_{50} in each year since 1997 to 2007 is using to estimate bed river morphology in each section from upstream to downstream. Table 5 is shown the recapitulation of estimation bed river morphology. It shown that bed river morphology is gradually change from upstream at MA Section 125 to downstream at MA Section 145 which shown ripple to dune. Otherwise, from MA Section 145 to MA Section 220 is more stable morphology which shown as dunes.

Table 5. Recapitulation of estimation bed river morphology

No	Section	Bed river estimation
1	MA Section 220	dunes
2	MA Section 215	dunes
3	MA Section 210	dunes
4	MA Section 205	dunes
5	MA Section 200	dunes
6	MA Section 195	dunes
7	MA Section 190	dunes
8	MA Section 185	dunes
9	MA Section 180	dunes
10	MA Section 175	dunes
11	MA Section 170	dunes
12	MA Section 165	dunes
13	MA Section 155	dunes
14	MA Section 150	ripple to dunes
15	MA Section 145	dunes
16	MA Section 140	ripple to dunes
17	MA Section 135	ripple to dunes
18	MA Section 130	ripple to dunes
19	MA Section 125	ripple to dunes

Based on pattern in changing of mean value time by time, it could be estimate that the river bed is dunes with three dimensions of shape geometry, water level irregularly and generally suspension material.

5. CONCLUSION

Based on data calculation and analysis, it could be concluded as follows:

1. Calculation data to determined statistical numeric using Excel and S-Plus is very useful for analysis and determination of sediment characteristic in each sample.
2. Based on mean value and graphic could be used to estimate grain size distribution from upstream to downstream that shown gradually from coarse to fine material
3. Based on standard deviation could be known that the distribution of sediment particle is reach to stable.
4. Estimation of river base morphology is dune which the geometry shape is three dimensions, water level irregularly with suspension material.
5. Result of estimation bed river morphology could be used as parameter in tailing management at ModADA such as embankment planning and gabion management as alternative to decreasing negative impact from tailing.

6. AKNOWLEDGMENT

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