Degradation and Aggradation Parabolic Model of Dengkeng Riverbed

Syifa Fauziyah[1], Cahyono Ihsan[2], Sobriyah[3]

Student of Civil Engineering Master Program, Engineering Faculty, Sebelas Maret University[1]

Lecturer of Civil Engineering Master Program, Engineering Faculty, Sebelas Maret University [2]

Lecturer of Civil Engineering Master Program, Engineering Faculty, Sebelas Maret University [2]

Abstract— **The stability of riverbed became an important part in the river. Basically, the stability would be maintained if the grains of sediment was not moving (transported). Riverbeds that were disrupted because of carried details (degradation) or stacked granules (aggradation) in certain parts of the river caused the structure to be damaged. Degradation and aggradation along the river road at a certain time would be figured out in this study, so that it could assist in making treatment recommendations layer riverbed. The case study was conducted on Dengkeng River along the 8 km segment Karangjoho-Jetis which was a fixed flow (quasi-steady) sub critical Froude number <0.6. Bottom sediment sample material with a grain diameter variation D35, D50, D65, and d90 in grain size analysis was used for the calculation. The process of degradation and aggradation riverbed sediment discharge was known by calculation using the method of Meyer-Petter & Muller. Parabolic model analysis with the help of MS Excel was used to calculate the degradation and aggradation happened. At the time of running, graph illustrating the comparison between degradation and aggrades with a segment length of the river at a certain time was seen. The graph showed the longer segment of the river, degradation and aggradation would less.**

Keywords: Riverbed stability, degradation, agradation, Meyer-Petter & Muller, Parabolic Model

I. INTRODUCTION

One of main problems encountered in river management as water source is erosion and sedimentation. Imbalanced sediment transportation occurring both naturally and due to human intervention affects negatively the morphology of river. Riverbed stability is an important element, particularly in river management. Riverbed stability will be maintained when the grains of Riverbed are immovable. These grains, also called sedimentation, are one cause of a river's damage. Riverbed inclination, water flow rate, and river stream speed highly affect the grains of riverbed carried away from the upstream to the downstream of river. Constant water flow results in abrasion on the riverbed; it results in degradation and agradation affecting the building around the river.

Considering the information obtained from a report of "Studi Morfologi Sungai Dengkeng tahun 2015", in BBWS Bengawan Solo, it could be found that the riverbank of Dengkeng River constitutes sandy soil; much damage is found in both left and right areas of river bank due to substantial flood stream speed, after the presence of shortcut. The high flow rate also results in degradation on the Riverbed leading many building to collapse or to slide. Sedimentation (agradation) elevation and abraded riverbed (degradation) occurring as the time progresses will help recommend the management of riverbed layer in order to reduce sedimentation occurring.

I. METHOD

Erosion and sedimentation highly affect the balance of riverbed configuration. The factor composing the riverbed configuration is highly affected by speed, flowing period and flowing depth [1]. Degradation occurs when the flow rate coming is less than the sediment transporting ability. Riverbed degradation is generally due to erosion with water as the main conductor being affected by flowing rate (speed) [2]. The Riverbed is eroded so that it goes down resulting in agradation in the next river segment. Agradation occurs due to the coming flow rate larger than the sediment transporting ability so that sediment deposition occurs leading the riverbed to go up and to be filled in with sediment grains.

1. Bottom Sediment Transportation

Degradasi Sungai suggests that river degradation highly affects the sediment transportation impacting on the condition of river surrounding environment [2]. Sediment flow rate is estimated using Meyer-Peter & Muller (MPM) method with the assumption that the research was taken place in Bengawan Solo River, the sedimentation transportation of which was estimated using MPM method [3].

Meyer-Peter & Muller's equation is as follows:

$$q_s = \phi \, . \, (\Delta \, . \, g . \, {d_m}^3)^{1/2} \qquad (1)$$

where:

q_s = sediment flow rate per m ($m^3/m/s$)
Δ = (sediment density –water density)/water density (kg/m^3)
d_m = median diameter of grains (m)
τ_{cr} = critical tension (N/m^2)
C = Chezzy Coefficient ($m^{1/2}/s$)

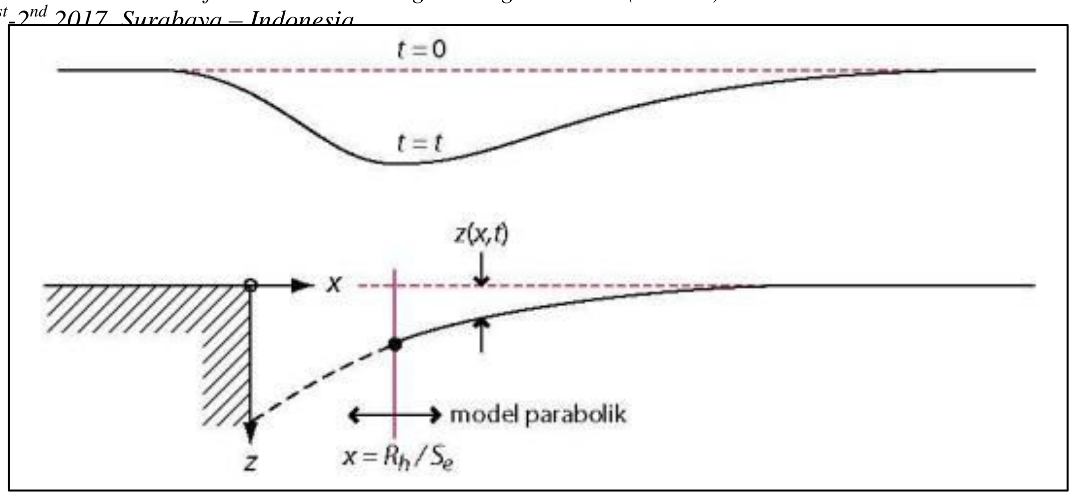

Figure 1. Parabolic model in degradation problem

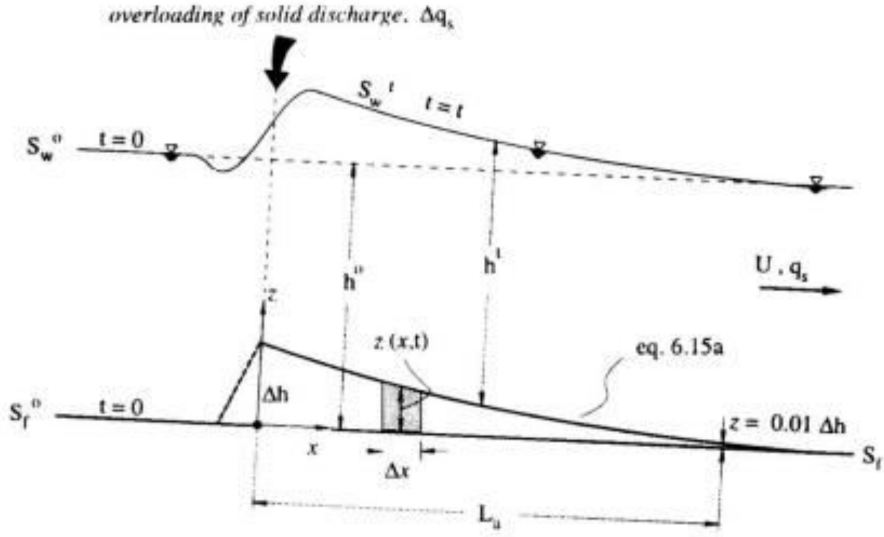

Figure 2. Parabolic model in aggradation problem

v = mean flow speed (m/s)

where

$u^* = \sqrt{g\,h\,I}$

$$\delta = \frac{11{,}6\;x\;v}{u^*}$$

$$K_s = D_{65}\;s/d\;D_{90},$$

If $K_s > 6\,\delta$

the Riverbedbelongs to coarse hydraulics

If $K_s < 0{,}3\,\delta$

the Riverbedbelongs to smooth hydraulics, then

$$(v) = 5{,}75\,.\,u^*.\log\frac{42\,h}{\delta}$$

$$\tau_o = \rho_w.g.h.i$$

$$R_e = \frac{u^*.d}{v}$$

$$\Psi_{cr} = \frac{\tau_{cr}}{\Delta.\rho_w.g.D}$$

$$\tau_{cr} = \Delta.\;\rho_w.g\,.d_m\,.0{,}4$$

If $\tau_o > \tau_{cr}$, the grains of Riverbedis immovable, there is sediment transportation

$$C = \frac{v}{(h.i)^{1/2}}$$

$$C' = 18\;\log\frac{12.\;h}{d_{90}}$$

$$\mu = \left(\frac{C}{C'}\right)^{3/2}$$

$$\Psi' = \frac{\mu\,.\;h.\;i}{\Delta\,.\;d_m}$$

$$\phi = (4.\;\Psi' - 0{,}188)^{3/2}$$

2. Parabolic Model Analysis

Degradation and Agradation process is a long-term process of riverbe devolution z(x,t). The river stream consists of quasi-steady and non-uniform flows. Parabolic analysis model based on Sain-Venant-Exner equation is used in estimating degradation and agradation with Froude score < 0.6, so that it can be found that degradation and agradation occurs on distance and in certain period of time parabolically.

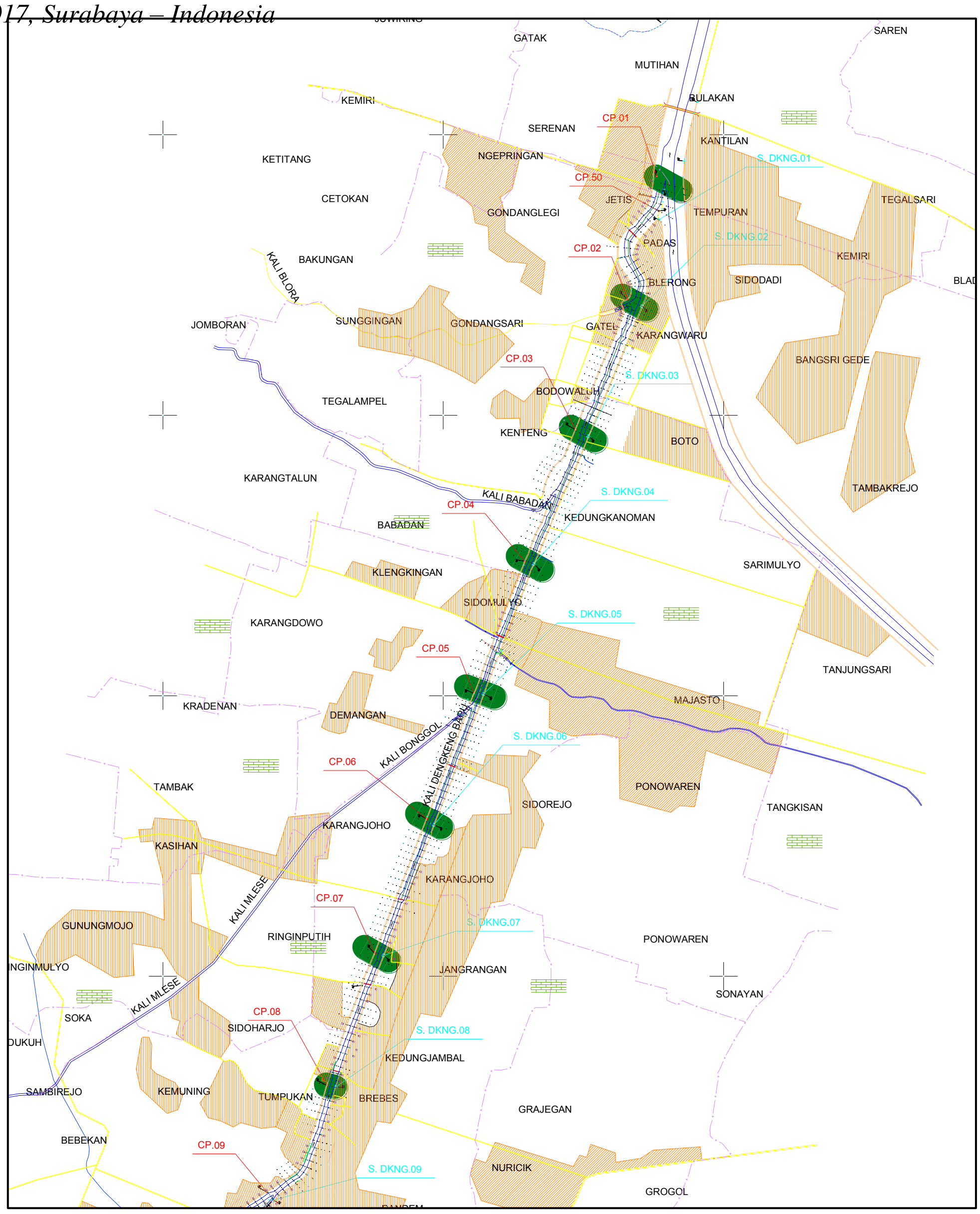

Figure 3. Research Location

Parabolic model used in degradation and agradation problems is as follows:

In degradation and agradation problems like the parabolic model above, x-axis follows the prior riverbed positively to the downstream. Z-axis shows the positive variation of riverbed downward.

The parabolic model equation is as follows :

$$\frac{\partial z}{\partial t} - K\,\frac{\partial^2 z}{\partial x^2} = 0 \qquad (2)$$

Prior and threshold conditions of equation above is :

$$z(x,t) = \Delta h\, erfc\, \frac{x}{2\sqrt{Kt}}$$

to find the time between degradation or agradation prior process and certain degradation depth or elevation, degradation depth or agradation elevation simulation is required occurring on point L = 6.R/Se. Time between degradation or agradation prior process and the achievement of Riverbed elevation on certain point can be estimated using the following formula:

$$t \cong \frac{x^2}{4Y^2K} \cong \frac{x^2}{1{,}44\,K} \qquad (3)$$

Degradation dept occurring (Δh), at time (t) can be estimated with the formula below:

$$\Delta h = \frac{q_s\,.\Delta t}{1{,}13\,(1-\rho)\sqrt{K.t}} \qquad (4)$$

Where :

z (x,t) = Riverbed elevation (m)
q_s = degradation flow rate occurring m^2/s
x = distance, position (m)
t = time (year)
Δh = degradation depth occurring (m)
K = coefficient of diffusion

Table 1. The result of sediment flow rate estimation for Karangjoho-Jetis segment of Dengkeng River in 8 km length

Location	Sediment flow rate (m^3/m/s)	Category	Difference
point. 1	0,000590816		
		aggradation	0,00000524
point 2	0,000585573		
		degradation	-0,00102738
point 3	0,001612955		
		aggradation	0,00136968
point 4	0,000243273		
		aggradation	0,00002506
point 5	0,000218214		
		degradation	-0,00179930
point 6	0,002017513		
		aggradation	0,00169201
point 7	0,000325499		
		degradation	-0,00040767
point 8	0,000733168		

Table 2. Profile of riverbed when aggradation occurs within 10 years

x (m)	x. Sc/Rh	Y= x/(2 . K. t) $^{1/2}$	z /delta h = erf Y	z
10000	1,479	0,209	0,767	0,136
12000	1,775	0,251	0,723	0,128
14000	2,070	0,293	0,679	0,121
16000	2,366	0,335	0,636	0,113
18000	2,662	0,376	0,594	0,106
20000	2,958	0,418	0,554	0,099
22000	3,253	0,460	0,515	0,092
24000	3,549	0,502	0,478	0,085
26000	3,845	0,544	0,442	0,079
28000	4,141	0,586	0,408	0,072
30000	4,436	0,627	0,375	0,067
32000	4,732	0,669	0,344	0,061
34000	5,028	0,711	0,315	0,056
36000	5,324	0,753	0,287	0,051
38000	5,619	0,795	0,261	0,046
40000	5,915	0,837	0,237	0,042

where: $K = \frac{1}{3} b_s q_s \frac{1}{1-\rho} \frac{1}{S_e}$
ρ = porosity
S_e = energy line inclination (flow inclination)

The case study was taken place in Dengkeng River, 8-km long, spreading out from Karangdowo Sub District, Klaten Regency to Jetis Village, Sukoharjo Sub District, Sukoharjo Regency constituting subcritical quasi-steady flow with Froude score < 0.6. Dengkeng River flows into Bengawan Solo with ± 45 km length and DAS width of 782,60 km^2 passing through Tawang Sari, Karangdowo, Cawas, Trucuk, and Bayat Sub Districts located in Klaten and Sukoharjo Regencies, with Kali Gawe, Kali Bonggol, Kali Sungapan, and Kali Kebo streams.

The original measures taken in this research was to collect secondary data in the form of flow rate data and topography measurement obtained from the report of "Studi Morfologi Sungai Dengkeng tahun 2015 in BBWS Bengawan Solo and primary data by taking sediment sample. Dengkeng River segment is divided into 8 points in 1-km distance. Sample sediment would be taken from each point in the form of input data to estimate sediment flow rate using Meyer-Petter-Muller's method so that degradation and agradation processes occurring could be found out. The sediment sample taken was measured for its diameter grain using grain size analysis by taking d_{35}-d_{90} grains. The instruments used to take sediment included: ruler (*rambu ukur*) and the tool to take the bottom sediment sample (hoe/scoop/etc).

Table 3. Profile of riverbed when degradation occurs within 7 years

x (m)	x. Sc/Rh	Y= x/(2 . K. t) $^{1/2}$	z /delta h = erf Y	z
10000	0,80794702	0,301249937	0,670084714	0,20
12000	0,969536424	0,361499924	0,609184346	0,19
14000	1,131125828	0,421749911	0,550878357	0,17
16000	1,292715232	0,481999899	0,495459789	0,15
18000	1,454304636	0,542249886	0,443166457	0,14
20000	1,61589404	0,602499873	0,394178853	0,12
22000	1,777483444	0,662749861	0,348619772	0,11
24000	1,939072848	0,722999848	0,306555576	0,09
26000	2,100662252	0,783249835	0,267998943	0,08
28000	2,262251656	0,843499823	0,232912891	0,07
30000	2,42384106	0,90374981	0,201215848	0,06

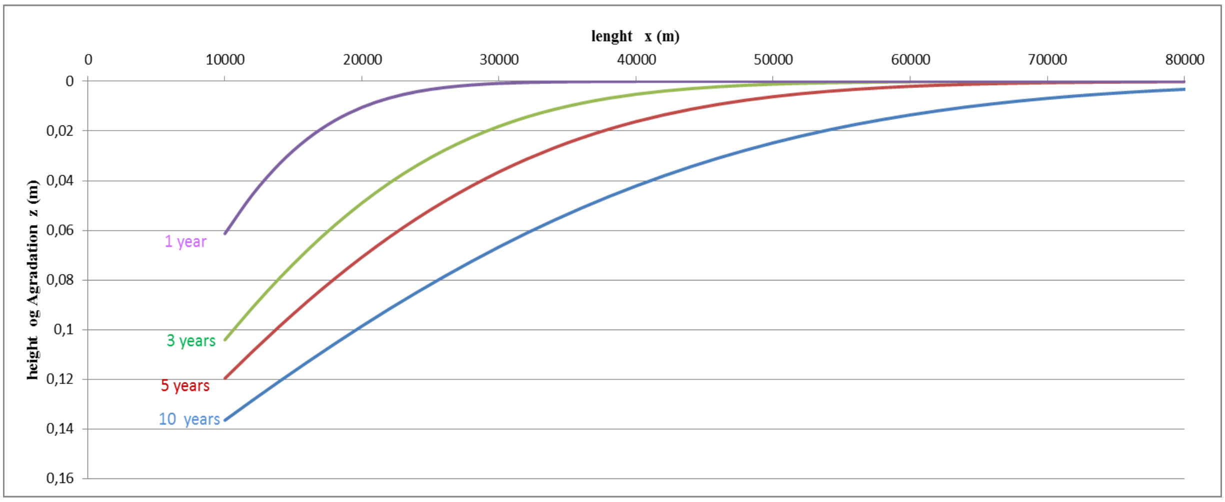

Figure 4. Parabolic chart of aggradation elevation occurring

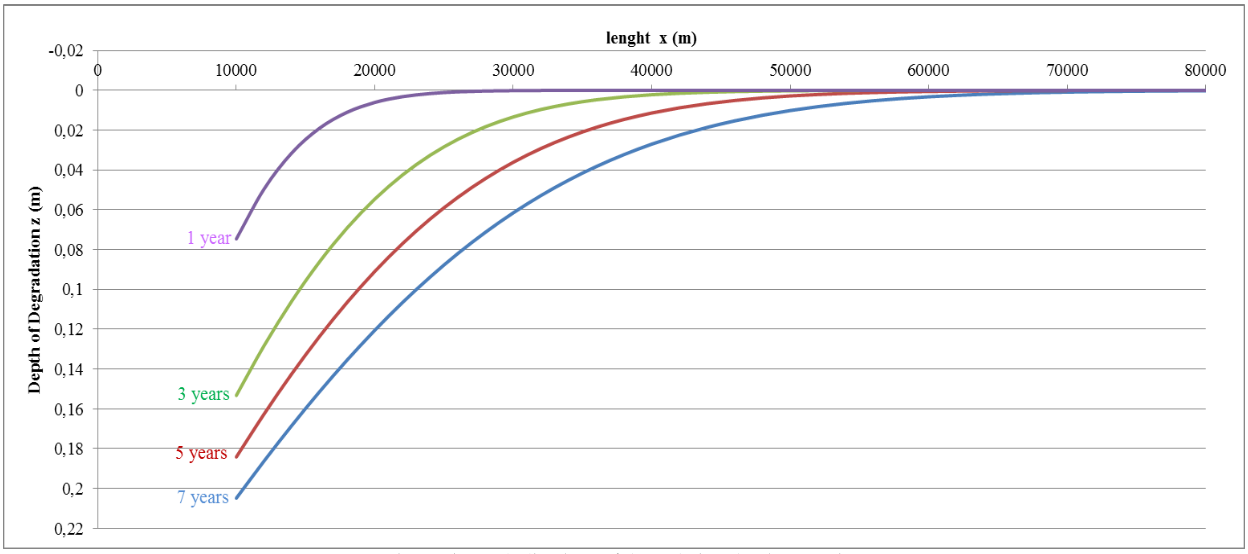

Figure 5. Parabolic chart of degradation depth occurring

Then, after degradation and agradation occurring has been found, its depth and elevation in certain distance and certain period of time using parabolic model analysis. Parabolic model analysis is conducted by making time simulation needed when achieving agradation elevation and degradation depth. The time resulting from simulation will show agradation and degradation occurring at elevation in certain distance. This estimation result will be the input in recommending the management of riverbed layer that can help maintain the stability of river bottom.

II. RESULT AND DISCUSSION

From Dengkeng River segment spreading out from Karangjoho to Jetis in 8 km length, divided into 8 sediment sampling points, it can be found that out of 7 segments studied, 4 segments encounter agradation: segments 1 (between points 1 and 2), 3 (between points 3 and 4), 4 (between points 4 and 5), and 6 (between points 6 and 7). Agradation and degradation processes occurring are estimated using Meyer-Petter-Muller method producing the mean score of sediment supply surplus (agradation) of 1,113 m^3/m/day and the sediment supply deficiency (degradation) of 1,552 m^3/m/day. The estimation of sediment flow rate on every point in Karangjoho-Jetis segment of Dengkeng River can be seen in the table below:

Meanwhile, the result of parabolic model analysis with agradation elevation simulation occurring on point 40,000 m takes 10 years between agradation prior process and the achievement of riverbed elevation when agradation occurs. Agradation elevation occurring is 0,18 m within 10 years.

The similar calculation is made to estimate the degradation depth occurring with depth simulation occurring on point 28,000 m taking 7 years between the process and the achievement of riverbed elevation when degradation occurs. Degradation depth occurring is 0.31 m within 7 years.

These two simulations are made for 1 year, so that agradation elevation or degradation depth occurring annually in Karangjoho-Jetis segment of Dengkeng River can be found. The profile of riverbed when agradation occurs within 10 years can be seen in table 2, while that when degradation occurs within 7 years can be seen in table 3. Parabolic chart produced for agradation and degradation process can be seen in Figures 4 and 5.

IV. CONCLUSION

From the discussion above, the following conclusions can be drawn:

1. From the calculation of sediment flow rate occurring using Meyer-Petter-Muller method, it can be found that Karangjoho-Jetis segment of Dengkeng River in 8 km length experiences agradation on segment 1 (between points 1 and 2), 3 (between points 3 and 4), 4 (between points 4 and 5), and 6 (between points 6 and 7) with the mean score of sediment supply surplus (agradation) of 1,113 m3/m/day and the sediment supply deficiency (degradation) of 1,552 m3/m/day. It indicates that the Karangjoho-Jetis segment of Dengkeng Riverbedis unstable with the assumption that the segment encountering agradation is more than those encountering degradation (imbalanced).
2. Parabolic chart shows based on that the longer the river segment length, the less are the agradation elevation and degradation depth occurring. The mean agradation elevation and degradation depth occurring will decrease by 1 cm annually.
3. The time between prior agradation or degradation process occurring and the achievement of bottom elevation when agradation or degradation occurs on point L is highly determined by the elevation of simulated agradation or degradation.

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VI. REFERENCES

[1] N. Suwartha, "Kajian Hidrologis Pola Sedimen Sungai Progo Bagian Hilir," Universitas Gadjah Mada, 2001.

[2] I. Suhardjo, "Degradasi Dasar Sungai, Journa Teodolita," *J. Fak. Tek.*, 2008.

[3] N. Y. N. Hidayah, "Kajian Angkutan Sedimen Pada Sungai Bengawan Solo (Serenan-Jurug)," *ejurnal matriks Tek. sipil*, 2013.

[4] Nur Hidayah Y.N., dkk, 2013, Kajian angkutan sedimen pada sungai bengawan solo (serenan-jurug), ejurnal matriks teknik sipil/juni 2013/69 sitasi tanggal 16 september 2015

[5] Tiny Manonama, 2004, Pengenalan Sistem Pendukung Pengambilan Keputusan di Bidang Pengelolaan Sedimen Sungai, PIT XXI, Kongres VIII, HATHI-BALI

[6] Istiarto, 2007, Degradasi Agradasi Sungai, Jurusan Teknik Sipil FT UGM, Yogyakarta

[7] US Army Corps of Engineering, 1995, Engineering and Design Sedimentation Investigation of River dan Reservoirs, EM 1110-2-4000, Departement of Army., Washington, D.C.20314