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Study on Various Measures for Flood in Specific Region: A Case Study of the 2008 Lao Flood

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***Abstract*—**In recent years, the number of natural disasters in Laos has a trend to increase, especially the disaster of flood. To make a flood plan risk management in the future, it is necessary to understand and analyze the characteristics of the rainfall and Mekong River level data. To reduce the damage, this paper presents the flood risk analysis in Luangprabang and Vientiane, the prefecture of Laos. In detail, the relationship between the rainfall and the Mekong River level has evaluated and appropriate countermeasure for flood was discussed.

***Keywords*—**Lao Flood; Mekong River; Rainfall, Risk Management.

I. Introduction

IN recent year, flood has occurred frequently in Laos,and it'sclosely associated with global warming and climate change.The flood damage has serious impact on environment, social and economic development and so on. According to the Asian Disaster Reduction Center country report a number of deaths due to floods in Laos from 2000 to 2003 in 3 years are 17 people and the total number of victims has reached more than one million people[1].

According to the Typhoon Vongfong on August 14, 2008 it was raining heavily in the upper Mekong River, Luangprabang prefecture was flooded on 16th and the Mekong River level on 18th was exceeded a warning level of the Vientiane capital at 12.5m, after reached the warning level the value continued increase.In addition, the water level of Mekong River had swollen and great damage to plural prefectures due to the heavy rainstorm which struck the Indonesian Peninsula in early August 2008.

After reached the warning value at 17.5 m on 9August Mekong River level has raised rapidly in the Luangprabang observation Station, and the River level has reached a peak at 20.38m on 13th August. After reached the warning value at 20.38m on 11th August, after 2days delay from the Luangprabang the river level continues and increased quickly at 11.5m on 11th August in the Vientiane observation Station and recorded a peak level at 20.38m on 15August. The flood was killed 5 people, 565 villages were damaged, and 151,020 of people were affected [2], [3], [4], [5].

The Mekong River is a headstream of the China Tibetan plateau which runs through Burma, Laos, Thai, Cambodia and China and flowing about 4,500 square kilometers from southeast China to the South China Sea though southern Vietnam. The Mekong River passes North through South and approximately 85.5% of the land belong to the Mekong River basin. The total of area basin is about 795,000 km^2 and the total length is 1,850km in the Laos alone [6].

Lao have been badly affected by heavy rain and floods as describe above but the flood control is not progressing much and the embankment also has not been well developed.

To increase the flood countermeasures which suit for the Country's regional status and economic situation, the possible future flood prediction, an estimate accuracy of water work engineering plans for water volume, data marshalling and require understanding nature of the previous data of the Mekong River level data, rainfall data, statistical nature and variation over time are needed.

II. Laos Overview

Lao PDR is a landlocked country which has a total area of 236,800 square kilometers in the center of the Southeast Asian peninsula and divided into 18 political provinces, and has borders with the people's republic of China, Cambodia, Thailand, Vietnam and Burma. Laos has a population of 6.38 million people and the average population density is 26.7 per square kilometer (2011) [6]-[8].

A. Vientiane Capital

Vientiane prefecture is a capital of Lao PDR located on a curve of the Mekong River which has a total area 3,920 km^2.

The prefecture is subdivided in to 9 districts include Sikhottabong, Chanthabouly, Sisattanak, Xaysettha, Naxaithong, Xaythany, Hadxaifong, Sangthong and Park Ngums. The Vientiane prefecture has a population of 783,032 people (2011) with density about 176 per square kilometer (2004).

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Fig. 1 Location of Vientiane Capital and Luangprabang province

B. Luangprabang Province

Luangprabang Province is the world heritage town located in the Centre of northern Laos which has area about 16,875 square kilometers. Luangprabang has a total population of 455,532 with average population density about 24 per square kilometer (2011).The prefecture is subdivided in to 11 districts include Chomphet, Luangphrabang, Nambak, Nan, Ngoi, Pak Xeng, Park Ou, Phonxay, Phoukhoune, Viengkham, XiengNgeun. Fig.1 shows a location of Vientiane capital and Luangprabang province.

III. Flood Prevention Activities on the 2008 Lao Flood

A. Sandbag (Anti-Erosion Work)

To protect the Vientiane capital from the great flood on September 2008, the Lao government had mobilized all government official stuffs, students, polices, militaries, local residents to pile up sand bags 19km length from Bo-O district to Kaoliewdistrict [5]. Fig.2 (a) to (d) shows a situation of sandbag bank on the 2008 great flood in Laos.

(a) Packing sand bag situation* (1)

(b) Packing sand bag situation* (2)

(c) Packing sand bag situation* (3)

(d) Sand bag bank*

Fig. 2 Sand bag bank flood protection (a)-(d) (2008 Lao flood)*

*Association of Japanese Residents in Lao P.D.R. Newsletter, September, 2008.

B. Sheet-Flood

To prevent soil erosion on the bank at Shibuanghuang district the sheet-floods are used [5]. Fig.3 shows a situation of erosion control work using sheet flood.

Fig. 3 Sheet-Flood erosion control work situation*

*Association of Japanese Residents in Lao P.D.R. Newsletter, September, 2008.

C. Drain Pump

To drainage behind levee at Thadua Street KM4 district the single engine was used and minimized inundation damage [5]. A location of drain pump is shown in Fig. 3.

Fig. 4 Location of drain pump*

*Association of Japanese residents in Lao P.D.R.newsletter, September, 2008.

IV. Rainfall and Mekong Level Data

This paper used rainfall data from the Department of Meteorology and Hydrology of Lao (DMH) and Mekong River level data obtained from the Mekong River Commission (MRC) [2]. This paper focused on the Vientiane Capital and the town of world heritage Luangprabang.

V. Analysis Result and Discussion

A. Rainfall

1. Vientiane Capital

Fig. 5 to Fig. 7 shows the 58 years of distribution of annual maximum rainfall, transition of annual rainfall mean monthly rainfall of the Vientiane capital respectively. According to the Fig. 5 the annual maximum rainfall of 1day, 3days and 7days are the largest values which are 224 mm, 263 mm and 328 mm respectively but it is a very rare case most values are shown between 50mm ~ 200mm.In addition, most values of the yearly rainfall are shown between 1,000 mm ~ 2000 mm. Looking at monthly rainfall on Fig. 7 the values start from 50mm in January and increase rapidly in May, after reached a peak in August at 260 mm the rainfall tend to decrease rapidly.

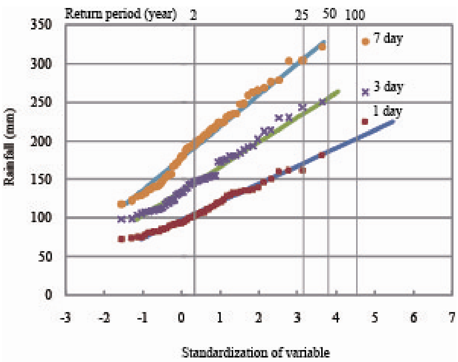


Fig. 5 Annual maximum rainfall (Gumbel Distribution), (Vientiane, 1951-2008)

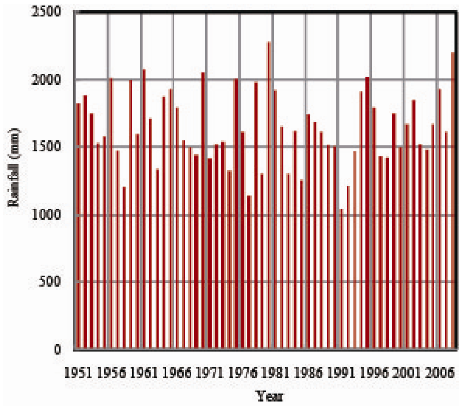


Fig. 6 Transition of annual rainfall (Vientiane, 1951-2008)

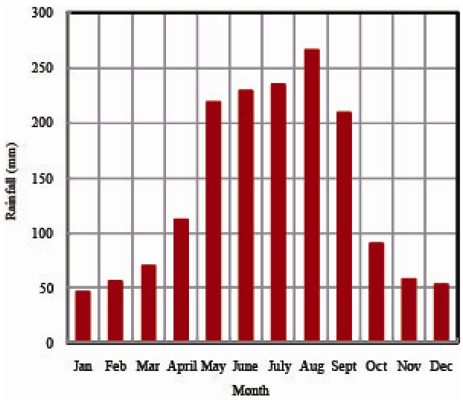


Fig. 7 Average monthly of rainfall (Vientiane, 1951-2008)

2. Luangprabang Prefecture

According to the Fig.8 the annual maximum rainfall of 1day, 3days and 7days are the largest values, which are181 mm, 287 mm and 305 mm respectively, the trend is similar as the Vientiane capital's, most values are shown between 50mm ~ 200mm, the yearly rainfall value are shown between 1,000 mm ~ 1500 mm. Looking at monthly rainfall on Fig.10 the values start from 50 mm in January and increase gradually, after reached a peak in august at 220mm the trend decreases little by little. The 58 years of the mean monthly values of annual maximum rainfall and the transition of annual rainfall of the Luangprabang are shown in the Fig. 8 to Fig. 10.

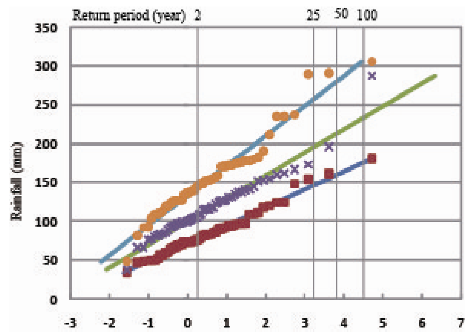


Fig. 8 Annual maximum rainfall (Gumbel Distribution) (Luangprabang, 1953-2008)

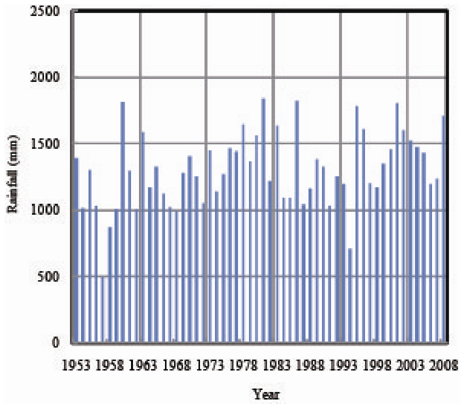


Fig. 9 Transition of Annual Rainfall (Luangprabang, 1953-2008)

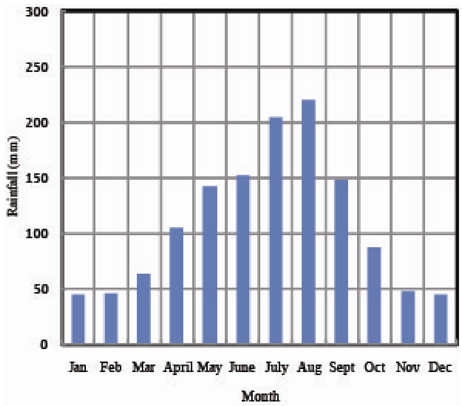


Fig. 10 Average monthly rainfall (Luangprabang, 1953-2008)

3. Return Period of Rainfall

The Estimate of R year Return Period of Rainfall data is calculated from the formula (1) which follows theGumbel distribution. The results are shown on the Fig.3.1 and Fig.4.1 respectively.

$$x(r) = \mu + \{0.78\ln(r) - 0.45\} \times \sigma \quad (1)$$

μ: Averagevalue; σ: Standard deviation; r: Return period

Based on the computation results the estimate values of 3days and 7days are higher than 1day about 1.38 times and 1.86 times respectively for the Vientiane capital. Also, for the Luangprabang, the estimate values of 3days and 7days are higher than 1day about 1.34 times and 1.76 times respectively. The calculated results of the estimate value of rainfall are shown in Table I.

B. Mekong River Level

1. Warning Value and Dangerous Value

The department of meteorology and Hydrology determined a dangerous value and a warning value of Mekong river level of Laos as below [3]. Table II shows the warning value and dangerous value of Mekong river level in Luangprabang and Vientiane Capital.

TABLE I
ESTIMATE OF R YEAR RETURN PERIOD OF RAINFALL

Return Period (Year)	Estimate Value of Vientiane$x$ (m)			Estimate Value of Luangprabang x (m)		
	1day	3day	7day	1day	3day	7day
25	1.72	2.37	3.21	1.46	1.95	2.57
50	1.88	2.59	3.52	1.62	2.15	2.84
100	2.04	2.81	3.83	1.78	2.36	3.11
200	2.20	3.03	4.15	1.94	2.56	3.37

TABLE II
WARNING VALUE OF MEKONG RIVER LEVEL**

	Warning Value (m)	Dangerous Value (m)
Luangprabang	17.5	18.0
Vientiane Capital	11.5	12.5

** The Department of Meteorology and Hydrology

2. Mekong River Level

(1) Mekong River Level of Vientiane Capital

Fig.11 to Fig.12 shows the 98 years of annual maximum Mekong level and monthly average respectively. Based on the Fig.11 the annual maximum value of the Mekong river level of Vientiane exceeds the warning value which determined by DMH almost every year in the past 96 years. Looking at monthly level the values start from 2,000 mm in January and after reached a peak in August at 12,000 mm the trend decreases gradually. This transition can be considered 2 to 3 months late increase as compared with a change in the amount of precipitation. It will be different from the country with a small temporal difference on rainy season and rainfall such as Japan, should suggests the possibility of different on countermeasure plan. The average yearly of Mekong river level by each year is shown between 3,000 mm ~ 6000 mm.

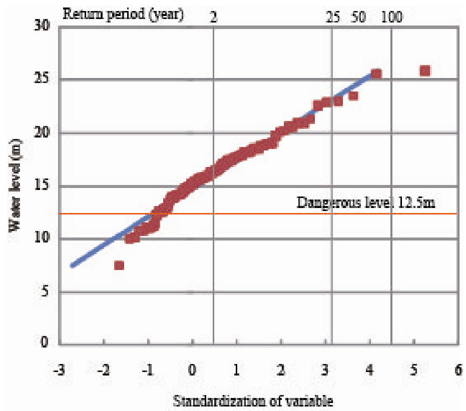


Fig. 11 Annual maximum Mekong Level (Gumbel Distribution)(Vientiane, 1913-2008)

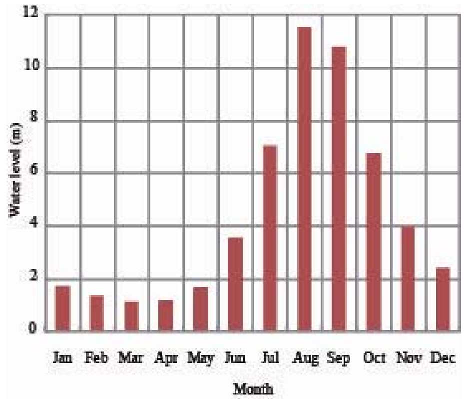


Fig. 12 Average monthly Mekong Level (Vientiane, 1913-2008)

(2) Mekong River Level of Luangprabang Province

The 70 years of annual maximum value and monthlyaverage respectively of the Luangprabang are shown in the Fig.13 to Fig.14.According to the Figure, the annual maximum value of the Mekong River level of Luangprabang exceed the warning value which determined by DMH 19 time in past 70 years. The average of the river level by each year is shown between 3,000 mm ~ 5000 mm with the exception of the mean of the river level on a year 2002 to 2008. The average of river level of Luangprabang is increasing sharply only the last few years. Looking at the average monthly of river level in Fig.14, the values start from 200mm in January and after reached a peak in August at approximately10,000mm the value tend to decrease slowly.

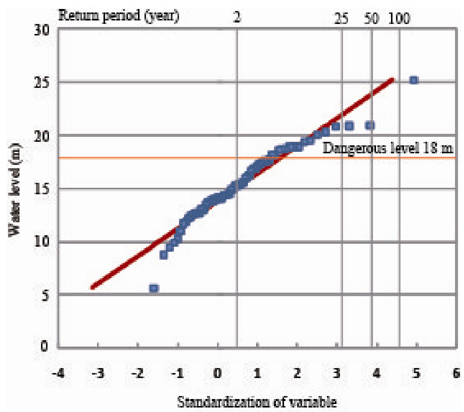


Fig. 13 Annual maximum Mekong Level (Gumbel Distribution)(Luangprabang, 1939-2008)

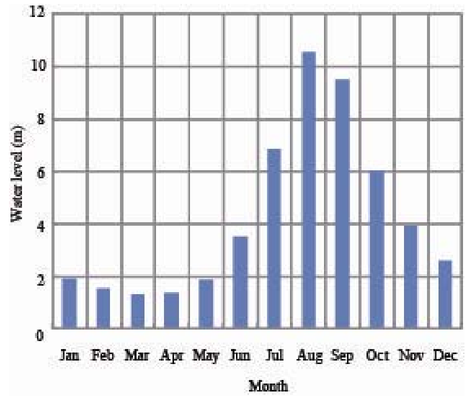


Fig. 14 Average monthly Mekong Level (Luangprabang, 1939-2008)

(3) Frequency

Fig.15 to Fig.16 shows the 96 years and 70 years, of the frequency count which exceed the monthly dangerous value of river level of Vientiane capital and the Luangprabang respectively. Based on the figure, the exceed numbers are76 times which the most often that has been observed on August. According to the statistics the numbers are 183 times in the past 96 years. On the other hand, a number which exceed dangerous values are 19 times in total of the 70years record of Luangprabang.

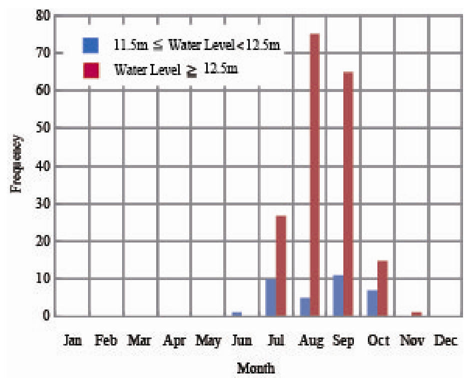


Fig. 15 Frequency of Exceed Dangerous Value (Vientiane, 1913-2008)

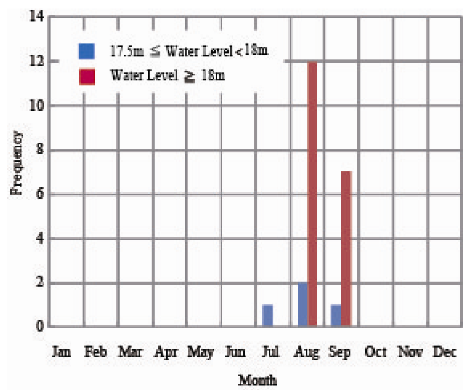


Fig. 16 Frequency of Exceed Dangerous Value (Luangprabang, 1939-2008)

(4) Return Period of River Level

The Estimate of R year return period of river level also calculated from the formula (1) which follows the Gumbel distribution. The calculated results are shown in Table III. Base on the table, the estimate value of Vientiane is a little bit higher than the Luangprabang's value.

TABLE III
ESTIMATE VALUE OF RETURN PERIOD OF RIVER LEVEL OF LUANGPRABANG AND VIENTIANE CAPITAL

Return Period Year	Estimate Value$x$ (m)	
	Vientiane Capital	Luangprabang
25	23.30	22.17
50	25.15	23.97
100	26.99	25.77
200	28.83	27.56

(5) Relationship between River Level and Rainfall

The rainfall values weren't so big in throughout the year but when we look at the monthly results the rainfall values and river level values reached a peak on August and October. Therefore, these months are subject to flood.

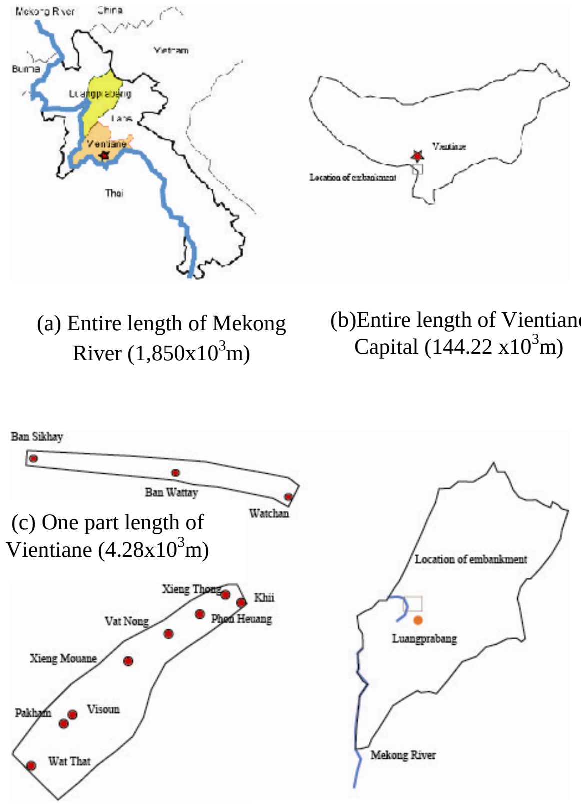
VI. FUTURE FLOOD CONTROL

According to the above results, building a monthly plan is more effective in flood disaster prevention in the future for Laos. Next, we have made a comparative review of the various measures which actually done in Japan and various countries. In particular, embankment measure, ring levee measure, sandbags measure, moving to high land measure, Aquadam measure which used for flood control in America.

A. Embankment and Ring Levee Measure

A scale of Chikumagawa River Embankment of Nakano City Yanazawa District has a length 760 meters and a construction cost is more than 22 billion yen about 2,895,000 Yen(38,208US$,1Yen=0.0128$) per meter[8], [9]. We used the cost to calculated and measure the entire length of Mekong River, the length of part of Vientiane Capital which connect with Mekong River coast, the entire length of Luangprabang Prefecture and the length of part of Vientiane Capital, and divided in to 5 cases to calculate the construction cost for build the embankment. The length is 1,850 x10^3m, 568.22 x10^3m, 6.322 x10^3m, 144.22 x10^3m, and 4.28x10^3m respectively. Fig. 17 (a) to (e) shows a location and desired length.

A place which we enclosed one part of the river of Vientiane Capital the river is a place which floods occur frequently and have area about 0.62x10^6m^2. For a place which we enclosed one part of Luangprabang prefecture both sides are surrounded by the river and it is a place where historic temples are gathered and have area about 0.878 x10^6 m^2.



(a) Entire length of Mekong River (1,850x10^3m)

(b)Entire length of Vientiane Capital (144.22 x10^3m)

(c) One part length of Vientiane (4.28x10^3m)

(e)One part length of Luangprabang Province (6.33x10^3m)

(d)Entire length of Luangprabang Province (568.22 x10^3m)

Fig. 17 Location and desired length (a)-(e)

B. Sandbag Embankment and Aqua Dam Flood Control

The result of the comparison between the Aqua Dam which used for flood control in America and equivalent dike witch built by Sandbags are as below. For build Sandbag embankment which has scale 0.95m x 30.48m, 3,400 pieces of sandbag are needed. In that, one of sandbag cost is about 3$, the cost is about 10,200$. Meanwhile, if used Aqua Dam Flood control the cost one fourth cheaper and can safe time about 220 minutes, the number of labor 2.5 times difference. However, when used the cost in Laos, 1 sand bag is about 0.5$[11], the total cost is about 1,385US$(including labor cost), compare with the cost in America 7.5 times different. The cost is 2 times as expensive as that used Aqua Dam. Table IV shows the cost comparison of Sandbag embankment and Aqua Dam flood control. Fig. 18 shows example of Aqua dam which used for flood protection.

TABLE IV
SANDBAG EMBANKMENT AND AQUA DAM FLOOD CONTROL

Measure	Height x Length (m)	Labor (People)	Built Time (Minutes)	Cost (US$)
Sandbag	0.915x30.48	5	240	10,200
Aqua Dam	0.915x30.48	2	20	2,816

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(a) Storage situation* *

(a) Actually used situation **

Fig. 18 Example of using Aqua Dam (a)-(b)

C. Moving to High Land Measurein Aounae District, Hokkaidou Prefecture

On the Hokkaido Nansei-Oki Earthquake the damage caused by Tsunami was great especially in Aonae District to recover a part of district was moved to high land. An average total of construction cost of housing in Japan is 23,696,000 Yen per one house (303,309US$). it can be assumed If we moved one part of Vientiane Capital about 22 household the cost is 521,312,000 Yen (6,672,794 US$). For moving 5 households of one part of Luangprabang District the cost about 118,480,000 Yen (1,516,544 US$), the exchange rate 1Yen=0.0128$, rate on 3October2012 [11], [13].

D. Estimate Value and the Height of the Embankment

The great flood of 2008, flood level of Luangprabang city was 2.38 m approximately to 12.4 years. Flood level of Vientiane capital is 1.17 m approximately to 1.3 years. In this study we had calculated and compared the estimate value for the return year, for build embankment which approximately to flood level of 25 years, 10.8 m height for Vientiane capital and 4.2 m height for Luangprabang city respectively is needed for embankment height. Sand bag measure and Aqua Dam measure is has a height limit at 2m, if we used 25 years return period we have to find other measures which capable with 8 meters height and 2 meters height of flood level. Combine with a stilted house is more realistic.

We used various measures and the result was compared as shown in Fig. 19. The cost of Sand bag measure about 94 times, 400 times for Aqua Dam measure. In fact, we could not build the embankment the entire length of the Mekong. In totality, moving to height land measure it looks cheapest, be thought to be the scale of village was small. If Village is big the cost will expensive. The Aqua Dam flood control can reuse and size of 1.2mx30.48m can be stored 90m^{3}of water. Moreover, built time and number of labors is smaller than sand bag measure. Therefore, for 2 meters height of embankment Aqua Dam flood control is the most efficient and economical measure.

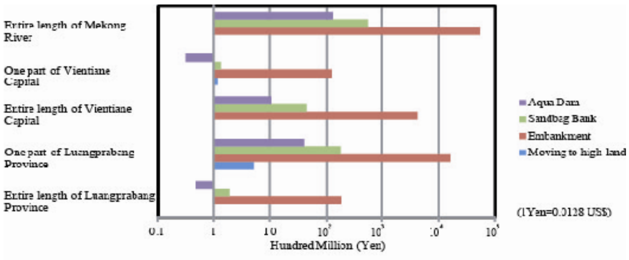

Fig. 19 Comparison cost of different measure

VI. Conclusion

In this study, the authors marshal the Mekong River level data and rainfall data and clarify the relationship between the two. The Vientiane capital is a flatland therefore floods occur easily, the authors found that the water level exceed the dangerous level almost every year. Furthermore, the highest rainfall in August and the September as well as the Mekong River level also reaches a peak, it is a season that flooding occur easily. According to the data, should store all crops to high place and cultivation of crops should finish on July. In addition, if we prepared pack sandbags it might reduce the damage from flooding. According to the result of comparison various measures, comparing the sandbag bank and the AquaDam flood control the difference is 4.3 times in cost, the Aqua Dam is cheaper. The Aqua Dam flood control is can re-use and considered to the most efficient measure.

To build 1,850 kilometers embankment for Laos's economic situation is impossible. As for second best measure the ring measure is realistic, it might be said that use combination with the Aqua Dam flood control measure is the most economical and efficient. The Aqua dam usually can stored we considered that to protect the heritage town as the Luangprabang city the Aqua Dam flood control measure is realistic and the most economical method.

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REFERENCES

[1] Asian Disaster Reduction Center (ADRC) Country report.
[2] Mekong River Commission.
[3] The Department of Meteorology and Hydrology: of Laos.
[4] Vientianemai Newspaper News.
[5] Association of Japanese Residents in Lao P.D.R, Magazine2008Year, Vol 9.
[6] http://www.ajrl.la/ajrl/k-200809/column-1.html
[7] Wikipedia: http://ja.wikipedia.org/
[8] Data Book of the World 2007, Vol.19
[9] Chikuma Rriver Office http://www.hrr.mlit.go.jp/chikuma/news/tayori/nakano/090413nakano.html
[10] http://www.bousai.go.jp/hnj/oline.htm http://www.s-housing.jp
[11] WajuTakasu: http://homepage1.nifty.com/fuufuyuuyuu/sub20/hiratatyou.htm
[12] Aquadam and sand bag: http://www.aquadam.com; http://www.waterstructures.com/
[13] Vientiane Urban Development at Ministration Authority of Vientiane Capital.