HYDROLOGICAL PROPERTIES OF BRIBIN UNDERGROUND RIVER SYSTEM (Experience learned for Seropan River System Project)

by

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ABSTRACT

This paper is principally aimed to express some hydrological aspects regarding to the 2006-2007 time series investigation within Bribin River system. The concept of karst watershed and the Bribin System historical review is firstly presented in order to give the understandable viewpoint with reference to hydrological investigation conducted in this site. Afterwards, this paper illustrates some aspects of 2006-2007 Bribin System investigation such as site selection, equipments, measurements, and spatial-temporal results on discharge fluctuation, karst flow component ratio, and rainfall intensity. Lastly, this paper also evaluates the 2006-2007 investigation constriction and gives some recommendations related to the next Seropan River System study.

INTRODUCTION

In hydrology point of view, karst aquifer is characterized by the domination of underground stream that consequences to the lack of surface drainage pattern. This uniqueness is controlled by limestone geological structure (Blair, 2004). Structure is used here in the structural geologic sense and is concerned with the attitude and deformational effects of bedrock. Limestone near the surface has a propensity to be deformed by brittle fracture. As consequences, it forms complex joint sets is directly responsible for the secondary permeability or fracture required for the development of subsurface solution drainage.

For surface hydrologists, the “*unidentified*” fractured within subsurface system is considered as the primary problem to apply the watershed water balance equation. In addition, the concept of single water outlet and accurate recharge area are impracticable to be defined in karst area. Figure 1 is then illustrates the different concept between the **surface** and **karst** watershed area (Haryono and Adji, 2004)

According to Figure 1 (left) it appears that the boundary of the watershed is undoubtedly defined. In surface stream, the border line is characterized by the highest elevation topography, so that the entirely precipitation falls inside this boundary and flow out into only **single outlet**. On the other hand, we can not consider that the highest topography within karst conical as a catchment boundary since the flow direction within karst aquifer is largely controlled by the conduit pattern within conical. Also, it is impossible to find only single outlet or spring within karst limestone. In practical, some karst researches seem to define the area of karst watershed, especially within insoluble dolomite karst aquifer like occur in Central Europe. However, in Bribin area where the calcite limestone is very soluble and also supported by the occurrence of million of joint and fracture systems (present by tectonic force), it seem not achievable to exactly define the catchment area of Bribin or Seropan. However, approaching topographical aspect such as elevation, general slope of

karst area, the lineament density and direction is believed to assist the better understanding of Gunung Sewu karst aquifer system.

Figure 1. Watershed of surface drainage area (left) and unknown watershed in sub-surface drainage area

HISTORICAL REVIEW OF BRIBIN HYDROLOGICAL SYSTEM INVESTIGATION

1. MACDONALD AND PARTNERS (1981-1984).

The initial investigation in regard to hydrologic system in karst Gunung Sewu is conducted by MacDonald and Partners (1984). In this research, they divided the source of subsurface karst groundwater into two groups, which are: (1) eight **allogenic** river sink from Wonosari Plateau System, and only three of these are perennial: Kali Tegoan, Kali Serpeng, and Kali Suci (Figure 2) and (2) **autogenic** source, mostly coming from rainfall within conical karst area that subsequently reaches conduit system by karst processes (Adji and Haryono, 1999). In addition, they also describe the distribution and contribution of the majority of cave sites to comprise sinkhole shaft systems in conical karst area. To define the flow regime of the conduit system, this research carries out water tracing experiment that mainly using fluorescent dyes. The result of water tracing is then listed in Table 1. After conduction tracer test investigation, they subsequently compose the North-East Gunungsewu hydrologic map that commonly used by many Indonesian stakeholders until this moment. However, according to our opinion, it seems that MacDonald and Partners sometimes locates the mistaken geographic position as well as the name in terms of the cave and surface streams within the map. Also, MacDonald and Partners doesn't find the location of Seropan Cave that actually performs the significant discharge of underground river. As consequences, this map pays no attention to the occurrence of Seropan point that may cause to the mistake interpretation of underground river pathway.

Figure 2. Possible recharge of Bribin-Baron Underground Water System

2. FAKULTAS KEHUTANAN UGM (1993)

This research is actually aimed to give the perspective related to the conservation of Bribin surface catchment area in terms of re-vegetation action. Consequently, the team decides to firstly introduce the exact area of the watershed since this research requires the total area for plantation in km². Afterward, geomorphological approach is conducted to define the boundary of the watershed as illustrated in Figure 3. In addition, this research also investigates the underground river system that related to main Bribin River. 39 caves were mapped and tracer technique is also carried out.

Table 1. Result of Gunungsewu Karst Water Tracing Experiment by MacDonald and Partners (1984)

Input site	Date	Output site	Travel time (days)	Velocity (km/day)
Kali Tegoan	5/8/82	Baron	4	2.8
Gua Bribin	5/8/82	Baron	14	1.5
Kali Suci	12/8/82	Baron	7	2.7
Gua Buri Omah	27/8/82	L. Grubug Baron	<20 hour 6-7	>1.2 2.6
Gua Gilap	24/8/82	Gua Bribin	>5	<2.3
Gua Jomblang Banyu	24/8/82	Gua Bribin G. Ngreneng	<5 <6	<1.9 -
Goa Sodong Dadapayu	27/8/82	Gua Bribin Gua Ngreneng	2-3 <3	1.5 >3.0
Gua Toto	12/8/82	Luweng Ceblok	-	-
L. Buhputih	19/8/82	Baron	15-16	1.0
Gua Sodong Mudal	25/8/82	Pracimantoro	>6	-

Concerning to the cave field mapping and tracer techniques, then this research produces the new map of Bribin river hydrographic network. This research believes that Bribin River is starting from the sinkhole of Petung River in Tambakromo. Then, the path of Bribin River is: **Petung River-Sinkhole Sawah Ombo – Luweng Jomblangan – Gua Gilap – Luweng Jomblang Banyu – Luweng Jurangjero – Bribin** and confirms that this underground water course also has some leakages, there are: **Bribin-Ngreneng** and **Jomblang Banyu-Ngreneng**, as also illustrated in Figure 3. The weak points of this research, in our opinion are: (1) the watershed boundary that simply based on topographical features and (2) no explanation in regard to the tracer test investigation. However, some researches refer to this watershed boundary such as Adji and Nurjani (1999), Adji (2005), and Suryanta (2001).

2006-2007 RESEARCH BY FACULTY OF GEOGRAPHY, GMU

A recent research is conducted by the author of this paper applying the hydrographic network and the watershed border line that is based on the combination of the last two researches. However, some modification is made according to the author's professional judgment. This research is a part of PhD thesis that is entitled: **"Temporal and Spatial Variation of Hydrogeochemistry and Karst Flow to Characterize Karst Dynamic System (KDS) Behavior along Bribin River"**, which is aimed:

1. To understand the spatial-temporal variation and the proportion of karst flow components (*diffuse/fissure vs. conduit flow*) along Bribin River
2. To define the hydrogeochemical variation and to find the correlation between hydrogeochemical and the proportion of karst flow component
3. To measure the aggressivity and dissolution rate of along Bribin River
4. To describe the behavior and correlation of KDS components ($\text{CO}_2\text{-H}_2\text{O-CaCO}_3$) along Bribin River

Figure 3. Watershed model by Fakultas Kehutanan (1993)

a. Karst watershed and hydrological properties equipment distribution

The northern and western part border lines of the watershed used in this research are still identical with the previous one (Figure 3), since the surface topographical phenomena is reasonable to separate groundwater district. The northern part is bounded by volcanic **"Pangung Massif"** rock topography; while the western part is bounded by the occurrence of large depression known as **"Polje Ponjong"** that lies continue to Wonosari Basin (Srijono and Aldila, 2006). However, we can not accept the southern and eastern watershed boundary since there is no obvious topography to separate water district. Then, the watershed model is illustrated in Figure 4.

Figure 4. Watershed used in 2006-2007 research

After defining the watershed, 3 rainfall and 3 water level data logger are installed within the watershed with some consideration, i.e.: water level data logger are put along Bribin River (upper - lower) with possible accessibility to be easily recorder (example: we avoid to install water level data logger in Jomblang Banyu and Jurang Jero cave since the accessibility is very difficult-take 2 days and 7 hours to achieve those river points, respectively); rainfall data logger is put representing upper part, middle part and lower part of the catchment, so that it will be reasonable to construct area rainfall by Thiessen or Isohyetal Method. The distribution of equipment in the research area is showed in Figure 5.

b. Water Level Fluctuation and Stage-Discharge Rating Curve along Bribin River

For figuring time-series water level fluctuation along Bribin River, the installation of water level recording station is needed. Figure 6 illustrated the example of water level data logger and its installation within Gilap, Ngreneng and Bribin Cave.

Figure 6. Water level data logger in Gilap Cave (left), installation data logger in Ngreneng Cave (middle), and Automatic Water Level Recorder -AWLR in Bribin (right)

Figure 5. Equipment and sampling distribution

Together with the water level recording, discharge measurement also conducted in every situation to construct the relationship between water level (m) and river discharge, so that the stage-discharge rating curve is achieved as showed in Figure 7.

Figure 7. Water level-discharge relationship in Gilap-upper catchment, Bribin-lower catchment, and Ngreneng-leakage

c. one- year discharge fluctuation

After achieving the rating curves in each discharge measurement stations along Bribin River, then the time series in every station can be figured out, as mentioned below.

Gilap Cave

Gilap cave represents the upper part of the Bribin watershed. The water in this cave is of reasonable quality and for much of the year below the entrance carries a flow of more than 20 litre/sec. However, within the late dry season the discharge showed only around 3 liter/sec (MacDonald and Partners, 1984). The measurement from 1 May 2007 to 30 April 2007 shows that the minimum discharge occurs in 7 December 2006 by approximately **6 litre/sec**, whereas maximum flood event discharged confirmed in 23 March 2007 by about **380 litre/sec**. The full one-year discharge fluctuation illustrated in Figure 8.

Figure 8. one-year discharge fluctuation in G. Gilap-the upper part of Bribin catchment

Bribin Cave

The AWLR and HOBO water level data logger installed in the old dam of Bribin cave to represent the discharge fluctuation of the lower part of the catchment. The measurement from 1 May 2007 to 30 April 2007 shows that the minimum discharge occurs in 4 December 2006 by approximately **1630 litre/sec**, while maximum flood event discharged confirmed in 23 March 2007 by about **2520 litre/sec**. The full 1 year discharge fluctuation is then illustrated in Figure 9.

Figure 9. one-year discharge fluctuation in G. Bribin, the lower part of Bribin catchment

Ngreneng Cave

Ngreneng Cave represents the leakage discharge of Bribin River. According to MacDonald and Partners (1984), the discharge of Ngreneng cave is proved as a leakage from Bribin and Jomblang Banyu caves. The measurement from 1 May 2007 to 30 April 2007 shows that the minimum discharge occurs in 12 December 2006 by approximately **60 litre/sec**, while maximum flood event discharged confirmed in 23 March 2007 by about **1900 litre/sec**. The full 1 year discharge fluctuation is then illustrated in Figure 10.

Figure 10. one-year discharge fluctuation within Bribin River Leakage (Ngreneng Cave)

d. the proportion of flow component along Bribin River

As clarified by White (1993), Ford and Williams (1992), Smart and Hobbes (1986) as well as Gillieson (1996), principally the flow component within karst underground river is divided into 2 main components, they are: **conduit flow** and **diffuse flow**. Conduit flow dominates the subsurface river within the flood event and related to the number of the sinkholes at karst surface, while diffuse flow (or known as percolated water by cavers) is infiltrated very slowly through the surface (epikarst) zone and reaches the underground river in the course of drips or seepages. The significant of diffuse flow is very important since it is the only component that contributes to the river during dry period, because no rainfall means no conduit flow to occur. The term of diffuse flow is identical to the term of **baseflow** in surface hydrology.

The diffuse flow separation and the calculation of conduit flow proportion in this study is approached by *automated base flow separation by digital filtering method* (Eckhardt, 2005). The key of this method is to calculate the digital filtering in every cave based on the constant recession within the one-year hydrograph and the definition of baseflow indices (BFI) within karst aquifer, by formula:

$$q_{b(i)} = \frac{(1 - BFI_{\max})aq_{b(i-1)} + (1 - a)BFI_{\max}q_i}{1 - aBFI_{\max}} \dots\dots\dots(1)$$

where $q_{b(i)}$ is the baseflow event in i , $q_{b(i-1)}$ is the baseflow in $i-1$, q_i total discharge in time i , a is the constant recession and $BFI_{\max}$ is maximum baseflow (obtained by table/references). Next, Figure 11 shows the baseflow separation in Gilap, Bribin, and Ngreneng Cave, and the comparison of diffuse flow percentage between wet and dry season is showed in Table 2.

Figure 11. Conduit and Diffuse Flow Separation using digital filtering within Gilap-upper catchment-top, Bribin-lower catchment, and Ngreneng-leakage-bottom

Table 2. The average of wet and dry season contribution of diffuse flow along Bribin River

No	Caves	Position	% of diffuse/baseflow	
			Dry season	Wet season
1	Gilap	Upper catchment	85.50 %	85.03 %
2	Bribin	Lower catchment	98.70 %	98.16 %
3	Ngreneng	Leakage	81.43 %	92.48 %

Note: the number of percentage of diffuse flow component is calculated (in average) in one-period of wet/dry season. The calculation in every month or between rainfall events will give very different value. For instance, within the Gilap peak flood event in 23 March 2007, the diffuse flow proportion is only **23.12 %**.

e. Rainfall intensity

Rainfall is the foremost input for hydrological processes within karst aquifer. Subsequently, 3 rainfall data logger is installed that represent the upper, middle, and lower part of the catchment as the distribution is showed in Figure 5. Next, Figure 12 illustrated the type of the rainfall data logger that installed within Bribin watershed.

Figure 12. Castella automatic (upper catchment-left); Onset-HOBO RG3M (middle catchment); semi automatic rain gauge (lower catchment -right)

The monthly rainfall intensity within Bribin watershed is then showed in Table 3. According to Table 3, it clearly seems that the upper part of the catchment experiences the biggest intensity of rainfall that achieves almost 4000 mm/year. Geomorphologically, this condition is due to the **orographic** rainfall since the elevation of Tambakromo station is extremely highest compare to that Karangasem and Dadapayu stations. Based on this data, then we can construct the isohyetal area of rainfall, but we can not present in this paper since the process is still in progress

Table 3. Monthly Rainfall Intensity within Bribin Watershed (May 2006-April 2007)

Rainfall Station	Position	Intensity (mm)												Total
		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
Tambakromo	Upper	151	3.5	23.5	0	0	0	67	1001	245.5	673.5	706.5	625.5	3497
Karangasem	Middle	56	0	7	8.5	0	0	8.75	692	94.2	425.8	331.8	197	1821
Dadapayu	Lower	68	7.5	8.5	10	0	0	17.5	604	31	176.5	325.5	111	1359

The duration of rainfall recording within Bribin watershed performs the same period as the recording of water level fluctuation (1 May 2006-30 April 2007) with the purpose of applying rainfall-runoff respond modelling along Bribin River. However, the rainfall-runoff responds modelling is still being conducted (in process), so we can not describe the result in this paper.

SCIENTIFIC CHANCE FOR NEXT SEROPAN SYSTEM INVESTIGATION

After conducting the investigation for one year representing the hydrologic condition of Bribin River, we understand that there are some weaknesses regarding to the availability of dataset. Also, we propose some suggestion regarding to the next Seropan watershed and subsurface hydrological network. There are:

- The minimum number of rainfall gauge data logger installed is only 3 which represent the upper, middle, and lower catchment. In our point of view, at least 9 rainfall stations should be installed.
- The watershed boundary is constructed by only considering topographical features, so that, the eastern and southern border line can not be defined. We propose to put some rain gauges within the eastern part of the watershed, and records only 1 or 2 times during storms event to apply rainfall-runoff responds. Then the border line may be roughly defined.
- The “**missing**” point of **SEROPAN** by MacDonald and Partners (1984) is very disturbing. If we look at Figure 4. It clearly appears that the leakage from L. Jomblang Banyu should flow through G. Seropan before reaching G. Ngreneng. So that, we propose to conduct “new” tracer studies to fully describe the hydrologic system of Bribin and Seropan System.
- We do not install any water level data logger in **L. Jomblang Banyu** (the consideration is due to the very long and difficult access to reach the river point of this luweng). However, by this point, in our opinion, is the “**KEY**” to define the whole watercourse and network in Bribin River and its vicinity since according to the tracer test conducted by MacDonald and Partners (1984), the river water from this point goes to Ngreneng and Bribin. Consequently, we propose to install water level data logger in this point in order to confirm this fact and to find the relationship with Seropan System by using rainfall-runoff respond model. Then, we need also to install 1 water level data logger in Seropan point.
- Until this moment, there is no information regarding to the local or regional base level (above mean sea level) of subsurface water course in Bribin watershed. So that, the calculation and the construction of local base level should be carried out previous to the tracer studies because the mistaken of local base level definition will give the wrong decision of input or output point of tracer studies. This method to define the local and

regional water base level is very simply to be conducted because we already have the detail cave map by MacDonald and Partners (1984) or other researches.

- Due to our intention that the application of water-cheap-microhydro energy in Bribin and Seropan should be sustain in very extended time, so that the understanding of Bribin and Seropan hydrological system as well as the recording of yearly fluctuation of diffuse flow must be seriously undertaken within this site.

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