MASTER THESIS

Socio-Hydrology of Keduang Sub-basin in Central Java, Indonesia using case study approach

Understanding the relation between hydrology of Keduang sub-basin and social aspects using qualitative case study

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by:

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TU Delft

Preface

Water resources is one of the major issues in Indonesia. Almost every day there are news about water problems in Indonesia. Flood in rainy season and drought in dry season. Born and raised in Indonesia, I have always wanted to do something about this issue. It is an honor to be able to have the opportunity to study water management in TU Delft. The first thing I had in mind when I wanted to start working on my thesis is to have the research in Indonesia so I would contribute right away to the water resources issue in Indonesia.

This thesis is about Keduang sub-basin, a sub-basin of the big Solo river basin in Java Island, which is located on the upper stream area. Located just upstream Gajah Mungkur dam, this sub-basin has caused problems on Gajah Mungkur dam by transporting a lot of sediments every day. With a lot of attention given to Gajah Mungkur dam to restore its function, Keduan sub-basin has taken the spotlight as the key basin in order to stop sedimentation in Gajah Mungkur dam. The attention given in this thesis is unlike any other researches. It tries to give an understanding of the whole basin as a socio-hydrology system, a subject that has not been known yet in Indonesia. Socio-hydrology is something new that I hope this thesis can give a new insight for water management in Indonesia, and perhaps more researchers will be interested in doing the same research approach for other water resources issue in Indonesia.

This thesis would not be finished without Allah s.w.t., the almighty God without whom I would not be here. I would like to say a big thank you to my family: my mother and my sister, who have been very supportive despite during my struggle in finishing my thesis I often ignored their phone calls. Not to forget a special thanks to my father who passed away on August 2015, just 2 weeks before I departed to the Netherlands to start my study. My father was the first one who encouraged me to study here. This thesis is for you, for your teenage dream of going abroad to continue your study. Honestly, it has been so hard keeping my motivation to graduate my water management without your sometimes harsh advices that I used to receive.

I would also like to say thank you to Erik Mostert. This research could not be done without him, who gave me this topic for thesis, even though I had no knowledge about qualitative study at all back then. I would also like to say thank you to Leon Herman and Olivier Hoes for their inputs during my struggle year finishing this thesis. Besides my thesis committee, I would like to say a big thanks to the librarians of Statistics Indonesia office in Wonogiri, the only office that replied to my email during data collection phase. Without them I would not get enough data for this thesis.

A special thanks to LPDP for granting a full scholarship for my first 2 academic years. I would also like to say thanks to Shenna Laarhoven, Karel Karsen, and Stephanie Meulemans, without their help I would have been dropped out after my 2nd year here.

Last but not least, I would like to say thanks to all of my Indonesian friends during my stay here in the Netherlands whom I can't mention all; with you guys, I could find a home away from home. A big shout out to my band during my stay here in the Netherlands: Potatone. Without you guys, I would definitely not survive in the Netherlands!

Wahyu Satrio Ardiko

Delft, 17 March 2019

Summary

Solo River is the longest river in Java Island of Indonesia, the most populated island in Indonesia. As one of the most important rivers in Java Island, it has been encountering many problems since centuries ago. Flood is one of the main concerns in the basin even until today. After a big flood event in 1968, the government decided build a multipurpose dam upstream, which would not only prevent flood but also would store water during rainy season and distribute the water during dry season. In 1974 the development started and in 1982 the dam construction was finished and started to operational. The planned operational year was 100 years, however in 1985 a several studies showed that due to over sedimentation, the dam could only be operational for less than 23 years. Since then, the sedimentation issue has not been resolved yet, even though many works have been done, especially in Keduang sub-basin, the sub-basin on the upper stream of Solo River basin, located just upstream Gajah Mungkur Dam.

This thesis research tried to give a comprehensive understanding on the socio-hydrology system in Keduang sub-basin regarding the sedimentation issue. Socio-hydrology can be useful in this case because sedimentation problem is often associated with human behavior. Qualitative case study was chosen to be the approach on this thesis, because many developed socio-hydrology failed to explain the social process in the socio-hydrology system in detail, even though socio-hydrology is a multidiscipline study. Some people argued that more attention to the social aspects is needed in the socio-hydrology literature to get a more detailed understanding.

This research follows the case study research approach proposed by Yin (2013). Three different analysis were done to examine the system: stakeholder analysis to identify the relevant actors and their characteristics, historical events analysis to examine what the actors have done that were related to the sedimentation issue, and Socio-cultural, Technological, Economic, Environmental, Political, Legal and Ethical (STEEPLE) analysis, to investigate those each sectors as external factors that might influence the decision making of the related actors. To summarize the

analysis, a conceptual model was created to describe the socio-hydrology system of Keduang sub-basin.

There are a total of 10 relevant actors in the system, which come from 3 different groups: government, society and external actors. The government consists of 7 government agencies, the society represents farmers, and the external factors consist of researchers and donators. Between these 3 groups of actors, there is a feedback loop connection between the government and the society, which implies that the government has created some programs based on the society characteristic. Meanwhile, the external actors only interact with the government towards coordination.

The human-water interactions are different between the government and society, the government has a negative feedback loop with the water system, which means the government reduce what occurs in the water system, for example the high sediment in the system influences the government to remove the sediment. Surprisingly, it is not the case for the society, as it has a positive feedback loop especially regarding high sediments. Once the river had high sediments, people started to throw more garbage there thinking it would not be back clean, which would make the river even worse.

The actions done by the government and society are not only influenced by the water system, but also other external factors. For the government, economic, socio-cultural and politic factors are very influential to their actions. On the other hand, economic and socio-cultural factors are very influential to the society actions. These external factors seem to be more influential than the water system itself for their actions towards the water system.

Qualitative socio-hydrology study is clearly different with the quantitative study. Qualitative focuses on the why and how of relations in the system. It can give a good understanding on how such relations occur in the system. Hence, qualitative study can complement the quantitative study so that the model for quantitative study will not be oversimplified and based on valid reasoning.

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1 Introduction

This chapter will explain about the background information about the topic chosen for the research. It will start with briefly explaining the case, which is sedimentation problem in Gajah Mungkur Dam. The explanation will include the history of the development of Gajah Mungkur Dam. Afterwards, the definition and challenges of socio-hydrology will be presented, as well as the explanation on how socio-hydrology can be useful in examining the sedimentation problem in Keduang sub-basin, which is the biggest sediment contributor to Gajah Mungkur Dam. This chapter will end with research objectives and research questions, based on the background information.

1.1 Solo River Basin

Solo River is the longest river in Java Island, Indonesia. It is approximately 548.53 km long. Solo River is a transboundary river, which flows through two provinces: Central Java and East Java. The river has two sources: Mount Lawu, which is on the border of Central Java and East Java, and Kidul Mountain, which is located in the southern part of Central Java. The river flows northeastward towards Java Sea, with its delta is located in Gresik regency. Not only the longest, its basin area is also the biggest in Java Island; it is approximately 16,100 km^2.

Figure 1 Location of Solo river basin on Java Island

Solo River is most likely the most well-known Indonesian river in the world, thanks to *Bengawan Solo* song (*Bengawan* means big river in Javanese), composed by Gesang Martohartono in 1940. The song describes how Solo River from his point of view back in the year when he composed the music. The song that was originally played in kroncong style, a traditional Indonesian folk music genre, had an appealing melody that it gained popularity in no time, even globally as the Japanese at that time brought the song back to the country and became popular throughout Southeast Asia and East Asia (Kartomi, 1998), and later spread to the other part of the world as a well-known Dutch singer, Anneke Grönloh, recorded the song in 1962. *Bengawan Solo* has become the first widely popular song by an Indonesian composer written in Indonesian language (Kartomi, 1998).

The appealing melody is not something that would interest present hydrologists, but the lyric is. The lyric indicates that in 1940, when the song was composed, Solo River had already encountered some water issues. "*Musim Kemarau, tak seberapa airmu. Di musim hujan air meluap sampai jauh*," that is the second verse of the song, which can be translated into "In dry season, the water is not much. In wet season, the water overflows far away" (Martohartono, 1940). This clearly shows that back then, Solo River had encountered flood and drought issues. These issues had not been solved even after Indonesia declared its independence in 1945. In 1966 and 1968, flood still occurred, even very furious, that they resulted dreadful damages of inundation of land more than 120,000 ha and more than 150,000 houses along 548.53 km Solo River (Overseas Technical Cooperation Agency, 1974).

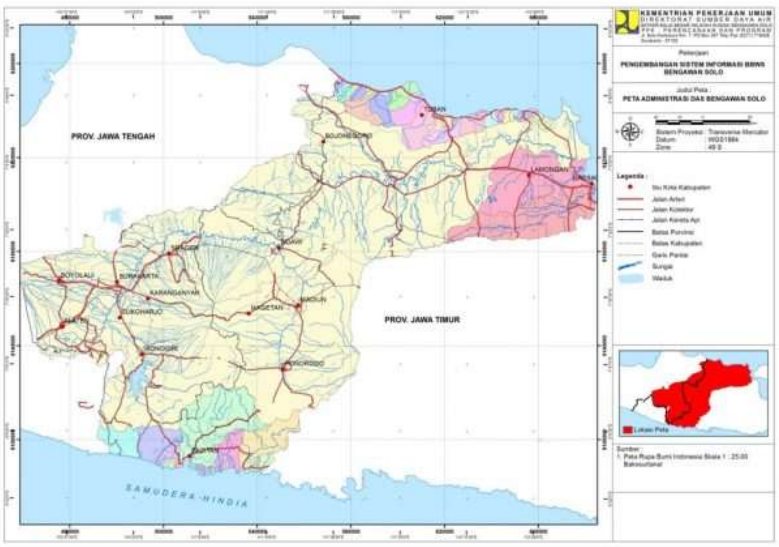

Figure 2 Bengawan Solo river basin map (Balai Besar Wilayah Sungai Bengawan Solo)

In response to those horrible floods, the government decided to take a huge change in the basin, by constructing a big dam on the upper stream part of Solo river basin, specifically in Wonogiri. The development of this dam started in 1974 with feasibility studies, and in 1982 the construction of the dam was finished and started to operational.

Initially, the dam was expected to be able to operate for 100 years (Japan International Cooperation Agency, 1975); so it means it was planned to operate until 2082. However, after the dam started to operation, the dam received much higher sedimentation from upstream than expected in the feasibility studies. Budi Santosa (2016) presented the revised values which were obtained from several researches, as can be seen on Table 1.

Table 1 Sedimentation research results (Budi Santosa, 2016)

Institute	Year	Annual sedimentation		Reservoir life prediction (up to year)	Method
		($10^6 m^3$/year)	(mm/year)		
JICA	1975	1.20	1.17	100 (2082)	USLE
DPMA	1985	5.20	4.10	23 (2005)	USLE
UGM	1985	6.60	5.40	18 (2000)	Echo sounding
PBS	1985	8.10	6.60	15 (1997)	Echo sounding
BRLKT	1985	6.60	5.40	18 (2000)	USLE
JICA	2000	4.50	3.50	8 (2008)	Echo sounding
Budi Santosa	2002	6.68	-	18 (2000)	River sediment

The first research found after the dam had started to operation was done in 1985. It might be that the issue in 1985 had already become a hot issue, hence there were 4 different researches done in that same year. Interestingly, all of them had different results, not only the 4 in 1985, but also the other 3 researches. One obvious

thing that most probably causes the difference in the results is the methods that were used. Even though Universal Soil Loss Equation (USLE) and echo sounding method are different (USLE uses empirical model that was developed by U.S. Department of Agriculture (USDA), on the other hand, echo sounding uses direct sampling using instrumentations), both USLE and echo sounding method are well-known methods that have been widely used in assessing sediments in a water body, so the quality of both methods is unquestionable. As for the river sediment method that was used in Budi Santosa (2016), it is based on the analysis from direct observation of river discharge and sediment transport, thus this method can also be considered viable. The question now is, which one is the most accurate? Budi Santosa (2016) stated that there was no clear answer in which method was the most accurate, as there was no data of actual sedimentation in the dam, hence no validation could be conducted.

Despite the differences in the results, one thing that can be concluded that, the initial assessment of sedimentation done in feasibility studies by Japan International Cooperation Agency (1975) was lower than the other researches. Did Japan International Cooperation Agency (1975) under-calculate the sediment? It can be argued that it is nearly impossible to be the case, as they used USLE method, which was also used by other researchers. Another argument is that the data they used in the analysis should be highly valid, as they did real survey works in the area in 1972-1973 (Japan International Cooperation Agency, 1975). What can be the case is that there were significant changes, especially on the upstream basin of Gajah Mungkur Dam, that caused different results in estimating the sedimentation, especially using USLE.

Table 1 shows that all researches (except the research done by JICA in1975) predicted the dam would be dead before 2010. Fortunately it did not happen. The dam is still operating today (2018), of course due to the findings in the 1980s, some works were conducted to restore the dam, for example in 1990s the government initiated to develop community forestry in the Solo river basin upstream of Gajah Mungkur Dam to reduce erosion rate (Handayaningsih, 2009). Despite some works have been done and Gajah Mungkur Dam has been saved from dying, the current condition of the dam is not great.

Figure 3 Gajah Mungkur Dam during dry season on 6th October 2014 (Kurniawan, 2014)

Figure 3 shows the condition of Gajah Mungkur Dam on 6th October 2014, when the dry season was still happening. The sediments are accumulated near the mouth, that the land formed by the sediments block the water flows from the upstream, resulting low water supply. As can be seen in Figure 3, there are some ponds formed at several locations in the middle of the reservoir, as the water is trapped and cannot flow downstream. At the day Figure 3 was captured, it was reported that the water level near the outlet was only at 124.78 meter above sea level (MASL), way lower than the designated normal elevation, which is 135.30 MASL (Kurniawan, 2014).

The problem is still happening until today (2018). An immediate yet comprehensive solution is importantly needed to stop the problem on the upstream of Gajah Mungkur Dam, especially on sedimentation problem. In order to formulate a comprehensive solution, a complete understanding of the system on the upstream of Gajah Mungkur Dam must be obtained. This is where socio-hydrology analysis could take a big role in understanding the system completely, instead of traditional hydrology.

1.2 Socio-hydrology: definition and challenges

Socio-hydrology, which was first introduced in 2012, was described as a new science of people and water which aims to understand the dynamics and co-evolution of coupled human-water system (Sivapalan et al., 2012). Unlike the traditional concept of hydrology where it is considered as a natural earth science, in which it only takes into account the processes of nature and takes social aspect as an external element,

the concept of socio-hydrology also includes social element as a part of the hydrology system (Sivapalan et al., 2012). Adding social factors in a hydrological system is not actually something new. Before the term socio-hydrology was introduced, hydrologists already took into account some social factors into hydrology analysis, one of which is the Curve Number (CN), which was developed by USDA, that took into account land uses in predicting direct runoff or infiltration from rainfall (Cronshey, 1986). However, what makes socio-hydrology different is with the main feature of socio-hydrology, which is a feedback loop relation between social and hydrology element (see Figure 4).

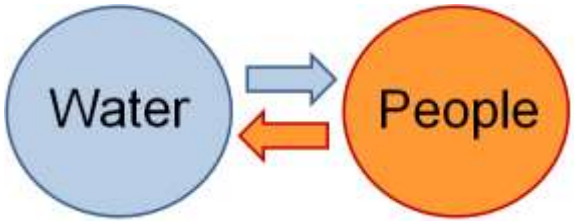

Figure 4 Water and people relationship in socio-hydrology concept

Unlike the traditional hydrology, which people are only considered as external forces to water systems, socio-hydrology treats people as an endogenous part of the water cycle (Sivapalan et al., 2012). It means in socio-hydrology people do not only have a unidirectional relation to water element (people influence water, but not the other way around), instead people co-evolve together with water so it has a bidirectional relation. The socio-hydrology has a feedback loop relation, which means that not only the hydrology of a water system is affected by social activities, but hydrology also gives feedback to social element, as some certain actions done by people can be a form of reaction to the water system they are in; for example the case in Chennai, India (Srinivasan, 2015), where people in the past invested in reservoirs and pipe infrastructures, but as time went by, the population kept growing, which caused the water storage in reservoirs decreased. The lower supply of water from reservoirs then had a feedback effect to people, that some of them started to invest in private well to fulfill their demands (Srinivasan, 2015).

Sivapalan et al. (2012) stated that there are at least three avenues through which socio-hydrology can advance:

a. Historical socio-hydrology
b. Comparative socio-hydrology

c. Process socio-hydrology;

Socio-hydrology studies have been predominantly done by making coupled human-water models, which is an approach in process socio-hydrology area where it gives more details into causal relationship, since the introduction of the term socio-hydrology, for example Di Baldassarre et al. (2013), Srinivasan (2015) and Chen et al. (2016). It is not a surprise that making models is popular in socio-hydrology, as this study mainly interests hydrologists, that in total of 238 authors of socio-hydrology related publications (until 2018), it is dominated by hydrologists by 101 people (Xu et al., 2018). The fact that hydrologists are more interested in quantitative analysis making coupled human-water model approach is more popular in socio-hydrology.

The popularity of coupled human-water model approach in socio-hydrology does not mean it is a perfect way in doing socio-hydrology analysis. There are some problems with the developed models. One of the main problems is the difficulty in incorporating human behavior in models, because human behavior is often unpredictable (Loucks, 2015; Massuel et al., 2018; Troy et al., 2015). For example, the model developed by Di Baldassarre et al. (2013), which conceptualizes human-flood interactions, tries to model society's respond regarding floods, in which one of the relation between human and flood is that human would gain awareness when the risk of flooding was higher. However, it is not always the case. On January 2005 there were several parts of the United Kingdom affected by river flooding, but some home owners in those area chose to rebuild their houses in flood hazardous areas rather than elsewhere where it was safer from flood (Watson et al., 2008). The premise of awareness level regarding flood level is one of the example how social aspects have been taken lightly in socio-hydrology models, that it was only based on assumptions which they believed to be logical. The fact is, decisions taken on water systems have been long known to be influenced more by economic and other social factors than by changes in its hydrological statistical properties (Loucks, 2015).

Another issue with coupled human-water model is that many of them simplify the actors on human part that they only treat society as one actor or a group of actors (Massuel et al., 2018; Mostert, 2018). It is indeed a form of simplification made to make the model easier, but apparently it is important to include management structures and decision making processes, which are recognized to be important in socio-hydrology literatures, but failed to deliver in models (Mostert, 2018). After all, in real life decisions

made to water systems have been done mainly by decision makers (e.g. water managers or government), thus there is a missing piece in models where they only have society as the only actor. For example the conceptual model made by Chen et al. (2016) for Kissimme River where they created a feedback loop relation between hydrology and community sensitivity of upstream and downstream society. They realized the importance of governance in decision making but they decided to ignore it by assuming that community sensitivity is the initial motivating force. The question now is, does the government really make decisions based on community sensitivity?

Both addressed problems in socio-hydrology model are leaning towards the social part. It is in fact caused by the low attention of hydrologists to give more details in social aspects (Loucks, 2015; Massuel et al., 2018; Mostert, 2018; Xu et al., 2018). Hence, in order to give a more accurate understanding of the co-evolution of people and water in a water system, giving more attention to social aspects is required.

1.3 Socio-hydrology analysis on Keduang sub-basin

Socio-hydrology analysis itself can be very interesting to conduct on the sedimentation issue on the upstream of Gajah Mungkur Dam because land erosion in a catchment, which is closely related to sedimentation in the river, is strongly related to social elements. According to USLE method, erosion can be described as the following formula (H Wischmeier & D Smith, 1978):

$$A = R * K * LS * C * P \quad (1)$$

Where:

- A : average annual soil loss (tons ha^{-1} $year^{-1}$)
- R : rainfall erosivity (MJmm ha^{-1} h year)
- K : soil erodability factor (tons ha^{-1} R $unit^{-1}$)
- LS : topographic factor (dimensionless)
- C : cropping management factors (dimensionless)
- P : practice support factor (dimensionless)

Looking at the Equation 1 *K, LS* and *C* are indirectly related to human activities. *K* depends on the land use, which is strongly related to human action. Different land use means it has different soil erodability. *LS* is not always related to human action

because topography is mostly a natural process. However in some cases, which also applies to upstream Solo river basin, topography can be affected by human activities, for example building terrace for rice fields. *C* is also related to human activities, especially in an agriculture area where the crops always change. Conversely, the erosion on the basin also affects human's life, as sediments directly affect the river flow (hydraulically and qualitatively), which the water is one of the main sources of their life. But how strong does the hydrology, in this case erosion and sedimentation, really affect the people in the basin? That will be one of the main goals of this socio-hydrology study.

To identify the problems on the sedimentation issue in Gajah Mungkur Dam, a socio-hydrology study is most suited to be conducted on the upstream part of Solo river basin, especially upstream of the dam. However, this research will not cover the whole upstream basin of Gajah Mungkur Dam, instead this research will focus only on doing analysis in Keduang sub-basin, one of the basins upstream of Gajah Mungkur Dam.

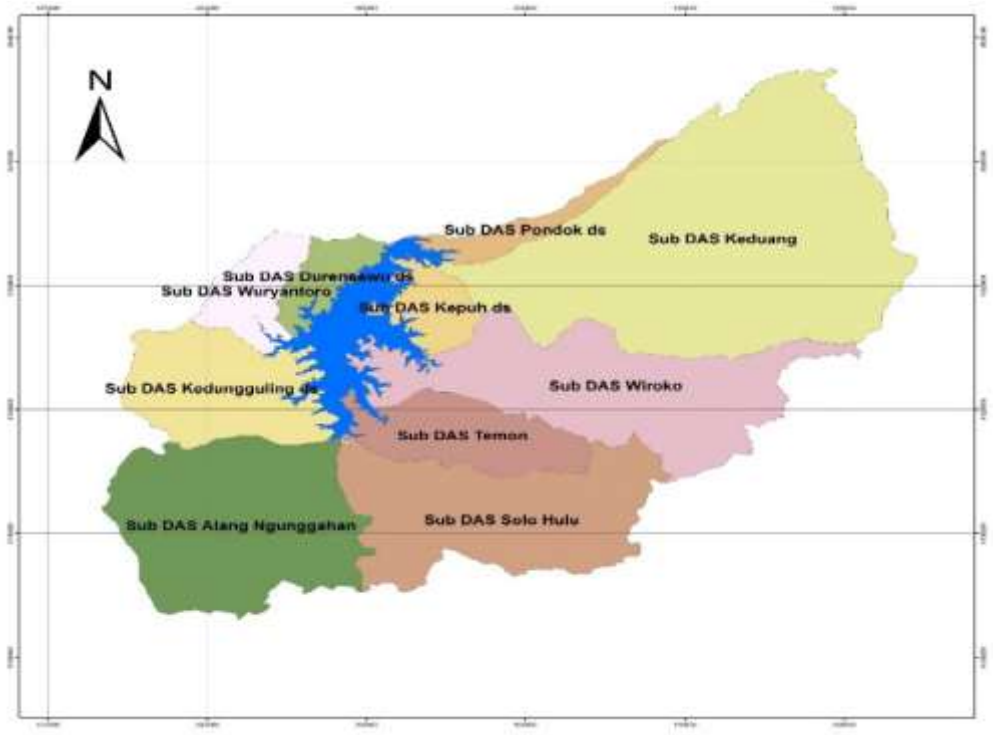

Figure 5 Upstream sub-basins of Gajah Mungkur Dam

It is not without any reason that Keduang sub-basin is chosen for this research. There are several considerations why Keduang sub-basin was chosen. First, with the catchment area of around 426 km^2, Keduang sub-basin is the largest sub-basin that

is located upstream of Gajah Mungkur Dam (see Figure 5), which also implies that Keduang sub-basin is the most contributor of sediments to Gajah Mungkur Dam (Handayaningsih, 2009; Indrawati, 2016). Second reason is because Keduang sub-basin was selected as one of the highest priority river basin that needs attention, thus government has made some works to Keduang sub-basin (Handayaningsih, 2009; Indrawati, 2016). Not only government, but also several researchers in hydrology, forestry, agriculture, economy and sociology have conducted their researches in Keduang sub-basin (Agustin, 2017; Budi Santosa, 2016; Handayaningsih, 2009; Indrawati, 2016; Utami & Trilaksana, 2015). Thus, the data needed for this research can be easily obtained.

This research tries to answer the challenges of socio-hydrology which were briefly mentioned in the previous section. This research aims to have more focus on social aspects, which have not been taken in details in most published socio-hydrology studies. The method chosen for the study is case study research, which was suggested by Mostert (2018) as an alternative approach for socio-hydrology study that can help more understanding especially in the social aspects.

Figure 6 Automatic Water Level Recorder (AWLR) Ngadipiro in Keduang

Using case study research in Keduang sub-basin, or in Indonesia in general, is also more suitable than using coupled human-water model. There are two main reasons why case study research is better for study in Indonesia. First, case study research does not need quantitative calibration and validation, which are done in coupled human-water model using observable quantitative data. In Indonesia, it is difficult to obtain such data. In Keduang sub-basin specifically, it only has river discharge data for recent years, as it did not have a water level measurement station until 2011, as can be seen in Figure 6. An AWLR named Ngadipiro was only installed

in 2011, even though it is a very important AWLR for Keduang sub-basin as it is located just before entering Gajah Mungkur Reservoir. The second reason is that case study research results in a descriptive qualitative model, which can describe better on complexity in systems than coupled human-water models or mathematical models. Mathematical models simplify complexities of real world systems, thus it cannot describe the system fully (Cilliers et al., 2013). It does not mean that mathematical model is not good for complex systems. It can be sufficient to describe a real world system where it has only little dynamics or is stable, especially in social elements, which is not the case for Indonesia where the country is still developing, hence it is so dynamist. Therefore, by using case study research it is hoped to be able to give a complete understanding on the co-evolution of social and hydrology in Keduang sub-basin.

1.4 Research Objectives

This research will present a socio-hydrology system of Keduang sub-basin in regards to the sedimentation issue qualitatively. Nevertheless, apart from the main objective of socio-hydrology research, which is to have a better understanding on how the social aspects and the hydrology have co-evolved together in the system, this case study research aims to give more details on the social side of socio-hydrology, which has been given a low attention by researchers. Based on the background information, there are several issues on the social part which have been given a low attention on the existing socio-hydrology literatures, which are:

a. The assumption of social responses towards hydrology system
b. The process of decision making, especially factors that influence the decision making such as economic and other social factors
c. The organization of water management
d. The presence of different actors with different views in the system
e. The interaction between actors

This research aims to give more attention to those issues using case study approach on the Keduang sub-basin, especially regarding the sedimentation issue. Furthermore, a more complex and actual conceptual socio-hydrology model of Keduang sub-basin towards the sedimentation issue will be created based on the results of analysis on the system. The whole socio-hydrology system from the

qualitative description, which will give more details on social aspects, and the conceptual model is hoped to be able to give an insight for water managers, especially to solve the sedimentation issue and for creating a future water management planning.

In order to achieve the objectives of this research, these research questions were formulated:

a. Who are involved in the socio-hydrology system in Keduang sub-basin?
b. How are the relationships in between stakeholders, as well as with the hydrology system?
c. What social actions or behaviors are or have been in the system that affect the over sedimentation in Keduang sub-basin?
d. To what extent social aspects are important to the hydrology of Keduang sub-basin, in particular on the actions that influence the sedimentation issue?
e. What hydrology aspects influence the social aspects in the basin?
f. How well does qualitative case study approach describe the socio-hydrology of Keduang sub-basins?

2 Methodology

In this chapter, the methodology used for doing the research will be explained. The first section will explain about the theory of case study research, including the steps of the analysis doing such method. The next section will explain about the theory of sedimentation process, which is the main element of this research. The explanation will start by describing the sedimentation process in a natural river basin, then later it will explain the conceptual sedimentation process when human interference is introduced in the river basin. The last section will briefly explain about STEEPLE analysis, which is an abbreviation of Social, Technology, Economics, Environmental, Politics, Legal and Ethics, that will be used as a tool to analyze the external factors that influence the sedimentation system in the river basin.

2.1 Case study research

Case study research is a research method which is used widely in social science research. Yin (2013) defines the case study research method as an empirical inquiry that investigates a contemporary phenomenon within its real-life context, when the boundaries between phenomenon and context are not clearly evident, and in which multiple sources of evidence are used. Case study research is preferred than any other methods in situations where the main research questions are “how” or “why” questions, the researcher has little or no control over behavioral events, and the focus of study is contemporary phenomenon. Case study research is done intensively on a single phenomenon over time with its original setting, thus it gives highly detailed results. However, the results of such study cannot be generalized thus different studies must be done for similar cases on different situations.

Yin (2013) suggests a 6 steps technique for conducting case study research, which are: plan, design, prepare, collect, analyze and share. Each step will be explained in details on the next section.

2.1.1 Plan

The first step is to plan the research, in particular to determine the focus of the research over the chosen case. The focus of the research needs to be clear and well established, so that it can be referred in formulating the research objectives, as well as research questions to accommodate in achieving the objectives. Literature review

is done in this phase in order to assist in targeting and formulating the questions. This review establishes what research has been previously conducted and leads to refined, insightful questions about the problem.

The plan for this research is presented on the introduction chapter, including the research objectives and questions. The research objectives and questions were formulated based on literature reviews especially on socio-hydrology publications, which gave some insights on the challenges socio-hydrology studies. Before literature reviews, the planning phase began with choosing the case for conducting socio-hydrology study, in which sedimentation issue in Gajah Mungkur Dam was selected. After some literature reviews on the case, it was decided that the research would focus on Keduang sub-basin, which is the biggest basin upstream of Gajah Mungkur Dam.

2.1.2 Design

Design in case study research technique basically acts as a bridge between the planning made beforehand and the result of the research. A research design is the logic that links the data to be collected and the conclusions to be drawn to the initial questions of the study. Traditionally case study did not have a formal design technique, however, Yin (2013) developed 4 basic types of case study design that could help researchers in designing the research. The basic types of case study design can be seen in Figure 7.

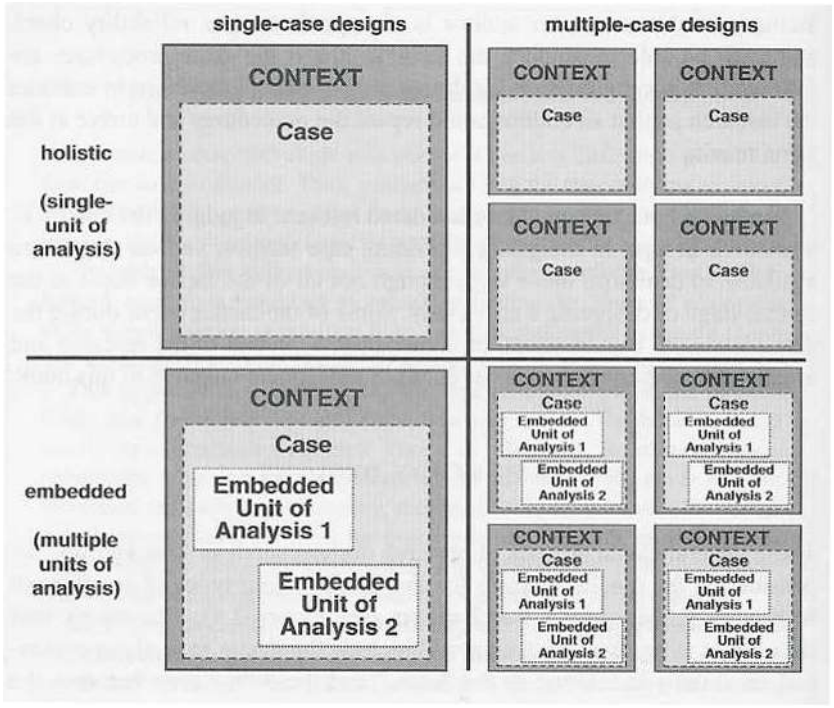

Figure 7 Basic types of case study design

In terms of the amount of cases to be examined, case study design can be divided into 2 types; single-case design and multiple-case design. When using multiple-cases, each case is treated as a single case, that are not related on each other, then the conclusion of each case are compiled and conclusions can be made. Both single-case and multiple-case design can be analyzed by using 2 different approaches: holistic, which only takes into account a single unit of analysis, and embedded, which uses multiple units of analysis. Based on the case study design matrix, this research uses the single-case design, which only talks about sedimentation issue in Keduang sub-basin, and the analysis uses multiple units of analysis, which in this research include stakeholder analysis, historical events analysis and external factor analysis using STEEPLE.

Apart from the type of case study design, in the design phase the technique for analysis is determined. The technique includes the time range of the case study and the method of analysis. The designed analysis also results in the lists of dataset needed for the analysis.

In this research, the design phase began with determining the research baseline. One of the objectives from this research is to determine the extent of social aspects that are important in socio-hydrology system of Keduang sub-basin, especially in regards to sedimentation issue. Despite being the objective, it is still important to set a boundary (baseline) so that the research stays in the main track. In this case, the baseline is determined based on the process of sedimentation.

After the baseline is determined, the next step of the research is to create a simplified socio-hydrology system in the Keduang sub-basin by adding social elements into the sedimentation process. In this step, it only takes into account all the immediate social interventions to the system that have influences on the sedimentation process. The adding of social elements into the sedimentation process may include various things, which depends on the condition of the basin. Some examples of immediate social interventions on river basins are water infrastructure, water consumption and irrigation. This process can be done only by seeing the general overview of the basin without looking into details. This system is later used as a starting point to explore more on the social elements, which is the challenge in socio-hydrology study.

The further analysis on the social element is done by doing historical data analysis. All related data are examined, such as important events, decisions, actions, behaviors and hydrological data. From examining historical data, two further analyses can be done in parallel: stakeholder analysis and in-depth socio-hydrology analysis. Stakeholder analysis focuses on the actor, who are involved in the system. Besides identifying the stakeholders, stakeholder analysis also examines the relations in between stakeholders. Meanwhile, in-depth socio-hydrology analysis focuses on action, what relations exist between stakeholders to the hydrology system, or the sedimentation issue. It examines all decisions made or actions done by the stakeholders that are directly related to the sedimentation issue. It also examines the influence of hydrology system to the decision making process. The time range for the historical study is from the construction of Gajah Mungkur Dam until recent year.

After both the stakeholders and their actions or decisions made that are relevant to sedimentation issue are understood, the next step is to analyze the external factors that influenced their actions or decisions. This analysis will answer the questions on the extent of social factors that have impacts on the sedimentation issue. The analysis is done on all relevant stakeholders. The analysis is done by using STEEPLE analysis as a tool.

2.1.3 Prepare

Prepare here refers to data collection preparation. One product from research design is a list of data needed for analysis. Case study research often requires a large amount of data. To prevent from losing sight of the original research purposes, an advance preparation of data collecting is needed. The preparation usually includes the creation of database that will help in sorting and categorizing the obtained data. The preparation also includes the method of collecting data (survey, interview, etc.), which depends on the designed technique of analysis.

The data needed in this research is categorized into four different categories:

2.1.3.1 Socio-hydrology literature

This data is used mainly in the planning phase, in which mainly are about the review and the challenges of the concept of socio-hydrology. In addition to that, some developed socio-hydrology studies are also used for comparison. All literatures are in

the form of scientific papers, thus they were planned to be obtained from various journals available online.

2.1.3.2 Social data

Social data includes demography and decisions, actions, or behaviors that have impacts on the sedimentation issue, as well as the external factors that influence the action (based on STEEPLE analysis). The demography data was planned be obtained from *Badan Pusat Statistik* (BPS), or in English is called Statistics Indonesia, a non-departmental government institute of Indonesia that is responsible for conducting statistical surveys. The other social data was planned to be obtained from various sources such as news archives, thesis from local universities, scientific papers, regulations, books and online articles. An interview or questionnaire was also planned to obtain the characteristic of local people in the basin.

2.1.3.3 Technical data

Technical data includes hydrology data, technical information of Gajah Mungkur dam and technical researches done in Keduang sub-basin. Information about Gajah Mungkur dam was planned to be obtained from JICA, which their works' documents are available online. Hydrology data was planned to be obtained from BPS and also the ministry of public works of Indonesia. Researches on Keduang sub-basin were planned to be obtained from online journals, and thesis as well as journals from local universities.

2.1.4 Collect

After preparing data collection, the next step is to collect the data. Data collection is done based on the prepared list done in the previous step. In reality, data collection may not be as planned, just like this research. Data collection was done from February 2018 until June 2018. One important data that cannot be obtained is data from BBWS Bengawan Solo which are mainly technical. However, after reviewing all the obtained data, some other sources like technical report from JICA and scientific papers also cover the important data needed. Interviews or questionnaire were planned to be conducted, however when gathering some literatures in local universities, there was already a thesis that did the similar thing. Thus, interviews were not done and data from that thesis is used instead.

2.1.5 Analyze

Based on the raw data collected, the fifth step is to analyze the data. Data analysis consists of examining, categorizing, tabulating, testing or otherwise recombining evidence, to produce empirically based findings. In case study research, there is no well-defined technique in analyzing case study evidence thus it can be difficult. Researchers can start analyzing by "playing" with the data. The raw data first is examined then processed into usable data that can be used for analysis. The analysis then is done by using the method that has been designed in the previous step.

In this research, there are many raw data that must be processed first, such as statistical data of land use, demography and precipitation. After processed, along with other data, it is analyzed by summarizing all important and relevant points from all data. The connections between all points from the data then are examined, so that in the end, a complete descriptive socio-hydrology model of the case can be drawn.

2.1.6 Share

The last step is to share the result of the research by presenting it on a preferred form. Depends on the purpose of the research, the form can be varied such as article, book, scientific journal, film, etc. Regardless the form, case study reports should be able to transform complex issues into something that can be easily understood by readers. Hence, the technique to present the research also depends on the readers, or audiences for video form of presentation. For example, governments are more interested in the result and recommendation of studies rather than the theory and analysis, on the other hand, scientists are more interested in the process of studies. Thus, reports for governments and scientific journal should be presented differently.

As this research was done for a master thesis, it is presented in a form of scientific writing. The results are presented as a qualitative description, supported with some quantitative data. The focus of the report gives more attention to the social part of socio-hydrology, which is one of the objectives of the research. At the end, a discussion part is presented, which discusses the results from analysis. To give a better understanding in describing the system, a conceptual system diagram will be made based on the results from all analysis.

2.2 Sedimentation process

Sedimentation, in river particularly, is a process of particles suspended in the water settling out from the suspension under the effect of gravity. The particles then become sediment that are deposited on the river bed. Sedimentation is not a stand-alone process that happens in rivers. Sedimentation is the end-product of 2 proceeding processes: soil erosion and sediment transport in the river.

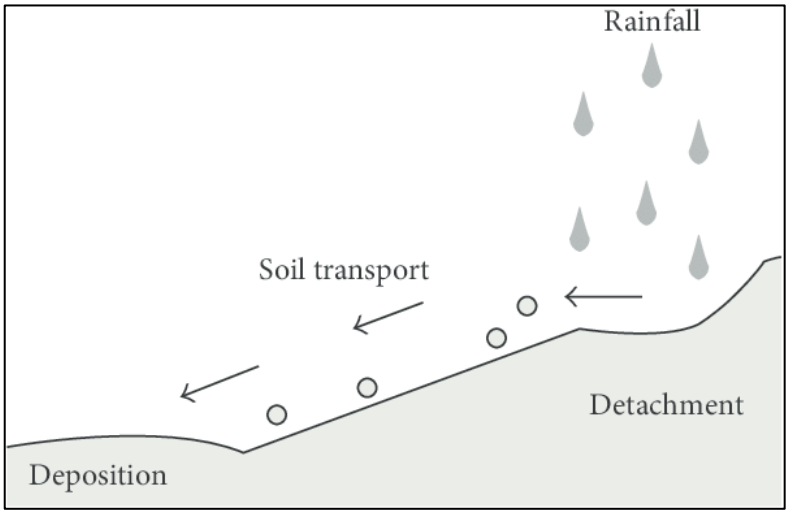

Figure 8 Mechanism of sediment displacement in a river (Shinji et al., 2016)

Soil erosion is a process that removes and displaces the upper layer of soil. Soil erosion is also often defined as the opposite of sedimentation, because instead of depositing particles, soil erosion removes particles. This natural process is caused by the dynamic activity of erosive agents, which include water, wind, snow and ice. In Keduang sub-basin, the only erosive agent that matters is water, as it is in the tropical region, thus there is no ice and snow, and. it has relatively low wind speed (see Figure 9). Thus, in this research, only water is taken into account as the only erosive agent.

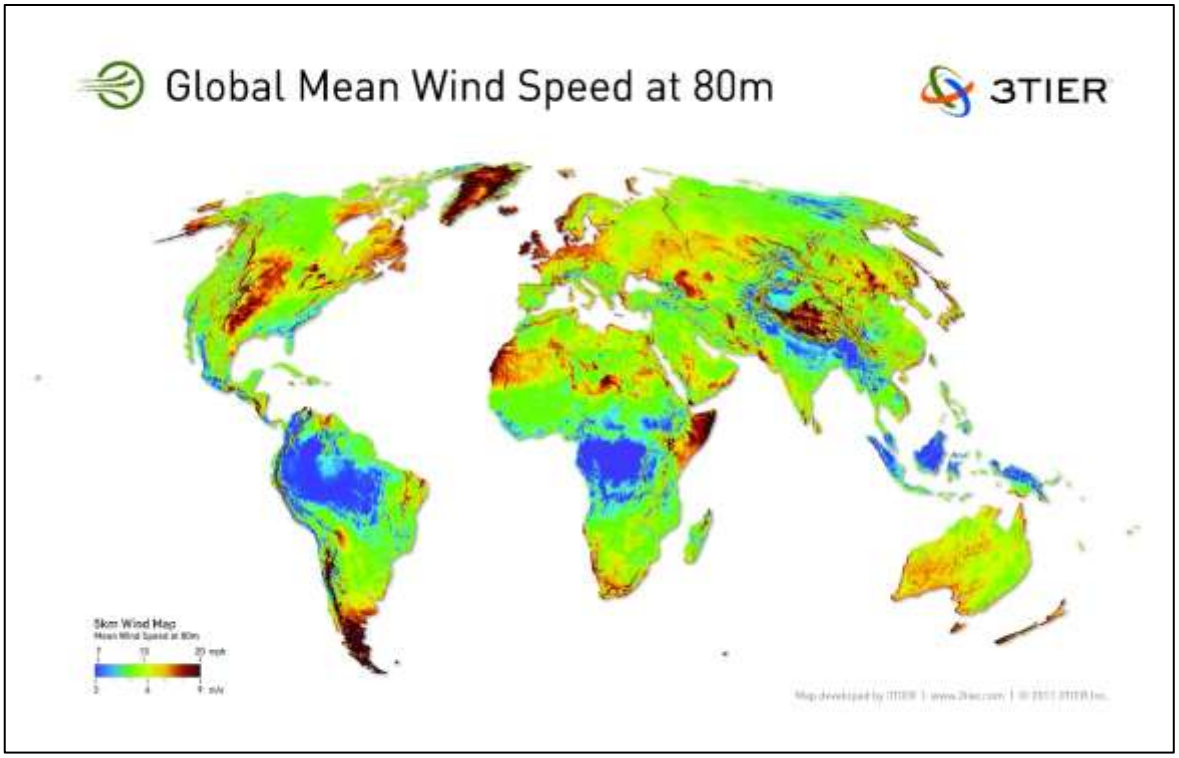

Figure 9 Global mean wind speed at 80m (www.3tier.com)

The eroded soil particles then are transported along with the water flow (surface runoff) to the river. In the river, sediment transport occurs. The particles continue to move in the river due to a combination of gravity acting on the particles, and the movement of the water in the river in which the particles are entrained. The soil particles that reach the river bed and deposited there become sedimentation. In a broader view, rivers have two properties that are related to sediment transport, which are stream capacity and stream competence. Stream capacity is a measure of the total sediments that can be carried in the stream. Stream competence is the ability of a stream to transport a particular size of particles, which usually is related to the maximum size of particles that can be carried. The major factor that affects both properties is velocity. Higher velocity means the stream has higher stream capacity and stream competence. The velocity itself depends on the volume of the water in the stream (water discharge) and stream morphology (narrower stream, higher velocity, and the other way around).

To conclude, sedimentation process depends on two important matters. First matter is erosion, which is related to the amount of sediments transported in the river. The amount of erosion occurred in a river basin can be estimated using USLE equation (Equation 1), which depends mainly on the landscape of the basin, such as land cover

and topography. The second matter is the river flow, especially the velocity that is related to stream capacity and stream competence. In order to give a clearer process of sedimentation in a river, the process diagram of sedimentation is drawn, as can be seen in Figure 10Figure 11.

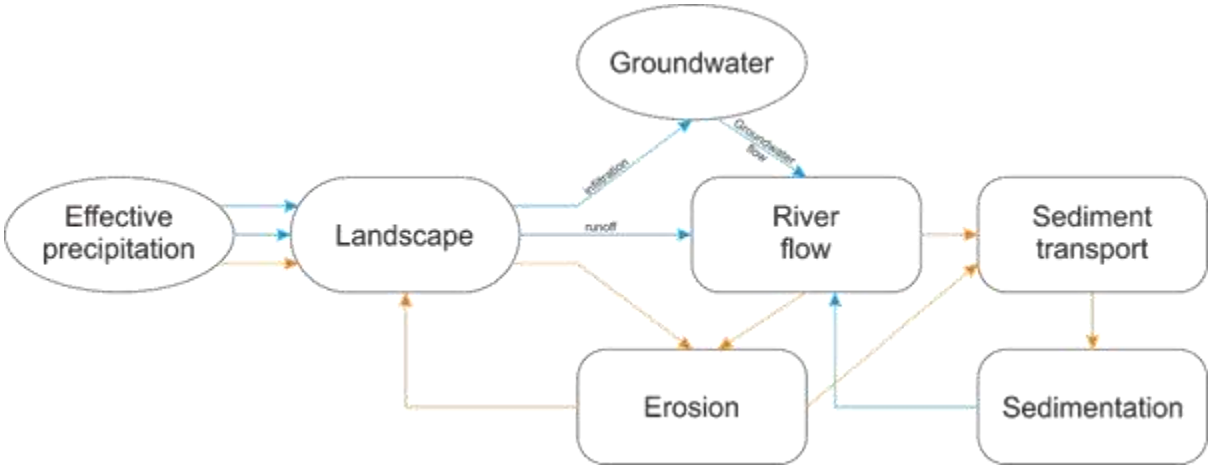

Figure 10 Sedimentation process in natural rivers

Figure 10 shows a sedimentation process in natural rivers, which ignores social elements in the basin. In the diagram, 2 different arrows can be found: blue and orange. Blue arrow indicates the rainfall-runoff process in the basin, meanwhile orange arrow indicates the sediment transport process. Even though this research only focuses on sedimentation process, but adding the rainfall-runoff process is important. It is helpful to know the process on how to get the velocity or discharge of the river, which is indicated as river flow in the diagram. Furthermore, later when adding social elements into the system, social behaviors have influences on the discharge in the river.

There are 2 feedback loops found in the sedimentation process diagram. The first one is between landscape – river flow – erosion. As explained on Equation 1, the landscape of a basin affects the amount of erosion. Something that is not explained in the equation is erosion also affects the landscape. Erosion, especially on hill slopes, can change the slope/topography, which is important in the calculation of erosion. River flow also takes role in this relation. In high discharge, when the river has high stream capacity, water flow can erode soils especially along the river bank, which of course adds more erosion in the river. The erosion can be very high in meandering rivers, in which a cut bank occurs in every curves, that the outer curves are easily eroded. The erosion caused by water flow is not taken into account in USLE as it

calculates erosion in broader scope: river basin scope. Nevertheless, it is also important to consider the local erosion along the river bank caused by the river flow as sometimes during flood it can cause severe landslide, which in the end causes a huge landscape change.

The second feedback loop happens between river flow – sediment transport – sedimentation. This feedback loop mainly occurs only at the inner curve of rivers and near water infrastructures. At the inner curve, the opposite of cut bank occurs. Soils deposited at the inner curve, which can be also called as sedimentation. The deposited soils change river morphology that can change the river flow as well. It also applies near water infrastructures. Especially, the deposited materials cause the river slope flatter that it decreases the flow velocity. Thus there is a feedback loop between sedimentation and river flow.

The sedimentation process diagram shown in Figure 1, however, can only represent the natural condition of river basins. It does not take into account social elements, which are the main focus of this research. As briefly mentioned before, adding “socio” into “hydrology” to get a “socio-hydrology” system can be done easily by understanding the sedimentation process diagram. According to the principle of socio-hydrology, the relation between socio and hydrology is a two ways relation. Thus, to add social elements into the system, there are 2 steps to do. The first step is to look for possibilities of people’s actions or decisions that might cause changes on the variables in the sedimentation process. Looking at the sediment process diagram, there are 4 variables that can be affected directly by people. The first variable is landscape, which can be changed due to land transformation done by people. The next ones are groundwater and river flow, whose water is used or consumed for daily needs. Following the use of water in the river, people must build a facility to get the water, for example building a dam for irrigation. Such infrastructures also have direct impacts on the river flow. The last variable is sedimentation. When people think that the sedimentation is very high, they can dredge it to remove deposited soils.

The second step is to identify hydrology elements that might influence people. Eventually, the variables that can influence people are also the 4 variables that are mentioned in the first step. Landscape can influence people in managing the land use of the area, especially when something is not preferable. For example, when there is an erosion on a hill slope, people might want to change the slope into terraces to

prevent erosion. River flow and groundwater can influence people in deciding which water source is used. For example when the river dries up, people change their water source for irrigation to groundwater. It can get more complex if water quality is taken into account. Similar as the first step, water infrastructure and river flow also have a reverse relation. People can decide to build an infrastructure based on the river flow, for example building dam check in a high velocity river flow to get a desirable velocity. The last one, sediment, has been briefly mentioned in the first step. The decision people make to dredge the sediments is based on the amount of deposited sediment. Not only to dredge, sedimentation can also influence people in deciding to build infrastructures such, especially check dams to prevent sedimentation.

Based on the assessed relations to social elements, social elements can be added in the sediment process diagram, and the diagram becomes as seen in Figure 11.

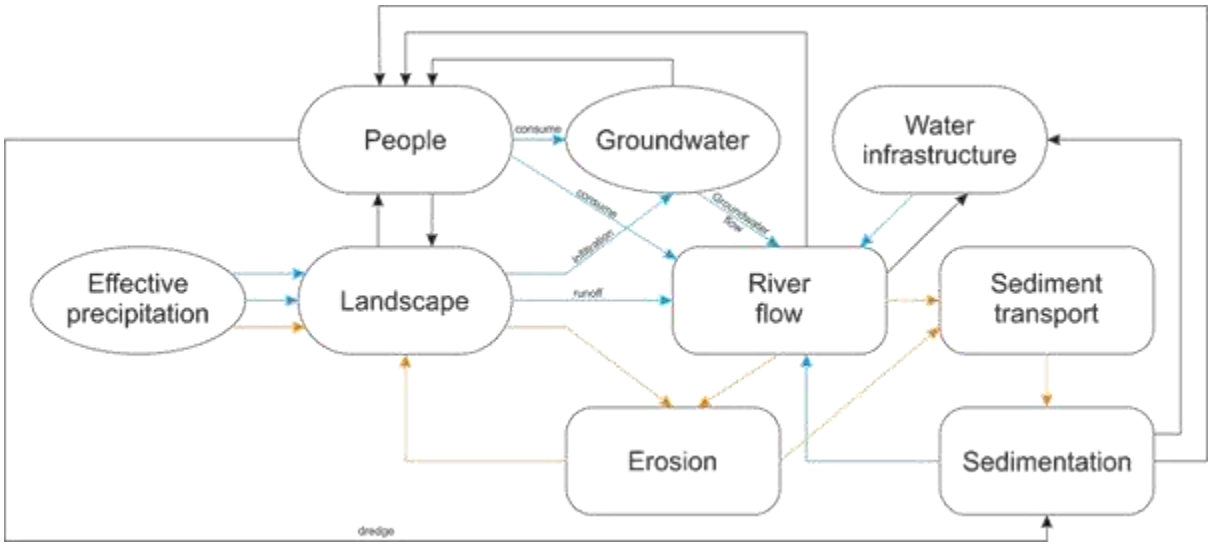

Figure 11 Conceptual socio-hydrology system diagram on sedimentation case

Only two new variables added into the diagram, which are people and water infrastructure. However, they give 11 more relations. People and water infrastructure here are separated to give a clear distinction on the relations towards river flow. But still, water infrastructure is part of people's decision.

This diagram then is used as a foundation for doing the case study. These relations established between social elements and hydrology elements are just predicted based on logical thinking. That is why in assessing the relations, so many "can" word are used (e.g. People can dredge sediments when the sedimentation is

thought to be high). An important question then arises: do all these relations really happen in Keduang sub-basin?

2.3 Stakeholder analysis

Stakeholder analysis is a process of identifying and assessing relevant stakeholders who are involved in a system. The main goal of doing such analysis is to understand who are involved in the system and where they stand in the system. Coined in 1980s, stakeholder analysis has been used widely on strategic management, both for business and public sector purposes. There are many different techniques that have been developed for analyzing the stakeholders. Hermans and Cunningham (2018) developed a step-wise approach for actor network scanning which was based on various techniques of stakeholder analysis that were introduced before. The step-wise approach can be seen on

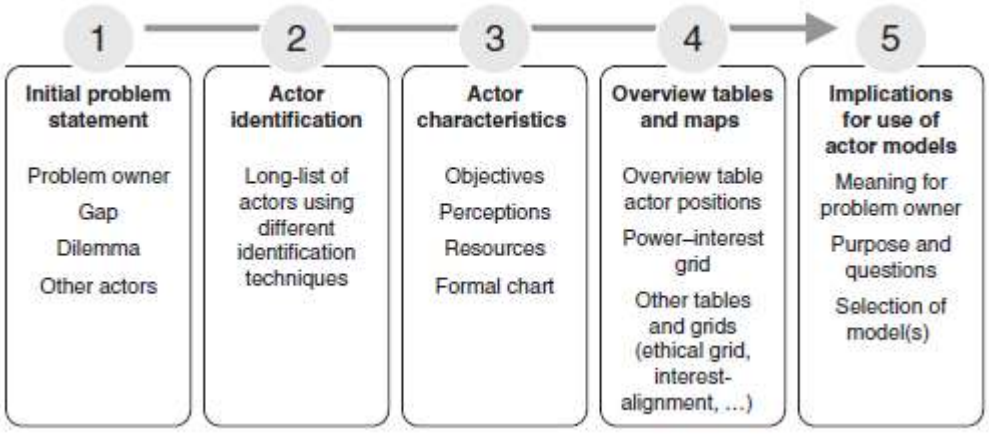

Figure 12 Step-wise approach of actor network scanning (Hermans & Cunningham, 2018)

The first step is initial problem statement, which starts with identifying the problem owner. In strategic management, the problem owner usually is a corporation which has a problem in a system, for example an electronic company who wants to develop a new smart phone for high-end market. However, in this socio-hydrology research, the problem owner is not one of the stakeholders, but the system itself. The system, which is Keduang sub-basin, is the one which has a problem: sedimentation problem. Nevertheless, this research tries to be neutral, which means it is not done for a specific purpose for a stakeholder. Choosing Keduang sub-basin as the problem owner will give a comprehensive understanding of the system which really can focus on the sedimentation problem.

The next step is actor identification using different techniques. The most important aspect in this step is to clearly define the problem, so that only relevant actors are listed. At first all possible actors can be gathered, but in the end only the relevant actors must be included.

The third step is actor characteristics. The actors are examined on three aspects. First is their objectives in the system. What interest the actors in the system are examined, which includes what they gain from the system. The next one is their perception, specifically towards the problem which is sedimentation problem in this case. The last thing is their resources, which can include their knowledge other resources such as technology. One other thing that is mentioned in the third step is formal chart. Formal chart refers to a chart that shows the formal relations between all related stakeholders.

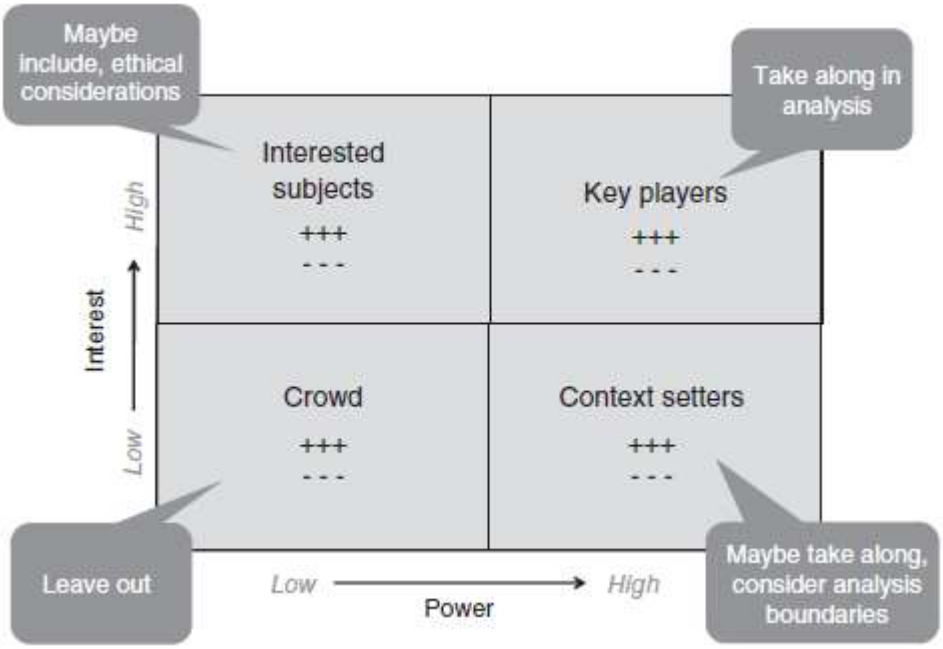

Figure 13 Power-interest grid in stakeholder analysis (Hermans & Cunningham, 2018)

From the third step, an overview can be made by making a power-interest grid. Power-interest grid provides a quick illustration of important patterns in the actor network. It consists of power on the x-axis and interest on the y-axis. There are 4 types of stakeholders that can be shown in the grid: key players, which is the most important one because it has high power and interest; context setters, which has high power but low interest; interested subjects, which has high interest but low power; and crowd, which has low interest and power. The power and interest here refer to the problem

that was developed in the first step. In this case, it is sedimentation problem in Keduang sub-basin. That said, this grid can give a quick insight on which actors are important in the case.

The last step is implications for use of actor models. This last step is basically the reflection of the whole analysis to the problem, which can be used as the base for further research or investigation. In this research, this last step will become the base on the historical event analysis and STEEPLE analysis. Hence, the focus of on what behaviors or actions taken in the past as well as the investigation of external factors using STEPPLE analysis will be based on the results of this stakeholder analysis.

2.4 STEEPLE analysis

STEEPLE analysis is a tool usually used in strategic planning. It is usually used by a firm in assessing its environment in order to have a good market from its product. STEEPLE is a rather new concept, which is an evolution form of PEST analysis. PEST analysis was first introduced in Aguilar (1967) as ETPS, which is an abbreviation of **E**conomic, **T**echnological, **P**olitical and **S**ocial. The abbreviation means that these 4 aspects are important to analyze in order to achieve a good strategic planning. Being difficult to pronounce or remember, ETPS is now more familiar recognized as PEST.

Over the years, the concept has evolved. Many people have added more aspects to it. The latest one is STEEPLE[1], which has 3 more aspects. STEEPLE is an abbreviation of **S**ocio-cultural, **T**echnological, **E**conomic, **E**nvironmental, **P**olitical, **L**egal and **E**thical. The 3 added aspects, which are environmental, legal and ethical, have become relevant in this era, thus it is now more often used that the traditional PEST analysis.

Even though this tool is usually used in business-related cause, it can also help in investigating the external factors of socio-hydrology in this research, as it gives guidance on what external aspects should be investigated, rather than doing investigation randomly. Thus, to answer the first research question, which is the extent of social aspect in socio-hydrology, the analysis is done by looking at the 7 aspects provided by STEEPLE analysis.

[1] It is unclear when and who was the first time STEEPLE introduced by. But the information is widely available in online websites such as https://pestleanalysis.com/steep-and-steeple-analysis/ and https://ceopedia.org/index.php/STEEPLE_analysis

There are various sources that can be used for analyzing each category of STEEPLE. For this research in particular, the sources used for STEEPLE analysis are shown in Table 2.

Table 2 Sources for STEEPLE analysis

Dimension	Sources
Socio-cultural	Statistics, Human Development Index (HDI), social researches, news
Technological	Statistics, social researches, sediment related literatures, existing infrastructures data, news, direct observation
Economic	Statistics, HDI, news,social-economic researches, national budgeting, history of Indonesia
Environmental	Direct observation, news, statistics
Political	History of Indonesia, Indonesian governmental system, diplomatic relations with other countries, news
Legal	Regulations, researches
Ethical	Self-assessment (subjective)

2.5 Conceptual system analysis

Conceptual system or conceptual model, is a representation of a system, which is composed with concepts. Conceptual model is used to give a better understanding of a system, or even simulate the system with modifications. In a way, conceptual model can be described as a simplification of a real system into a much lesser complex system.

In this research, conceptual model will be created to give a better insight on how the socio-hydrology system in Keduang sub-basin works. As the objectives of this research are not quantitative, the creation of conceptual model will follow the approach developed by Thissen and Walker (2012) which specifically focus on model for policy analysis. Unlike models from engineers and scientists, policy models are built to give information to policy makers who try to develop policies to solve future problems (Thissen & Walker, 2012). The main idea that differentiate policy models with

mathematical models is policy models are intended to be used for alternating different policy alternatives and scenarios, which means policy models must include a wide range of factors (e.g. technical, economy, social, etc.), but not give a lot of detail on one of the factors, unlike most developed socio-hydrology models that even though social factors are incorporated into the models, but more detail is given into the hydrology calculation.

According to Thissen and Walker (2012), there are 6 phases for specifying policy models:

a. **Planning**. Decide on the objectives and what is to be estimated. Planning includes defining the system boundaries and selecting the outcome indicators. In this research, the objective of the model is to calculate the sediment in Keduang sub-basin. As the focus is sedimentation, the boundaries will be sedimentation process, which includes erosion, sediment transport and sediment settling, as has been explained on chapter 2.2. No other hydrology process is taken into account.
b. **Design**. Determine the level of aggregation and general form of the model and specify the details to make it relevant to the objectives. It is important to make the model as simple as it can, but not too simple. In this research, this is done by adding the results of stakeholder analysis and STEEPLE analysis into the sedimentation process.
c. **Implementation**. Represent the model in a way that can be executed by the computer. Apart of it requires more data and more data means it is trickier, make the model not too complex is also intended so that it can be executed by computers. As this is not the main objective of this research, the model will be represented as complete as the results can, without considering the availability of data.
d. **Calibration and Validation**. Build confidence in the model and identify the questions it will be able to address.
e. **Employment**. Make use of the model to further the policy analysis.
f. **Documentation**. Explain what the model does, how it does it, and why (and to what extent) its results ought to be trusted.

Note that phase d, e, and f will not be done in this research as it is not the objective of the research.

3 Study area

This chapter will give a brief description of the study area, which is Keduang sub-basin. Before that, a brief description of subdivisions in Indonesia will be presented.

3.1 Subdivisions and government of Indonesia

It is important to understand the subdivisions system in Indonesia before explaining further, because in the explanation many words regarding administrative area of Indonesia will be found, especially in the stakeholder analysis.

There are four level administrative divisions in Indonesia. The first level is *provinsi* (English: province). Indonesia is divided into 34 provinces. Each province is headed by a governor, and has its own regional assembly, called *Dewan Perwakilan Rakyat Daerah* (literally meaning "Regional People's Representatives Assembly"). Since 2005, governors and representative members have been elected by popular vote for five-year terms.

The second level is *kabupaten* (English: regency) and *kota* (English: city). Both are the same level, but they are different in the size and economics. Regency has a larger area than city, and city has non-agricultural economic activities. A regency is headed by a *bupati* (English: regent), meanwhile a city is headed by a *walikota* (English: mayor). Both regency and city have their own local government and legislative body. Just like governors, since 2005 regents, mayors, and the representative members have been elected by popular vote.

The third level is *kecamatan* (English: sub-district). It is headed by *camat* (no English translation), who is directly responsible to the regent or mayor. *Camat* is chosen by the regent or mayor.

The forth level is *desa* (English: village) and *kelurahan* (English: urban communities). Both are the same level, but they are different. *Desa* is more autonomous, that the chief (called *kepala desa*) is chosen by the people, meanwhile the chief of *kelurahan* (called *lurah*) is appointed by the regent or mayor in the region. *Desa* is usually smaller and possesses lower technology than *kelurahan*, hence

usually a *desa* exists under a regency not a city, and *kelurahan* exists under a city not a regency.

Since 1999 when Law Number 22 Year 1999 regarding Local Government was issued (the law was revised by Law Number 32 Year 2004), local governments now play a greater role in administering their areas. They are able to issue a regional regulations that are suitable for their own region, but still follow the national law. In addition, there are local agencies on level 1 and level 2 region that serve as ministries of a certain expertise that are responsible to the governor or regent or mayor, not to the national level ministry. For example every provinces and regencies or cities have an agency of public works that is responsible for the infrastructure in the area, and responsible directly to the governor or regent or mayor, but not to the Ministry of public works of Indonesia. Nonetheless, the agencies must follow the code of conduct that is issued by the national level ministry. Local governments are not able to autonomously administer their area on all sectors. Foreign policy, defense (including armed forces and national police), system of law, and monetary policy, however, remain the domain of the national government. So for instance a province cannot establish a foreign cooperation with another country by its own.

In terms of natural resources and infrastructures, local governments are indeed the ones that are responsible for them, unless the scope is transboundary. If the system is a transboundary system then the responsibility goes to the upper level government. For example, a forest area that lies only in a regency, it becomes the responsibility of the regent. If the forest is big and lies on 2 or more regencies, it becomes the responsibility of the governor. If the forest lies on 2 different provinces, it becomes the responsibility of the Ministry of Forestry of Indonesia.

3.2 Gajah Mungkur Dam

After the horrible flood happened in Solo River in 1966, the government of Indonesia began to take action to save Solo River basin. Two years later, at the end of 1968, the government of Indonesia, under the presidency of Soeharto, made a 5 years national planning document, in which Solo River was mentioned as one of the most critical river basins in Indonesia, hence Solo River had gained a high priority in the planning (Republic of Indonesia, 1968). Several years after the document was signed, the government on Indonesia hired a consultancy service from a company

from Japan, Overseas Technical Cooperation Agency or OTCA (now called as Japan International Cooperation Agency or JICA), to assess and make master plan for water management in Solo River. They began the survey works in July 1972 until December 1973, with the main report was handed in in 1974 (Overseas Technical Cooperation Agency, 1974). Overseas Technical Cooperation Agency (1974) concluded in the main report that:

a. During rainy season, Solo River had very low capacity to carry down flood flow. Every rainy seasons, inundation was most likely to happen, that brought damages about US$ 17.3 million per year in the basin.
b. Annually, the basin had a high surplus water that was wasted because it lacked storage capacity. Thus, most surplus water just flows straight to the sea.
c. Many agriculture areas were in the basin, however, the water demand for irrigation was still higher than the water supply. Furthermore, the demand of crops, especially rice, was also higher than the production. Thus, more efficient agriculture was desired by developing new irrigation system, especially because they had already concerned about the situation that it would be a problem to further transform forests into agriculture areas as the forest areas were already in low proportion.
d. At that time, urban water supply only benefited about 9% of total population. With the increasing population, a more reliable water supply was needed.
e. Electric power supply in the basin was far from an adequate to meet the demand. Power shortage often occurred and it disturbed the economic development, as it was in industrial expansion.

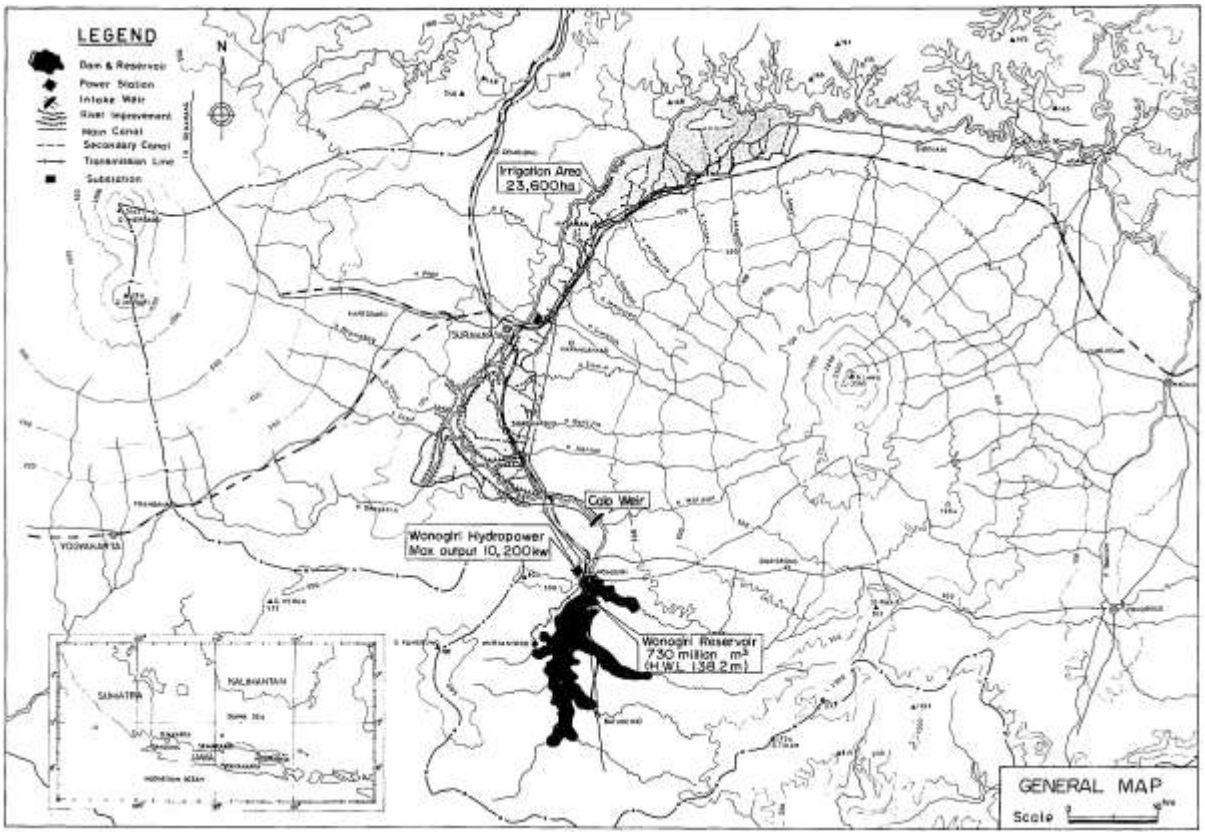

Figure 14 Gajah Mungkur dam planning layout (Overseas Technical Cooperation Agency, 1974)

According to the problems addressed in the document, a construction of Wonogiri multi-purpose dam on the upstream was proposed, along with Colo Wier on the downstream as water discharge control, to be the solution for the basin, which would not only function as a flood control, but also for irrigation, water supply and hydropower plant (Overseas Technical Cooperation Agency, 1974). The Indonesian government agreed to the idea of constructing the Wonogiri multi-purpose dam (which later named Gajah Mungkur Dam). At the same year of the finished master plan document, 1974, the same Japanese company, that just changed the name from OTCA to JICA (Japan International Cooperation Agency, 2016), was chosen to conduct the feasibility studies. In November 1974, they began working on the feasibility studies for the dam construction, and to follow up their result on feasibility studies, Indonesian government signed a contract with Nippon Koei Co., Ltd. In 1976 as the company to design the dam.

Finally in 1981, the construction of the dam was finished, and in 1982 it started to operate; it is still in operational until now (2018). The dam is rockfill earth dam with 40 m high and 830 m long. It has approximately 730 million m^3 of total storage, 90 km^2

of open water area, and 1,260 km^2 of catchment area, which consists of several big sub-basin, such as upstream Solo, Keduang, Tirtomoyo, Parangjoho, Temon and Posong (Budi Santosa, 2016). The dam was planned to be able to lower the peak of flood discharge from 4,000 m^3/s to 400 m^3/s, and it was planned to irrigate about 23,600 ha agriculture area in Sukoharjo regency, Klaten regency, Karanganyar regency and Sragen regency (Japan International Cooperation Agency, 1975; Nippon Koei, 1982). Furthermore, it is installed with a hydropower plant with capacity of 12.4 MW (Adi & Jb, 2015).

3.3 Keduang sub-basin

3.3.1 Geography

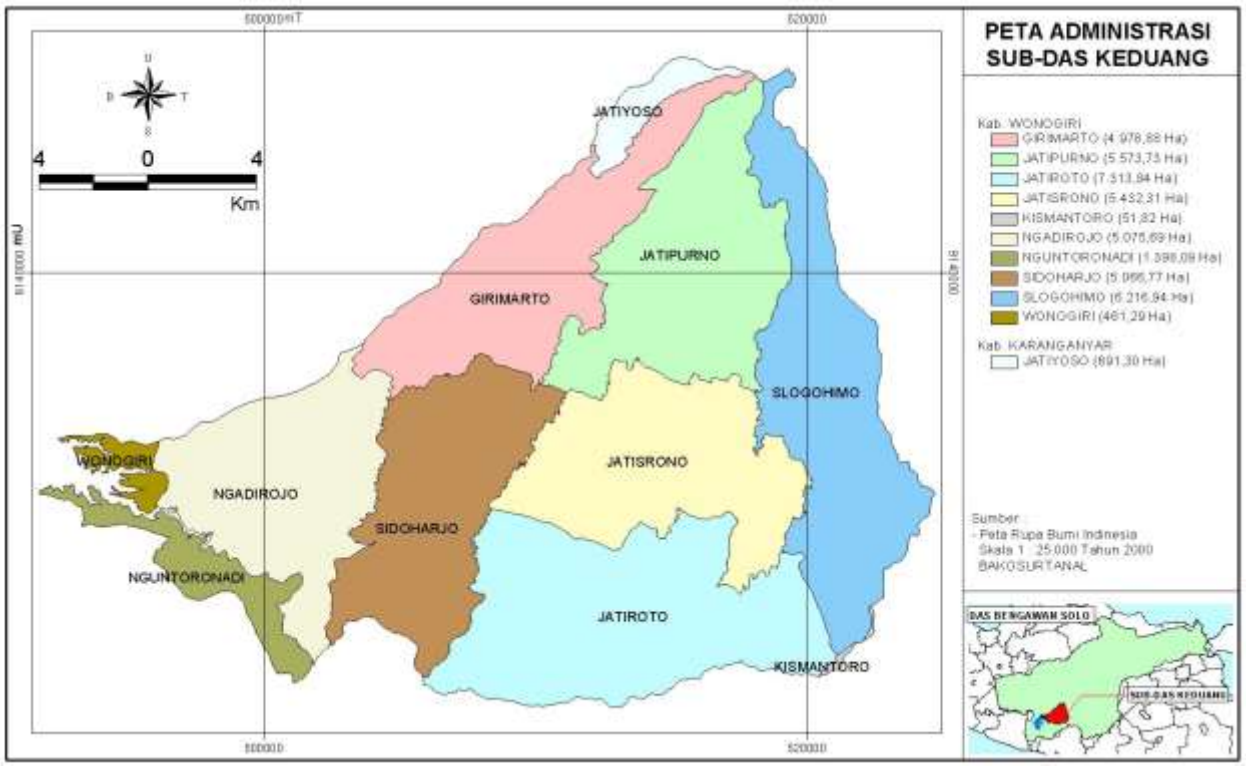

Figure 15 Administration map of Keduang sub-basin

Keduang sub-basin is a river basin located upstream of Gajah Mungkur dam. With the area of about 426 km^2, Keduang sub-basin is the largest basin within several basins that are located upstream of Gajah Mungkur dam (see Figure 5). Administratively, Keduang sub-basin lies on 11 sub-district; 10 of which are in Wonogiri regency and the other 1 is in Karanganyar regency. The complete list of the sub-districts in Keduang sub-basin can be seen on Table 3.

Table 3 Sub-districts in Keduang sub-basin

Sub-district	Regency	Area (Ha)	Area in Keduang (Ha)	% Area in Keduang
Girimarto	Wonogiri	6,236.68	4,978.88	79.83%
Jatipurno	Wonogiri	5,573.73	5,573.73	100.00%
Jatiroto	Wonogiri	7,313.84	7,313.84	100.00%
Jatisrono	Wonogiri	5,432.31	5,432.31	100.00%
Kismantoro	Wonogiri	6,986.11	51.82	0.74%
Ngadirojo	Wonogiri	9,325.56	5,075.69	54.43%
Nguntoronadi	Wonogiri	8,040.52	1,398.09	17.39%
Sidoharjo	Wonogiri	5,719.70	5,066.77	88.58%
Slogohimo	Wonogiri	6,414.80	6,216.94	96.92%
Wonogiri	Wonogiri	8,292.36	461.29	5.56%
Jatiyoso	Karanganyar	6,716.00	691.30	10.29%

Keduang sub-basin is located in a mountainous area, above 130m elevation above mean sea level. Hence, the landscape mostly has medium to high slope. Keduang sub-basin consists of 29.98% flat area, 34.97% bumpy area, 23.92% hilly area and 11.13% steep area (Agustin, 2017). Based on map analysis, the main river of Keduang is around 45km long, with slope about 3.5%. The hill slope along the river in Keduang sub-basin varies between 3%-73% (Agustin, 2017).

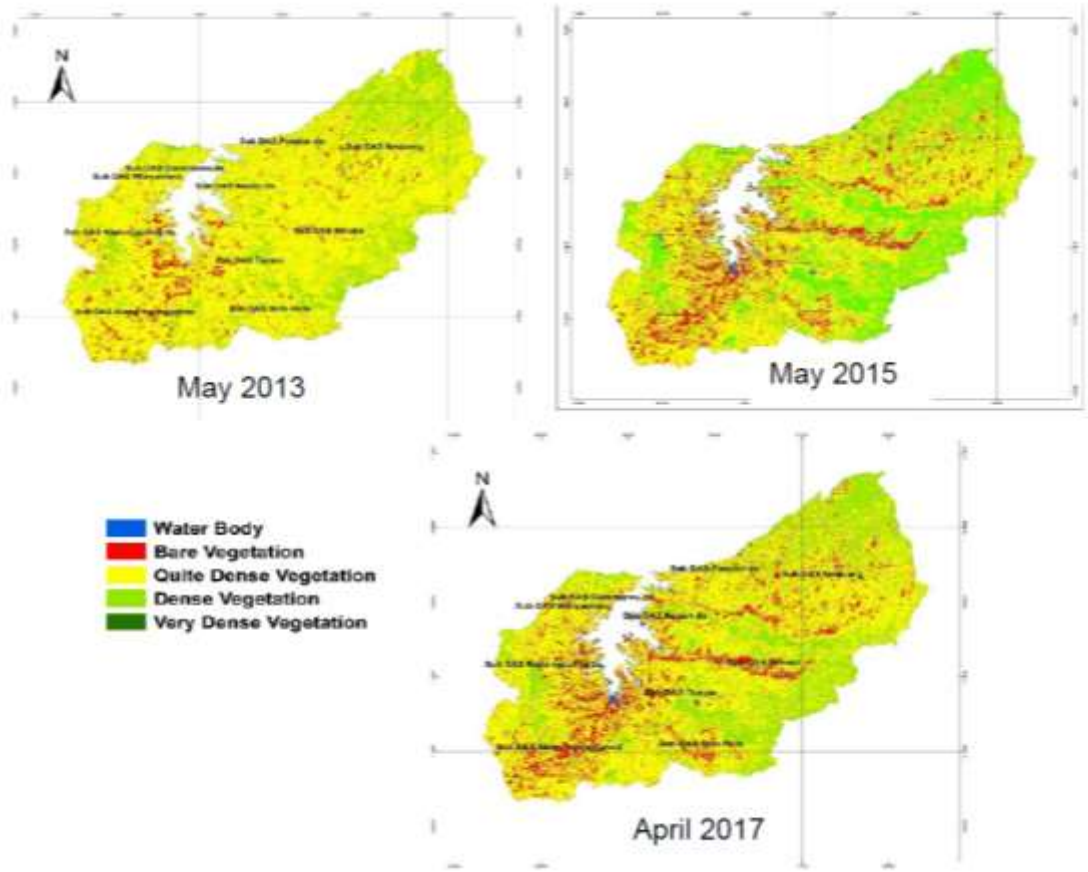

Figure 16 Distribution of vegetation Density in upper stream Solo river basin (Sudarsono et al., 2018)

Keduang sub-basin is not densely populated. It consists of mainly vegetated area, as can be seen on Figure 16. In details, the land classification based on vegetation cover can be seen on Table 4 and Figure 17.

Table 4 Vegetation cover in Keduang sub-basin (Sudarsono et al., 2018)

Year	Area (ha)		
	Bare vegetation	Quite dense vegetation	Dense vegetation
2013	1250.00	26818.18	10795.45
2015	3522.73	23295.45	11704.55
2017	7272.73	21022.73	10340.91

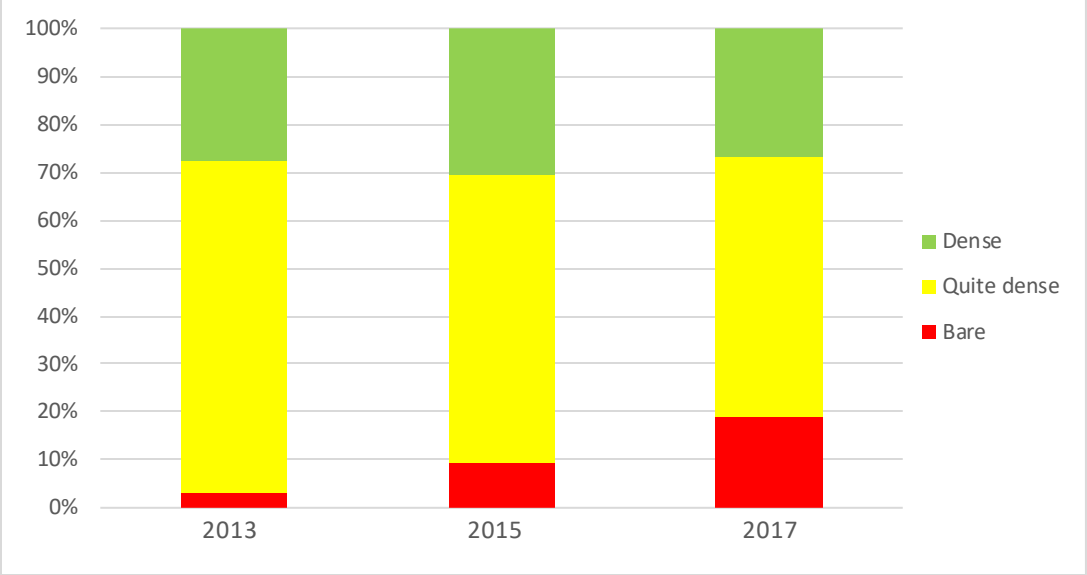

Figure 17 Vegetation cover in Keduang sub-basin (Sudarsono et al., 2018)

The land use in Keduang sub-basin is dominantly an agriculture area, as can be seen on Table 5.

Table 5 Land use change in Keduang sub-basin (Widyaningsih, 2008)

Land use	1996	2001	2006
Forest	1.61%	1.39%	0.86%
Agriculture	83.78%	84.28%	84.14%
Residential	2.24%	2.60%	3.11%
Shrubland	12.34%	11.44%	11.25%
Bare land	0.03%	0.29%	0.64%

3.3.2 Demography

There is no specific demography data in the Keduang sub-basin, as the population is calculated based on administrative areas. Nevertheless, the rough estimation of population and its growth can be gathered from the population of all sub-districts that are inside Keduang sub-basin. The population of sub-districts in Keduang sub-basin can be seen on Figure 18[2].

[2] The population data is only shown from 1973 until 2011, because since 2012 Statistics Indonesia started to use a different method in projecting population growth that it does not match with the previous years. Nonetheless, the population growth after 2012 until 2018 using the new projection seems to be constant and flatter; only below 600 population/year for every sub-districts.

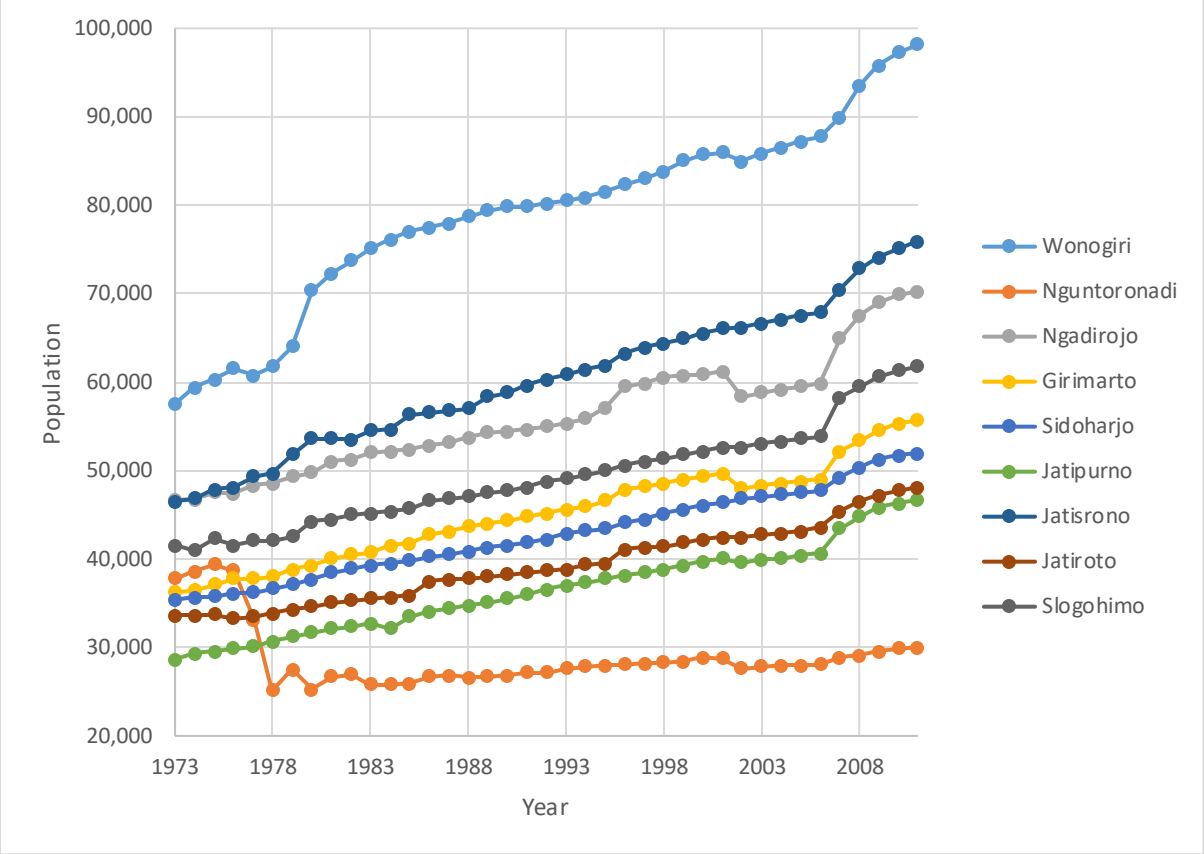

Figure 18 Population of sub-districts in Keduang sub-basin in 1973-2011 (Statistics Indonesia)

There are 2 noticeable irregularities in the population graph. The first one is around 1977-1981 in which Wonogiri population significantly increased while Nguntoronadi population significantly decreased. It was due to Nguntoronadi was mostly in the Gajah Mungkur reservoir area that it would be inundated. Thus, many people were relocated, and apparently some of them moved to Wonogiri sub-districts, the capital of Wonogiri regency. It was not only people moved to Wonogiri sub-district from Nguntoronadi. The fact that the new dam started to operate in 1981, many professionals moved there to manage the dam. As a multipurpose dam it also attracted people to move there. Wonogiri sub-district as the capital of Wonogiri regency thus had a huge leap of population and became more developed.

The other irregularity happened around 2001-2008. It can be explained with the urbanization phenomenon post Asian financial crisis in 1997. After the crisis many people were impacted that many were struggling to earn money. One of the most popular options was to move to big cities to find a more proper job. That is why it shows a significant decrease of population in several sub-districts. Later in 2007, the population shows a huge increase because in 2006 a new regulation was issued,

which was Law number 23 year 2006 about population administration. With holding on to the law, many local governments of big cities started to control their population by doing *Operasi Yustisi Kependudukan* (OYK), which was an administrative inspection that kicked people out of town, whose identification card showed different place of issuance. They were forced to go back to their hometown. Hence, in 2007 it shows a high increase of population in several sub-districts.

Based on the land use data from previous section, it can be concluded that the majority of people in Keduang sub-basin are farmers. The rough estimation of the proportion of farmers to the total population can be seen on Figure 19, which was calculated based on the data from 9 sub-districts (Wonogiri, Nguntoronadi, Ngadirojo, Girimarto, Sidoharjo, Jatipurno, Jatisrono, Jatiroto, and Slogohimo).

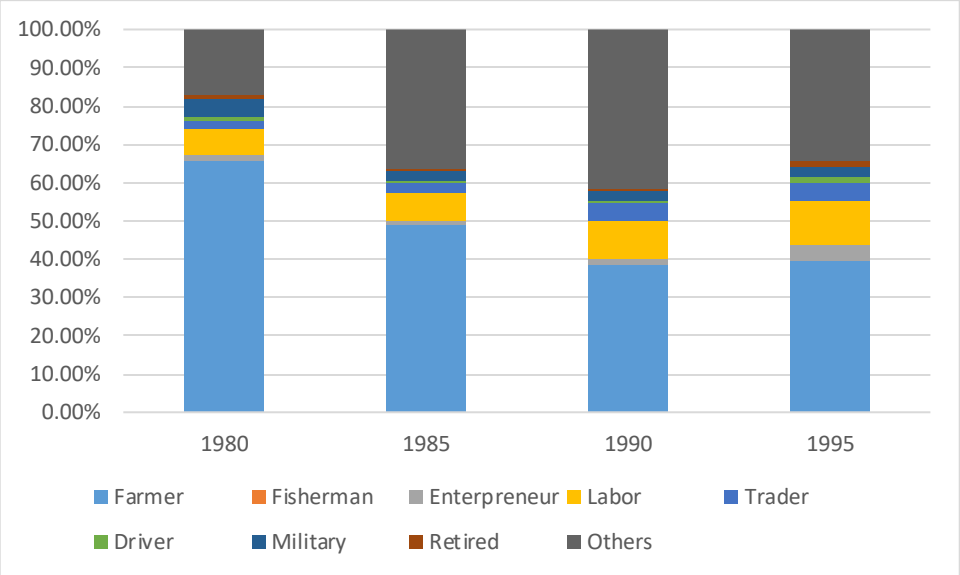

Figure 19 Occupations in sub-districts in Keduang sub-basin 1980-1995 (Statistics Indonesia)

Again, it is similar to the population data that it is not specifically in Keduang sub-basin but rather the sub-districts that are inside Keduang sub-basin. It shows that the majority of people were farmers, except in 1990. However, it is important to note that this data does not represent Keduang sub-basin specifically, it takes into account the number from each sub-districts. The huge increase in others occurred in Wonogiri sub-district that more occupations were introduced after the operation of Gajah Mungkur Dam. Not to mention, only 5.56% area of Wonogiri sub-district is in Keduang sub-basin.

The data shown was only between 1980 until 1995, not until recent years. Statistics Indonesia did not continue to publish this data between 1995 until 2011.

Since 2012, however, it started to publish the similar kind of data. The difference is, it stopped dividing the data into sub-districts, and instead it just published a single number for the whole Wonogiri regency. The data can be seen on Figure 20. It shows that the majority for recent years is still agriculture in Wonogiri regency.

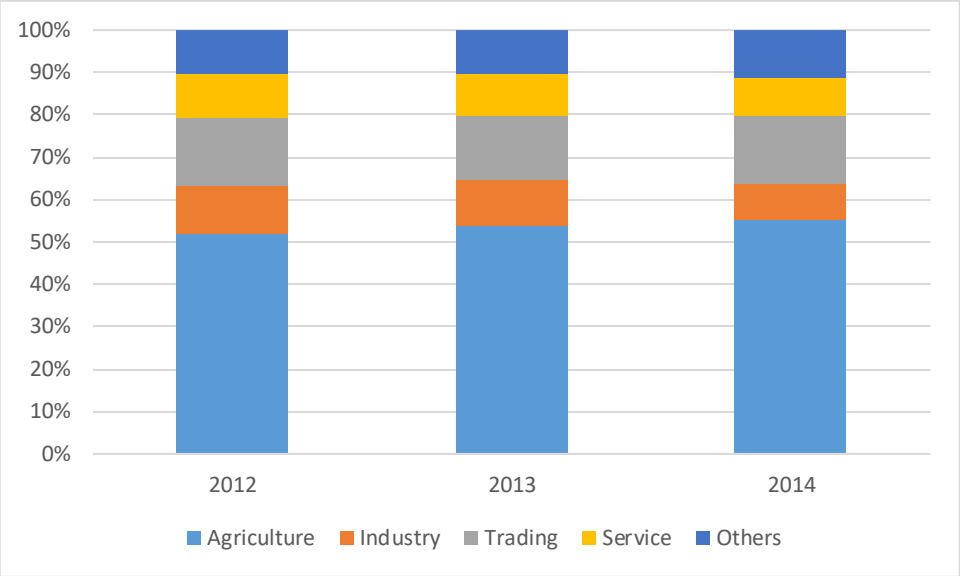

Figure 20 Economy activities in Wonogiri 2012-2014 (Statistics Indonesia)

4 Stakeholder analysis

In the conceptual socio-hydrology system diagram shown in Figure 11, the social element is simplified to only 1 variable, which is people (as explained in the chapter, water infrastructure is actually part of people, but it is separated to distinguish the relation towards river flow). In real life, people cannot consist of only 1 actor. There may be several individuals or groups of people. Those actors also may have different views and perspective towards an issue. Hence, it is important to identify the stakeholders.

In Keduang sub-basin, it is apparent that in general actors in the system can be divided into society and government. Both can be clearly distinguished based on their difference in seeing the sedimentation issue. The difference can be clearly seen in the feedback loop relation between people and landscape shown in Figure 11. The government in general has made several projects in response to the poor land use in Keduang sub-basin, such as creating public forests and conducting counselling. On the other hand, local people there do not really care about the poor land use, for example they have been expanding their agriculture area by cutting down trees instead, which has caused worse erosion. This behavior will be explained further in the next section.

Dividing the people element into only two different actors is, however, too oversimplified. In reality, both government and society can be divided into smaller groups of actors, which every one of them can be clearly distinguished because of their different views toward the issue. The details on both and their division will be explained in the next section. Furthermore, people element can also be people that are not in the system, but have impacts on the issue in the system, for example researchers that have interests in the issue that their researches might influence the decision making process done by the associated agencies. Such people can be classified as external people, that apparently in Keduang sub-basin there are external people involved in the sedimentation issue. The details will be explained in the next section.

In order to describe the dynamic of people in the socio-hydrology system in Keduang sub-basin, the explanation will be divided into 2 parts: before Gajah Mungkur dam construction and current condition.

4.1 Pre dam construction stakeholders

Before the construction of Gajah Mungkur dam, Keduang sub-basin was not so popular that it did not receive special attention. In fact looking back before the big flood in Solo river basin in 1966, Solo river basin as the biggest river basin itself even did not have a special attention by the government of Indonesia. Since the declaration of independence in 1945, the very first government cabinet of Indonesia already had a ministry of public works, which took over *Ministrie van Verkeer en Waterstaat*, the public works department under Dutch colonization.

When it was still under the Dutch colonization, Solo River Basin was getting a high attention. As mentioned in the introduction chapter, flood occurrence in Solo river basin had already happened even before the independence of Indonesia. Apparently, flooding already occurred way back in the 19th century, as the Dutch at that time tried to develop a canal system in Solo valley, a diversion channel in Gresik and an irrigation system in Bengawan Jero but got cancelled due to financial issue (Ravesteijn, 2017). Despite of those cancelled projects, there were still some works done in Solo river basin, one of which is very important to this research, which is a diversion channel of Solo river mouth. Initially Solo river mouth was located in the Madura strait. However, due to sedimentation problem a new canal made to divert the flow directly into Java Sea, because there is Tanjung Perak port, a hub port for the east part of Indonesia, in Madura strait, that the Dutch engineers were afraid that the sediment would destroy the sea transportation (Balai Besar Wilayah Sungai Bengawan Solo, 2018).

Figure 21 The new river mouth of Solo River

The construction of diversion canal does not mean that Keduang sub-basin at that time already had a sedimentation problem. That case was for a whole big Solo river basin so the erosion could be from other sub-basin than Keduang sub-basin. But still, it implies that human activities along Solo River that could cause erosion, especially agriculture, already existed during Dutch colonization. In fact, Dutch colonial government introduced new plants to be planted in Solo river basin, such as coffee, sugar and cotton (Rachman, 2017).

The agriculture activities must have continued even after Dutch colony left Indonesia. On contrary, the attention of the government to the development of Solo river basin did not seem to continue after the independence of Indonesia. It is understandable, because there could be some good reasons behind that. First of all, Indonesia just started a new government and at that time, there were only few educated people, especially engineer. Furthermore, after declaring the independence in 1945, Indonesia still faced some conflicts, especially with Dutch who still wanted to take over Indonesia, until in 1949 they gave up. Later in 1960s Indonesia faced a conflict with the communist movement. After that incident and Soeharto became the president, the new government cabinet was reformed and it looked well-structured. In 1968 a new decree issued by the minister of public works regarding the organization of the ministry.

A year later in 1969, following up the flooding in 1966, the ministry of public works began to focus on specific cases, one of which is Solo river basin. Even though at that time it did not make a new separate department that focus on the management

of Solo river basin, the ministry of public works created a project based team to solve the problems in Solo river basin. In 1969 *Badan Pelaksana Proyek Bengawan Solo* or can be translated into Solo river project team was created to solve the problems in the basin. Back then it felt like the attention was only given if there was a problem, not because there was a need of a proper management on natural resources. Thus, at that time there was no sign of the ministry of forestry involvement, or any other governmental bodies in the Solo river basin management. The cooperation with JICA which resulted in the construction of Gajah Mungkur dam also was done through this project team.

4.2 Current stakeholders

In the current condition, there are many stakeholders involved in the case of sedimentation in Keduang sub-basin. In this section the explanation will be divided into part. First it focuses explaining the government, then next will explain the society and at the end will explain the external actors.

4.2.1 Government

The most obvious division can be made is the government. It is not simply just dividing the government based on their administrative area, like sub-district and regency government, but it can be divided into agencies that every one of which dedicates to a specific field of expertise. There are several agencies of government that are related to the sedimentation issue of Keduang sub-basin, which include:

a. Balai Besar Wilayah Sungai (BBWS) Bengawan Solo
b. Balai Pengelolaan Daerah Aliran Sungai (BPDAS) Solo
c. Perusahaan Umum Jasa Tirta I (PJT I)
d. Badan Perencanaan Pembangunan Daerah (BAPPEDA) Wonogiri
e. Dinas Lingkungan Hidup (DISLH) Wonogiri
f. Dinas Pertanian dan Pangan (DIPERTAN) Wonogiri

Between those agencies, BAPPEDA Wonogiri, DISLH Wonogiri, and DIPERTAN Wonogiri are all under the regency government of Wonogiri, that they are directly responsible to *Bupati* (Regent) of Wonogiri. In fact, there is also another agency under the regency government which should be very relevant, which is *Dinas Pekerjaan Umum* (DPU) Wonogiri, or can be translated to public works agency. In DPU Wonogiri, it also has a water resources section which should also work on river

basin management. However, after examining all relevant decisions and actions toward the sedimentation issue, DPU Wonogiri has not shown any relevant works to the issue. This could happen as there is also BBWS Bengawan Solo, which is a national level agency under the ministry of public work of Indonesia. The fact that the sedimentation is big and has become national issue, the scale of works is too big for DPU Wonogiri to handle, that all works related to infrastructure such as check dam construction have been done by BBWS Bengawan Solo. Therefore, DPU Wonogiri is not included in this research, even though it is included in a stakeholder analysis of upper stream Solo river basin management (Yudi Lastiantoro & Andy Cahyono, 2015), in which they did not explain in details about the role of DPU Wonogiri in the river basin management.

There are actually few more agencies under regency government of Wonogiri that have connection to the issue such as *Dinas Kelautan dan Perikanan dan Peternakan* (DISPARLENAK) Wonogiri, which is the fishery and livestock agency, and *Dinas Pemberdayaan Masyarakat dan Desa* (DINAS PMD) Wonogiri, which is the community and village empowerment agency. However, the other agencies only have a minor connection to the issue, especially in terms of land use because this is the main cause in the sedimentation issue that will be explained further in the next chapter. For example, the high sedimentation causes fisheries in Gajah Mungkur Dam affected, but there was no action found by DISPARLENAK that related to the sedimentation issue or action that affected Keduang sub-basin in general; the amount of fishermen are way lower than farmers on a first place. Thus, only these 6 agencies are taken into consideration in this research.

4.2.1.1 BBWS Bengawan Solo

Balai Besar Wilayah Sungai (BBWS) Bengawan Solo is a national level agency under the ministry of public works and public housing of Indonesia, specifically water resources directorate general, which is responsible in managing Solo river basin (*Balai Besar Wilayah Sungai* literally means big office of river territory). It is a national level agency due to Solo river flows through two different provinces; Central Java and East Java. Being a sub-basin of Solo river basin, Keduang sub-basin is also in the hand of BBWS Bengawan Solo. BBWS Bengawan Solo is basically the same as *Badan Pelaksana Proyek Bengawan Solo* created in 1969. But, instead of just a project team, it is already a separate agency from the ministry of public works.

According to the article 19 of Ministry of Public Works and Public Housing of Indonesia regulation number 20/PRT/M/2016 about organization and working procedure of technical implementation unit in the Ministry of Public Works and Public Housing, BBWS's duty (in general, not specifically to BBWS Bengawan Solo) is to manage water resources in the appointed river basin, which includes planning, construction, operation and maintenance in order to conserve and utilize water resources, as well as damage control in water landscapes such as rivers, shores, reservoirs, lakes, irrigation systems, swamps, ground water and springs. It is also responsible in the management of primary urban drainage systems.

Important to mention that even though BBWS manages a river basin as whole, but because BBWS stands below the ministry of public works and public housing, it is only interested in the technical aspects in the river basin. Their interest in only technical aspects is also supported by the 4 keywords that are stated in the regulation above: planning, construction, operation and maintenance. Thus, when talking about river basin conservation, BBWS does not care about land uses and forestry in the area, and only cares about technical conservation in the river such as dam construction and operational. In Keduang sub-basin case, it does not mean BBWS Bengawan Solo does not realize the land use issue, but it cannot do anything about it. Instead what it can do is to incorporate other agencies to help solving the land use issues. Other thing that BBWS does to support on managing river basins, BBWS is also responsible on the hydrological data in the basins, that they must provide measurement instruments and record the data regulary.

As the owner of Keduang sub-basin, in theory BBWS Bengawan Solo has high power and high interest in sedimentation issue. It must be underlined that its power and interest are only limited to engineering works only. However, in reality its power and interest is not as high as an owner should have. The reason is because its responsibility in managing the basin is shared with PJT I, which will be explained further in the next section.

4.2.1.2 BPDAS Solo

Like BBWS Bengawan Solo, *Balai Pengelolaan Daerah Aliran Sungai* (BPDAS) Solo, or can be translanted into Solo river basin management agency, is a national level agency that manages Solo river basin. The difference with BBWS Bengawan Solo is that BPDAS Solo is under the Ministry of Environment and Forestry. Thus, the

focus of BPDAS Solo is on the land management aspect of the basin, while BBWS Bengawan Solo focuses on technical aspect.

According to the Ministry of Environment and Forestry of Indonesia regulation number P.10/Menlhk/Setjen/OTL.0/1/2016 about organization and working procedure of river basin management agency, BPDAS's duty (in general, not specifically to BPDAS Solo) is to conduct planning and implementation of forest and land rehabilitation, as well as land and water conservation. It is also responsible for water damage control, and evaluation on river basin and protected forest management.

This agency is crucial in the sedimentation issue, as the main cause of the over sedimentation is the land use change from forests to agricultures. Thus, a good forest management is believed to be the key solution for the issue. BPDAS Solo fills the gap in the river basin management that is not taken care of by BBWS Bengawan Solo, which is the land management aspect. BPDAS Solo's position is somewhat similar to BBWS Bengawan Solo, that it has high power but not so high interest, due to the existence of PJT I, which is more focus on the river basins around Gajah Mungkur Dam, while BPDAS Solo manages the whole Solo River Basin.

4.2.1.3 PJT I

Perusahaan Umum Jasa Tirta I (PJT I), formerly known as PJT without the number "I", is a government-owned entity that specializes in water service. The idea of establishment of this entity was first emerged in the early 1970s, following the completion of 2 reservoirs in Brantas River. The idea came out due to the potential funding problem that might be faced by the government in order to operate and maintain existing water infrastructures at that time. The funding issue could lead to poor operation and maintenance on infrastructures that their technical age and performance could become below the expectation. Thus, a business entity in water services was initiated as a solution to such issue. After studies were conducted from early 1980s until late 1980s, in 1990 PJT was established with working area in the region of Brantas River Basin.

As the water infrastructures had increasingly developed in Indonesia, in 1999 the government issued Government Regulation no. 93/1999 about the corporality of PJT, which rebranded PJT into PJT I, which focused only in Brantas River Basin. Meanwhile, PJT II was also established which focused on Jatiluhur reservoir in West

Java. Later in 2000, PJT I started to also operate in Solo River Basin, specifically on the upstream part around Gajah Mungkur Dam (which includes Keduang sub-basin), which was appointed by Presidential Decree no. 129 year 2000. Until now (2018) PJT I is still operating in both river basins.

The main duties of PJT (still applicable to PJT I) are stated in the Minister of Public Works regulation no. 56/PRT/1991 about General Operational Policy of Jasa Tirta Public Corporation, which include:

a. water resource facilities maintenance and operation
b. water resource exploitation
c. management of River Basin Area such as: conservation, development, and utilization of water resource
d. water resource facilities rehabilitation (based on company duties)

Even though PJT I is not a governmental agency, it can be categorized into government, due to its duties which does not only work as a business entity, but PJT I also has a river basin management responsibility in its operational, in other words it governs the river basin. That is why it was mentioned before that the BBWS Bengawan Solo's interest and power are not as high as expected to be as the owner of Keduang sub-basin. In fact, the scope of PJT I management could be said wider than BBWS Bengawan Solo. PJT I's works are not limited to specifically manage the basin in the technical or engineering area. PJT I manages the basin as a whole that its works also include land conservation. As an entity, PJT I is also responsible in doing Corporate Social Responsibility (CSR) that the CSR can also contribute in the river basin management from its social, economy or environmental aspect.

In terms of interest on the sedimentation issue in Keduang sub-basin, PJT I definitely has high interest, that it might be higher than BBWS Bengawan Solo, due to the fact that BBWS Bengawan Solo focuses on the whole Solo River Basin, while. PJT I focuses only on the basins around the Gajah Mungkur Dam, which is only approximately less than 20% area of Solo River Basin. The power of PJT I, however, is not very high. From the infrastructure aspect, PJT I can only operate and maintain them, while planning and construction are in the hands of the ministry of public works, in this case it is represented by BBWS Bengawan Solo. PJT I can only suggest the development of infrastructures if needed.

4.2.1.4 BAPPEDA Wonogiri

Badan Perencanaan Pembangunan Daerah (BAPPEDA), which can be translated as Regional Development Planning Agency, is an agency that is responsible in the development planning of its area. BAPPEDA is the regional level agency of *Badan Perencanaan Nasional* (BAPPENAS), which is the development planning agency of the country.

There are two types of BAPPEDA in terms of work area, which are provincial level (first level) and regency or municipality level (second level). The first level BAPPEDA is responsible directly to the governor of the province in helping on development planning, while the second level BAPPEDA is responsible directly to the regent or mayor of the area.

Its duties were stated in Presidential Decree no. 27 year 1980, specifically on article 5 for first level and article 6 for second level (both contain similar points, the only difference is the scope). There are 9 duties stated in the decree, which are:

a. compose the fundamentals for long term development planning and 5 years planning
b. create the 5 years development planning
c. create yearly development programs
d. conduct planning coordination between related agencies
e. set regional budgeting in coordination with financial bureau and secretary of the region
f. conduct and coordinate researches on development issues
g. follow up the preparation and implementation of development plans
h. monitor the implementation of development plans
i. conduct other development-related activities that are appointed by the head of the region (governor or regent or mayor)

It is very apparent that BAPPEDA in the sedimentation case in Keduang sub-basin has an important role. One of the important products of development planning, either the 5 years or long term planning, is land use planning. Land use planning is very important in sediment management, as mentioned in the methodology section that land use affects the amount of sediment produced in an area. However, land use plan is not formulated based on environmental value only. Land use plan is also

formulated based on other values such as economy and health. Thus, the plan cannot just direct the regent to plant as many trees as the area can have to reduce erosion, without thinking about the allocation area for residential and industrial purposes. That is why coordination is an important keyword in the duties of BAPPEDA. The development planning is not only a single agency work, but also multi-agencies work.

Important to note that in the sedimentation issue on Keduang sub-basin, only the second level BAPPEDA is involved, which is BAPPEDA Wonogiri, under the regent of Wonogiri. The fact that Keduang sub-basin is located almost entirely in Wonogiri Regency makes the development of the area inside Keduang sub-basin is in the hand of the BAPPEDA Wonogiri.

BAPPEDA Wonogiri has definitely a high interest in the sedimentation issue of Keduang sub-basin, as its development planning should take the issue into account. However, the interest is not as high as BBWS Bengawan Solo and PJT I as BAPPEDA Wonogiri does not specifically work on that issue, but only take the issue into account. In terms of power, however, BAPPEDA Wonogiri can be said has high power because BAPPEDA makes the development master plan that needs to be obeyed by all people.

4.2.1.5 DISLH Wonogiri

Dinas Lingkungan Hidup (DISLH) Wonogiri, or environmental agency of Wonogiri if translated into English, is an agency that manages the environment of Wonogiri. DISLH is a second level agency under the regent of Wonogiri. DISLH Wonogiri's main duty is to realize a clean and green environment for the prosperity of Wonogiri. The scope of its works include not only on waste management and building permit, but it also covers forest management. Unlike most regencies in Indonesia that has forestry agency that is responsible for their forests, DISLH Wonogiri is also responsible in managing forest areas in Wonogiri. Works that are done by DISLH in order to achieve its vision include planning phase, implementation, monitoring and evaluation all environmental related programs. Some of the programs that are conducted include reforestation, building permit issuance and counseling.

Forest management is actually new for DISLH Wonogiri. It was appointed in 2016 by the regent of Wonogiri at that time, through the Regent of Wonogiri regulation no. 58 year 2016 about arrangement, position and working procedure of regional organization of Wonogiri Regency. In the regulation, there was no *Dinas Kehutanan*

dan Perkebunan (DISHUTBUN) Wonogiri, which can be translated as the agency of forestry and plantation. DISHUTBUN Wonogiri was known as a former agency that was responsible for forest and plantation management in Wonogiri, that it was included in the important stakeholders in a stakeholder analysis research on upper Solo River Basin management (Yudi Lastiantoro & Andy Cahyono, 2015). Prior to the regulation, the duty of forest management was transferred to DISLH Wonogiri. The decision of merging 2 agencies into only environmental agency followed the composition of the ministry in the working cabinet of President Joko Widodo since 2014, that he decided to merge ministry of environment and ministry of forestry into one ministry under the name ministry of environment and forestry.

Actually, DISLH Wonogiri's duties on forest management is not that apparent, due to the existence of BPDAS Solo, which is really focus on that matter. However, unlike DPU Wonogiri which is excluded in the analysis, DISLH Wonogiri is still included due to its important duty that is very relevant to land management, which is issuance of building permit. As the whole area of Keduang sub-basin lies in the administrative area of Wonogiri Regency, DISLH Wonogiri is the only agency that has rights to issue building permit in the area. Based on that duty, DISLH Wonogiri cannot be considered having high interest in the sedimentation issue, as it was already covered by BPDAS Solo and PJT I. However, due to its right to issue building permits, DISLH Wonogiri can be considered having a moderately high power to the sedimentation issue, as its action has a relevant connection to the issue.

4.2.1.6 DIPERTAN Wonogiri

Dinas Pertanian dan Pangan (DIPERTAN) Wonogiri, which can be translated to agency of agriculture and foods, is the agency under regent of Wonogiri that is responsible in agriculture and foods. Its vision is to have a good agriculture condition and zero hunger. As the agency stands at the same level as DISLH Wonogiri, DIPERTAN Wonogiri's duties and responsibilities in general are similar with DISLH Wonogiri, but DIPERTAN Wonogiri concerns on agriculture and foods. Thus, DIPERTAN Wonogiri's works also include planning phase, implementation, monitoring and evaluation all agricultural and foods related programs. Some of the programs that are conducted include improving productivity by conducting counseling and giving loan to small scale farmers.

Due to the sedimentation issue, DIPERTAN Wonogiri has changed its perspective in agriculture management. Now, DIPERTAN Wonogiri also concerns about environment, that it has encouraged farmers to do a sustainable farming, instead of just concerning about high productivity and high profit. It makes DIPERTAN Wonogiri has changed its interest from low to high. This change could be caused by 2 factors; first the coordination from BAPPEDA Wonogiri, and second the sedimentation in the river indirectly affects water supply for agriculture in the basin. Therefore, DIPERTAN Wonogiri is also an important actor in solving the sedimentation issue. It has a high power to manage the agriculture areas that if they are poorly managed, it will cause a poor land condition that can increase the erosion.

4.2.1.7 Hijau Lestari

Hijau Lestari is a government-owned entity that specializes in agribusiness. The establishment of this entity came from the fact that in Indonesia there were many agribusinesses that did not operate responsibly, for example they cut trees that were not in the criteria which was issued by the government, or they did not do reforestation after the trees were cut. To solve these issues, in 2007 Hijau Lestari was established. The establishment of this agribusiness entity was hoped to still maintain agribusiness sector, but at the same time also concerns about the environmental value. Thus, just like its name (*hijau* is the Indonesian word for green, and *lestari* is the Indonesian word for sustainable) its vision is not only to earn high profit from the business, but it is also expected to help in achieving sustainable land management. By making its own business entity, the government can monitor the practice agribusiness more easily and effective. Not only that, Hijau Lestari was created to also incorporate local community, so that small businesses, which was very difficult to monitor, could end then the people would join Hijau Lestari instead. To attract local communities, Hijau Lestari also proposed a consumer cooperative business model, so people would get their benefits directly from their activites.

It is unclear when Hijau Lestari started to operate, as very few sources could be found, but until now (2018) it has operated in 4 provinces, which are West Java, Banten, Central Java and East Java. All of them are in Java Island. Wonogiri is one of its operational area. Programs that have been done are not only related to forest products, Hijau Lestari also helps in improving local livestocks. In Wonogiri, however, it focuses on forests-related activites.

In terms of interest, Hijau Lestari in Keduang sub-basin can be classified as a stakeholder that has high interest. As one of its vision is to have a sustainable agribusiness practice, sedimentation in Keduang sub-basin has become an important matter that acts as the indication of its success in achieving sustainability. While having high interest, Hijau Lestari only has moderate power, as all activities they do in the area, it must get a permission from the authorized agencies such as DISLH Wonogiri.

4.2.2 Society

Society here refers to the people living in the Keduang sub-basin, which has been mentioned before that majority of the people are farmers. In regards to the sedimentation issue, farmers hold an important role. Poor land use is identified as the major problem in the sedimentation issue, and farming activities contribute in it. Thus, for this case farmers represent the society.

To assess society position in the sedimentation issue, a division can be made according to their area as they can give different perspective. Praptadi (2013) divided the society into 3 different groups, which are upstream, middle and downstream. According to him, the upstream and middle group has a very low awareness regarding the poor condition of the basin, while the downstream group has relatively higher awareness than other groups, though still on the moderately awareness level. It is in fact due to the upstream and middle group had not observed a bad impact that affect their life, on the other hand the downstream group had observed the changes in the river that they could see the sedimentation happened in the basin.

Talking about power of society is tricky in this case. Theoretically, society must have low power and the government has high power. However, as mentioned before, people in Keduang sub-basin have a low awareness of the poor condition of the basin, that even though there have been many programs done by the government that involved local community such as socialization and counseling, the participation level was always low which lead people to still do a bad agriculture practice (Indrawati, 2016; Praptadi, 2013; Pudjianto, 2009). Furthermore, in Keduang sub-basin around 70% of its area is owned by society, therefore the decision on how the land is used mostly comes from society, as the land owners, not government (Indrawati, 2016; Sutrisno et al., 2013; Widyaningsih, 2008). Thus, it cannot be said that common people only have low power, because what they have done were impactful to the

sedimentation issue. Interestingly, it can be said that society can have higher power when the government has lower interest. If the government really have had a high interest in the issue, they would have really done their programs seriously by always monitoring the programs they made. But in reality, the government failed to do so, for example DISLH Wonogiri with BPDAS made a counseling session about what plants should be planted so that people could benefit both financially and environmentally, but because people did not have a high awareness and the government did not follow up the program after the counseling session, people did not follow what the government taught (Indrawati, 2016). Thus, it shows how society's power is higher than expected, due to the lower than expected interest that the government has.

4.2.3 External actors

External actors are people that are outside of Keduang sub-basin, but have a relevant action or decision to the sedimentation issue. There can be in various forms, which apparently in Keduang sub-basin, there are two types of external people found that have done something relevant to the sedimentation issue. The first type is researcher, which did research regarding the sedimentation issue. Sedimentation issue in Keduang sub-basin has been quite popular especially for local universities around Wonogiri such as UGM Yogyakarta and UNS Solo. Not only researches about water resources, many researches done regarding the sedimentation issue come from various fields such as agriculture, forestry, agribusiness, economy and sociology. The second type of external people is donator. The reason why researchers do research on Keduang sub-basin is not only because the sedimentation issue that has become a national issue, but also because often researchers are engaged by a government agency such as PJT I or BPDAS Solo. This way, JICA as a main consultant in Solo river basin management can also be considered as an external actor, because JICA is hired by the government.

Donator here refers to someone who donate or do a voluntary work that has an impact to the sedimentation issue. In 2016, a collaboration of Indonesian Red Cross Society (PMI), International Federation of Red Cross and Red Cresent Societies (IFRC), and Zurich Insurance Indonesia made a program called Community Flood Resilience, in which they planted about 6,000 palm trees along Keduang river that was expected to help preserving the river basin ("Enam Ribu Pohon Aren Ditanam

Sepanjang Sungai Keduang," 2016). This voluntary work also coordinated with PJT I as the local representative.

As the sedimentation issue in Gajah Mungkur Dam in general, or specifically in Keduang sub-basin as the largest contributor, has become a national issue, makes the issue interesting for external people to get involved in, especially researchers as there are many researchers have done their researches regarding the issue. However, as mentioned before, it only interests mainly local universities around Wonogiri. Meanwhile for donators, there was only one event found. It is understandable because it can be due to 2 reasons. The first one is, Indonesia is still facing many problems that many donators prefer to donate or do voluntary works on other issues. The second reason is that the scale of the sedimentation issue is huge that it needs a huge donation or work to have a significant impact, just like the Community Flood Resilience that planted a very big amount of palm trees.

To assess its position, external people should be divided into two different people; researchers and donators, because both are different. While researches may only have a very low power, as the best they could only do is to give recommendations, donators can be in a position with a moderate power. If the donation or is huge, it can have a very significant impact, which means donators can have a high power. In term of interest, both can be identified as having a moderately low interest. As mentioned before, there are many other issues in Indonesia, that can be more interesting for researchers to do their research or donators to donate on.

There is another important thing that only the external actors have, which is neutrality. As they do not live in the system and do not really have a benefit from the system (except new knowledge and experience for researchers and satisfaction for donators), their act can remain neutral and without any motif.

4.3 Formal network of actors

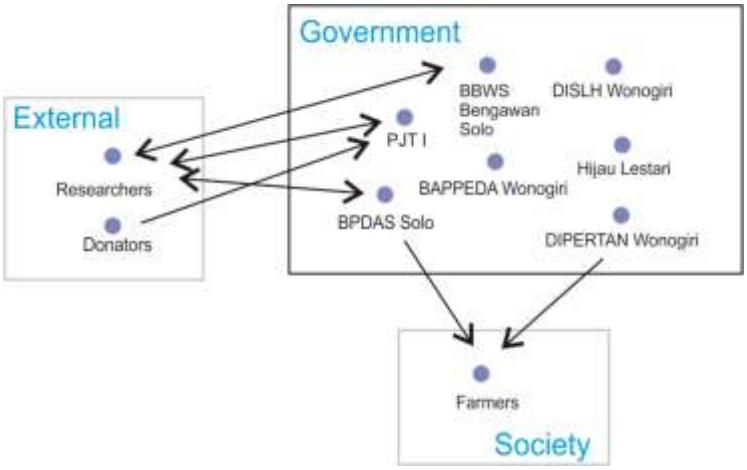

Figure 22 Formal network diagram in Keduang sub -basin

There are 3 groups of stakeholders in Keduang sub-basin: government, society and external. The connections between stakeholders can be seen on Figure 22. There are top-bottom one-way connections between BPDAS Solo and DIPERTAN Wonogiri to farmers. Both BPDAS Solo and DIPERTAN Wonogiri have had programs to encourage good agriculture practices in Keduang sub-basin, but there is no feedback from the farmers. Another interactions between stakeholders can be seen between researchers and 3 different government agencies: BBWS Bengawan Solo, PJT I and BPDAS Solo. Unlike the connections the farmers have, these connections that the researchers have are 2 way. These 2 way relations show that not only the government agencies hire the researchers for input, but the researchers can also work independently by interest, then in the end deliver the results to the related agencies. Obviously there are supposed to be many connections in between the government box. However, to simplify the government box is drawn with bold black border instead to show that inside the box, all stakeholders interact with each other.

4.4 Stakeholder overview

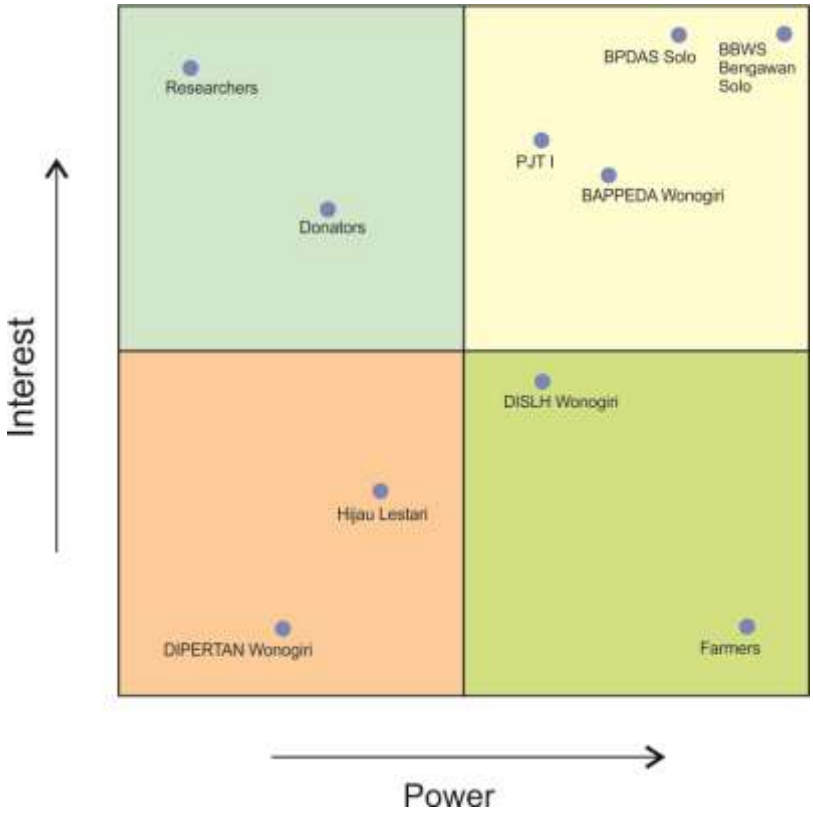

Figure 23 Power-interest grid of sedimentation issue in Keduang sub -basin

The overview of stakeholder analysis can be seen on Figure 23. The grid shows the power-interest of stakeholders, specifically towards the sedimentation issue. It shows that there are 4 key players, which are BBWS Bengawan Solo, BPDAS Solo, PJT I and BAPPEDA Wonogiri. BBWS Bengawan solo has higher power than BPDAS Solo as infrastructure works seem to have more immediate impacts than land management. However, as both own the basin, both have the same interest. Between those4 key players, BAPPEDA has the lowest interest because it does not only focus on the Keduang sub-basin issue, but Wonogiri as a whole. Some of its other programs may contradict to sedimentation issue, thus the interest is lower. PJT I has the lowest power between the key players because technically it is not a real government agency. Some actions that PJT I wants to do must be granted by the related government. However, PJT I still has a relatively high power, which makes it in the key players, because PJT I operates Gajah Mungkur hydro power plant, which is one of the main electricity source of Java. Thus, the importance of its existence makes it has high power. It can demand water for the operational of the hydro power plant.

Farmers have very high power, but low very low interest. As technically they do not really feel the impact of sedimentation in the river, they can be considered to have a very low interest. However, due to their actions, which will be explain more details in the next chapter, they have huge impacts to the sedimentation problem. Alongside with farmers, DISLH Wonogiri also is considered as context setters. It does not have high interest, because its works do not include sedimentation problem specifically. However, the ability of making building permits makes DISLH Wonogiri has a high power.

Both external actors are considered interested subjects. They have high interests, but very low power. Researchers have higher interest because the issue is more interesting to them. Contrary, there are many other causes for donators to donate on. However, donators have slightly more power because their actions have direct impacts. On the other hand, researchers only do and present research, which does not always end up being implemented. Thus researchers have the lowest power in general.

DIPERTAN Wonogiri and Hijau lestari are identified as crowd, which means they have low interest and power. Sedimentation is not their concern at all, however their works indirectly have impacts on the sedimentation, such as agriculture development and agribusiness. Hutan Lestari has higher power because forest utilization is believed to be more impactful than agriculture, which will explain more details on the next chapter.

5 Historical events analysis

In this section, all relevant actions and decisions that have been taken in regards to the sedimentation case in Keduang sub-basin will be presented. Not only actions or decision that caused the sedimentation, in this section the responds from the sedimentation case will also be represented.

5.1 Forest exploitation program

One of the most important events which contributed to the poor land use practice, not only in Keduang sub-basin but in Indonesia in general, is the forest exploitation program. It was not literally named 'forest exploitation program', the name was used in Rachman (2017) to emphasize the effect of a government decision made in 1967. In order to open up investment from local and international, a set of regulations was issued in 1967. One of the regulation, Law number 5 year 1967, was related to business in forestry. The regulation stated about how the government had the rights to determine whether a forest area is considered a regular forest or a conserved forest. Moreover, the regulation stated that the government had the capability to give permission for forest business rights (*Hak Pengusahaan Hutan* or HPH in Indonesian), that in a way it gave easier access for people, either a big company with high capital or individuals with low capital, to utilize the forest for business than before (Rachman, 2017). The only requirement to get HPH for a new business was to pay a license fee and some royalty. The results of this, many forest businesses were developed; in 1988 about 52 million hectare, or about 37.1% of total forest area in Indonesia was "owned" by 531 HPH holders (Rachman, 2017).

The downside of this big business in forestry was the business owners failed to preserve the forest. The government already made a program called *Tebang Pilih Indonesia* (TPI), which basically told people in the business to only cut trees that were in the criteria (e.g. size and size) in order to prevent the negative effects of such business development on forestry. However, many people disobeyed it (Rachman, 2017). Besides that, the government also tried to make reforestation programs in around 1976 and 1977, but unfortunately nothing succeeded, because back then the environmental impact did not really apparent, that made people did not really care with the programs (Indrawati, 2016).

Figure 24 Deforestation activity on Keduang river bank in 2017 (private documentation)

This practice of bad forest utilization for economy purposes, especially in around Wonogiri, still continues until present days. Figure 24 shows a deforestation activity which happened in 2017 at a river bank area of Keduang River near the inflow to Gajah Mungkur Reservoir. It clearly shows the timbers that had been cut down ready to be transported by the yellow truck. Even worse, it was done on a river bank, where it is supposed to stay planted with hard vegetation to help strengthening the river walls so it prevents erosion.

5.2 Transmigration and agriculture expansion

The construction of Gajah Mungkur Dam inundated 51 villages that consisted of about 14,000 households, therefore those affected people were needed to be relocated. The government decided to make a transmigration program for the affected people. In Indonesia, transmigration is defined as a migration of people from an area with high population density to an area with low population density. Transmigration was chosen to also support decentralizing Indonesia's population, as most people were, and still are, located in Java Island; in 1971, 63.83% of Indonesian population lived in Java Island (76,086,327 people of 119,208,229 total Indonesian population), despite area of Java Island is only approximately 7.29% of total land area of Indonesia. The transmigration program (it was called *Bedhol Desa* which can be translated to moving an entire village) was planned to relocate the affected people to several places

outside Java Island, such as South Sumatera, West Sumatera, Jambi and Bengkulu (Utami & Trilaksana, 2015).

The transmigration program should not have any effect on the sedimentation issue on the upper basin of Solo River. However, it actually had some impacts. In general, the program was done successfully, that people were willing to join the program. The fact that at that time Indonesia was in the presidency of Soeharto, was known to be authoritarian, helped in the success of the transmigration program. Even though the enforcement was strong at that time, some people were against the program, that they would not want to move to other island, or some people that already moved then came back (Utami & Trilaksana, 2015). The evidence can be seen clearly in Figure 18 that in 1980, the population of Wonogiri sub-district significantly increased. This increase followed by the rapid decrease of Nguntoronadi sub-district population, in which many people were the target of the transmigration program. Moreover, due to most of people were farmers, an expansion area of agriculture then occurred, thus it changed the land use of the area that in the end caused in higher erosion and sedimentation.

The expansion of agriculture in Keduang sub-basin still continues until present days, which is expected as it is the consequence of population growth. However, this expansion gets worse as farmers, at least until 2016, still did bad practices of agriculture due to their low awareness on environmental issues practice (Indrawati, 2016; Praptadi, 2013).

5.3 A new type of sediment

In natural process, sedimentation in river basin consists of materials that come from eroded soil, which mainly are clay and silts because both particles are small and easy to transport. However, in Keduang sub-basin there is also another type of sediment which is domestic garbage such as plastics.

Figure 25 Garbage removed from Gajah Mungkur Dam in 2007 (Japan International Cooperation Agency, 2007)

Garbage is an issue in Wonogiri. It was reported that as of May 2018, only 79% of total garbage produced daily in Wonogiri are transported into the dumpsite (Susanto, 2018). According to Nurwigati (2018), as of February 2018 people in Wonogiri produced 341m^3 of garbage daily and it was estimated to increase in the future. Hence, around 71.61m^3 of garbage are untreated daily. So where do they go? Most likely, with people low environmental awareness, they end up in the river. As can be seen in Figure 25 so many domestic garbage found in Gajah Mungkur reservoir. What makes it interesting is that, their behavior throwing off garbage into the river is a feedback respond of the changes in the river flow. The river used to have a clean and clear water that people used to wash anything from their bodies to their appliances there (Indrawati, 2016; Kompas, 2008). But once the water in the river became opaque, which one of the cause was the high sediments flowing into the river, they stopped washing anything in the river. Even worse, they started to throw away their garbage into the river, thinking that it was already dirty that it would never come clean again (Indrawati, 2016)

It is unclear since when they shifted their behavior, as the sources did not mention about the specific time. One thing for sure that they must have not used the water in the river for washing after 1985, in which people started to realize that Gajah Mungkur reservoir had received so many sediments, that several sediment measurements were conducted in that year (Table 1). Looking at the result of sediment measurement in Table 1, there was a probability that around 1975 people still used the water in the river, because in 1975 the sediments was only around 20% of the sediment measured in 1985, which was significantly different.

5.4 Not so successful river basin rehabilitation programs

After the finding on how high the actual sediment was in Gajah Mungkur Dam in 1985, Indonesian government started to make programs that could solve the problem. There are 4 big programs that have been done, and are still happening. The programs are:

a. Rehabilitasi Hutan dan Lahan (RHL)
b. Model DAS Mikro (MDM)
c. Pengembangan Usaha Tani Konservasi Lahan Terpadu (PUKLT)
d. Gerakan Nasional Kemitraan Penyelamatan Air (GNKPA)

All programs were not made specifically for Keduang sub-basin or upper Solo River Basin to solve the sedimentation issue in Gajah Mungkur Dam. They are all national programs that can be implemented in the area that are needed.

Rehabilitasi Hutan dan Lahan (RHL) can be translated to forest and land rehabilitation. RHL has been happening since 1950ish, decades before the issue in Keduang sub-basin. It was created because in Indonesia even before the "forest exploitation program", deforestation in Indonesia had already happened hundreds years back in the colonization era, when Dutch colony especially sent woods back from Indonesia to the Netherlands for heating materials in winter or making furniture (Rachman, 2017). However, there was no significant environmental impact such as sedimentation and pollution that could be observed at around that year, thus the early program of RHL was only to encourage people to plant trees in their garden, which was called Karang Kriti program that was started in 1950ish (Indrawati, 2016).

It is not clear when RHL was first introduced to Keduang sub-basin. In Keduang sub-basin, BPDAS Solo is responsible for the RHL programs. There have been many programs done in the forest area in Keduang sub-basin. However, all programs were not well documented that the exact time when the programs started are unclear. RHL programs can be classified into 2 types: community empowerment and land work.

Community empowerment programs of RHL that have been done in Keduang sub-basin are as follows:

a. Tutoring on improving creativity and knowledge
b. Business development

c. Legality access for business development
d. Incentive for low budget farmers
e. Giving access to market
f. Developing a network between farmers and business owners

The idea of these community empowerment programs is to give knowledge to local community, especially about land management so that people can gain awareness. Furthermore, to compensate the sustainable farming or plantation that are encouraged, which could lower the income of local farmers, RHL programs also include knowledge transfer in business related topics, as well as creating networks and markets. From these activities, it is hoped that even though the farmers cannot expand their land, or only able to plant certain types of plants, their products can still give good income.

Besides community empowerment, RHL programs also include land works directly to the area, such as reforestation, making public forests and building conservation structures, such as terraces and infiltration wells. Even though the start of RHL in Keduang sub-basin is unknown, the start development of public forests in Keduang sub-basin is known; it started in 1990 and since 2004 it started to have a more organized planning (Handayaningsih, 2009). RHL in Keduang sub-basin is still far from success, even though many works have been done. One of the main cause is there was no continuity in the program, for example after trees were planted, they were not monitored and maintained (Kumalajati, 2017; Nawir et al., 2007). Not to mention that apart the poor maintained trees that have been planted, there are still big land areas that have not been well treated. Kumalajati (2017) estimated that 5,047.56 ha area needed to have reforestation, and 16,607.62 ha bare area needed to be planted with trees.

Other than RHL, BPDAS is also responsible for a program called *Model DAS Mikro* (MDM), which can be translated into micro river basin model. Basically, MDM is just a smaller version of RHL, as it is called micro. The idea is that the management of river basin is divided into smaller areas of the whole river basin. By using this program, a more bottom-top approach is expected, as it really focuses a specific small area. MDM consists of very similar programs like RHL, which include community empowerment and land work, however, MDM more focuses on community empowerment. By focusing on the people, MDM expects to give more awareness to

people that would make them coming out with their own solutions to the land issues. Having their own solutions means that local community would have a sense of belonging to their area, that in the end the land management could be sustainable.

In Keduang sub-basin, MDM has been implemented 7 villages: Bubakan, Sanan, Semagar, Selorejo, Wonorejo, Wonokeling and Petung (Indrawati, 2016). Those 7 villages are parts of Naruan basin, a sub-basin of Keduang basin. There were various works done by MDM program in those villages, which are making public forests, multipurpose tree species plantations, plantation of smaller crops between big trees, building a community center that serves as a meeting place for farmers, as well as for training and tutorial purposes.

While MDM is a smaller scope program than RHL, the works done in the program could be more suitable to local communities, as it really cares about the characteristic of communities in a rather small area. However, due to RHL is a bigger scope program than MDM, RHL is supported by some regulations, such as Law no. 37 year 2014 and president instruction on reforestation year 1978-1988. As a national program, RHL must be done by BPDAS or local forestry agency if there is no BPDAS, in the area that has land and forest problems. On the other hand, MDM is not a national program that it is only a program proposed by BPDAS as a follow up to RHL. Therefore, the implementation of MDM cannot be forced as it does not have a law that enforce it. Thus, in Keduang sub-basin, MDM program has not been successfully done, because people there (especially in the 7 villages that have MDM), who have low awareness, cannot be forced to follow the program (Indrawati, 2016).

In general, people in Keduang sub-basin have low awareness, not only those in the 7 villages that have MDM program. As most people there are farmers, bad awareness leads to bad agriculture practices. It is apparent that farmers in Keduang sub-basin are ignorance towards environmental impacts due to their bad agriculture practices. In order to solve this issue, a program was created called *Pengembangan Usaha Tani Konservasi Lahan Terpadu* (PUKLT), a program that is done by DIPERTAN Wonogiri. PUKLT means development of integrated farming business and land conservation in English. This program focuses not only on giving farmers guidance in good agriculture practice, but also developing farming business. Again, it is unclear when the first time this program started was, the only thing that can be known is that it has been going for years.

PUKLT is very important in Keduang sub-basin, as has been mentioned many times that the existing agriculture practice done by the farmers harms the land, that in the end causes the sedimentation issue. It is not that they choose to do bad things, but it is because they are not well informed, especially about environmental impacts. They just do what the older generations did, and they only concern about their profit. From this fact, PUKLT was initiated.

There are at least 4 major issues in the existing agriculture in Keduang sub-basin, which PUKLT tries to solve. The first one is the type of crops. In land management, especially to prevent erosion, big and strong trees must be planted especially in slope area to strengthen the soil. The problem is, such trees require longer time to harvest that farmers think not profitable. To solve this issue, through PUKLT, farmers have been given seeds or young trees such as mango, rambutan and durian, which have fruits and can be harvested regularly when matured. Not only those woody plants, PUKLT also has given some other seeds such as rice and corn that are more suitable environmentally.

The second issue is cropping pattern. There are 2 different cropping patterns done in Keduang sub-basin (Wiryanto, 2014), which are rice-rice-secondary plants for farmers with rice fields, and rice in rainy season and other plants that can survive in dry condition, such as corn, sweet potato, peanut and soy bean outside rainy season, for farmers with dry land. Regardless which land the farmers have, both are alike in terms of how many types of plant are planted in each season; both are monoculture. However, polyculture agriculture is believed to be a more environmentally friendly, especially it can prevent erosion. Therefore, one of PUKLT's missions is to introduce polyculture agriculture in Keduang sub-basin. That is why besides big trees such as mango, rambutan and durian, PUKLT also has given seeds of smaller plants such as coffee, which can be planted in between big trees.

Figure 26 Poor river cliff condition in Keduang River (private documentation)

The third problem is about the land. Many farmers do not care about the land they farm on, that their farming activity can worsen the sedimentation problem. An example can be seen on Figure 26. In the figure taken in 2017, it shows corn field on a cliff, which looks very vulnerable to erosion. The problem with the picture is that the farmers who cleared the land for their corn field left the cliff open that it could easily eroded. The farmers should have either made terrace or left trees that were originally on the cliff. There it also shows that there were young trees planted along the cliff, which is an approach to prevent more erosion. That is one kind of works that is done in PUKLT program. However, in the picture, it is unclear who did the plantation of trees along the cliff. Not only planting trees, PUKLT also has done some construction works such as terraces and drainage channel in order to preserve land.

The last problem is regarding to farmers' profit. One of PUKLT's main goals is to improve farmers' wealth. In order to achieve that, some PUKLT programs have been done such as donation of good quality seeds and fertilizers to farmers, and conducting workshops for farmers. However, the latter is only a small portion of PUKLT, as this kind of works is more of RHL program, which focuses on community empowerment.

Keduang sub-basin with its sedimentation issue was one of the first basin that was proposed to have an integrated water management system, instead of a

traditional water management system. A program was created to follow up this idea, which is called *Gerakan Nasional Kemitraan Penyelamatan Air* (GNKPA), or can be translated to national movement of water rescue partnership. There is a keyword that makes this program different than the traditional water management, which is partnership.

Initiated by former president Susilo Bambang Yudhoyono in 28 April 2005, GN-KPA was expected to be a big water management program that covers all aspects. Before that, water management especially river basin management had been done separately by different agencies, that they did not have much coordination between them. In Keduang sub-basin for instance, BBWS Bengawan Solo and BPDAS Solo had been doing their works separately without considering each other views, that BBWS Bengawan Solo might not know how large area that had had reforestation, and vice versa, BPDAS might not know how many infrastructures would be built. As mentioned before, there is BAPPEDA Wonogiri that serves as a coordinator, but BAPPEDA only focuses on planning phase, thus coordination between agencies only existed on the planning phase but not on the implementation phase.

The main objective of GN-KPA is to rescue water resources in Indonesia, as can be seen from its name. GN-KPA is important because at that time when this program was initiated, Indonesia already had many critical condition water resources. Traditional water management that had been done was not enough to restore the critical water resources, thus an integrated water management, that should give a better management, was initiated. Nonetheless, Indonesia at that time had not had an integrated water management system, thus such program was necessary to start. The initiation of GN-KPA came also with 6 elements that were to be included in the program, which are:

a. Spatial planning, physical development, land management and population
b. Forest and land rehabilitation, and water conservation
c. Water damage control
d. Water quality management
e. Water saving and water demand management
f. Fair, efficient and sustainable use of water

GN-KPA in Keduang sub-basin involves all related agencies, which were mentioned on the government part in stakeholder analysis section. Not only those 7 big actors, GN-KPA also involves smaller less relevant agencies such as DISPARLENAK Wonogiri, and DINAS PMD. As GN-KPA was proposed to involve as many agencies as it can, they are included in GN-KPA program as supportive agencies.

As a program that covers all aspect, GN-KPA includes both technical and non-technical works. All previous programs that had been done had become parts of GN-KPA, such as RHL, PUKLT and infrastructure development.

Even though there have been many programs to solve the sedimentation issue, unfortunately the programs seem to be not successful. There are 2 indications can be observed. First, the land use was not getting better, but it was getting worse, as can be seen on Figure 17 and Table 5. The second indication is, the total suspended soil (TSS) in the Gajah Mungkur reservoir increased overtime, especially during 2013-2017 (Sudarsono et al., 2018). The TSS distribution in Gajah Mungkur reservoir can be seen on Figure 27, that TSS in 2017 was the highest, and in 2013 was the lowest.

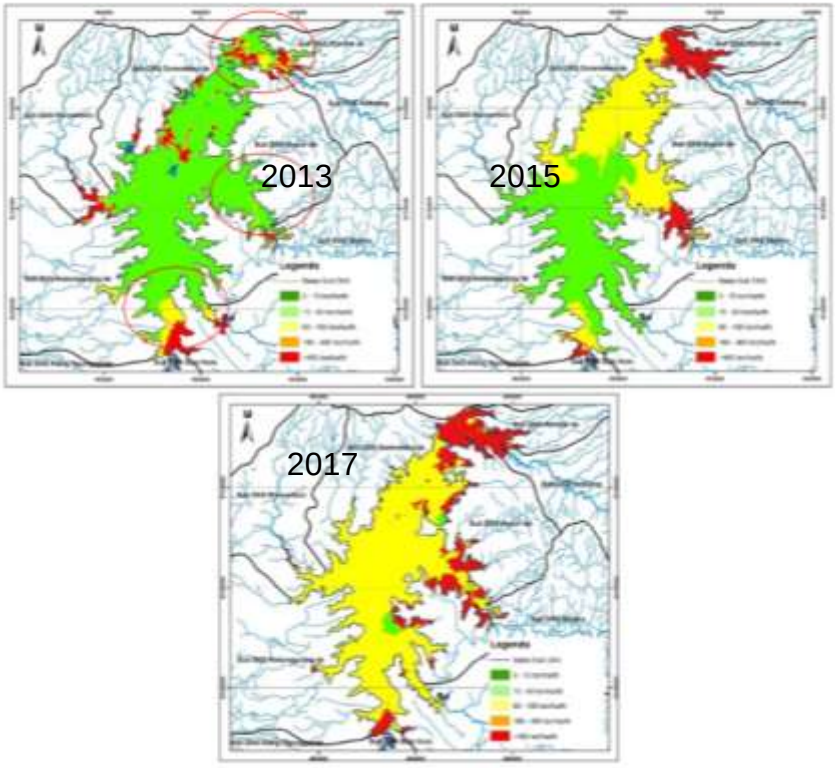

Figure 27 Map of concentration distribution of TSS Gajah Mungkur Reservoir in 2013, 2015, and 2017 (Sudarsono et al., 2018)

5.5 Infrastructure works

Talking about problems in a river cannot be complete without mentioning about infrastructure. After all, one of the most fatal problems caused by the over sedimentation of upper Solo River Basin is a damage to an existing infrastructure, which is Gajah Mungkur Dam. As the owner of the infrastructure, BBWS Bengawan Solo also tries to solve the problem by developing other infrastructures that can serve as a support.

There are 2 big water infrastructure works that have been developed and constructed in Keduang sub-basin. The first one is check dams development. Check dam is a small dam constructed across a stream to counteract erosion by reducing water flow velocity. By adding a massive object which is higher than the surface water level makes the gradient of water flow becoming flatter, thus the flow becomes slower, which in results the erosion due to high velocity flow can be reduced. Usually, check dam is not constructed only one in a river, but it is constructed as a series of check dams, depending on the length and slope of the river. As Keduang main stream is long, which is around 37.82 km, and has a quite steep slope, which is around 0.035, a series of many check dams can be found.

It is not really clear when was the first check dam constructed in Keduang River, as already mentioned in the methodology section, BBWS Bengawan Solo could not be reached for data. However, the amount of check dams constructed along the river can be observed. By 2015, 21 check dams had been constructed in Keduang, and 1 of them were broken (Mahmud, 2015). The broken check dam means that its sediment capacity is already full that it cannot store more sediment. Apparently, even though the basic idea of check dams is to control stream velocity, check dams in Keduang sub-basin seem to server more as a sediment catcher, so that it will not flow to Gajah Mungkur reservoir. It can be seen from the research done by Mahmud (2015) that he did an analysis on how effective check dams could block sediment for flowing into Gajah Mungkur reservoir.

Even though there are 21 check dams constructed in Keduang main stream, does not mean they contribute a lot in preventing sediment flowing into Gajah Mungkur reservoir. Mahmud (2015) estimated that by the condition in 2015, there is about 19,013 m^3/year sediment that cannot be retained by check dams and flows to Gajah

Mungkur reservoir, that within less than a year if there was no dredging work on check dams, all check dams' capacity would be completely full.

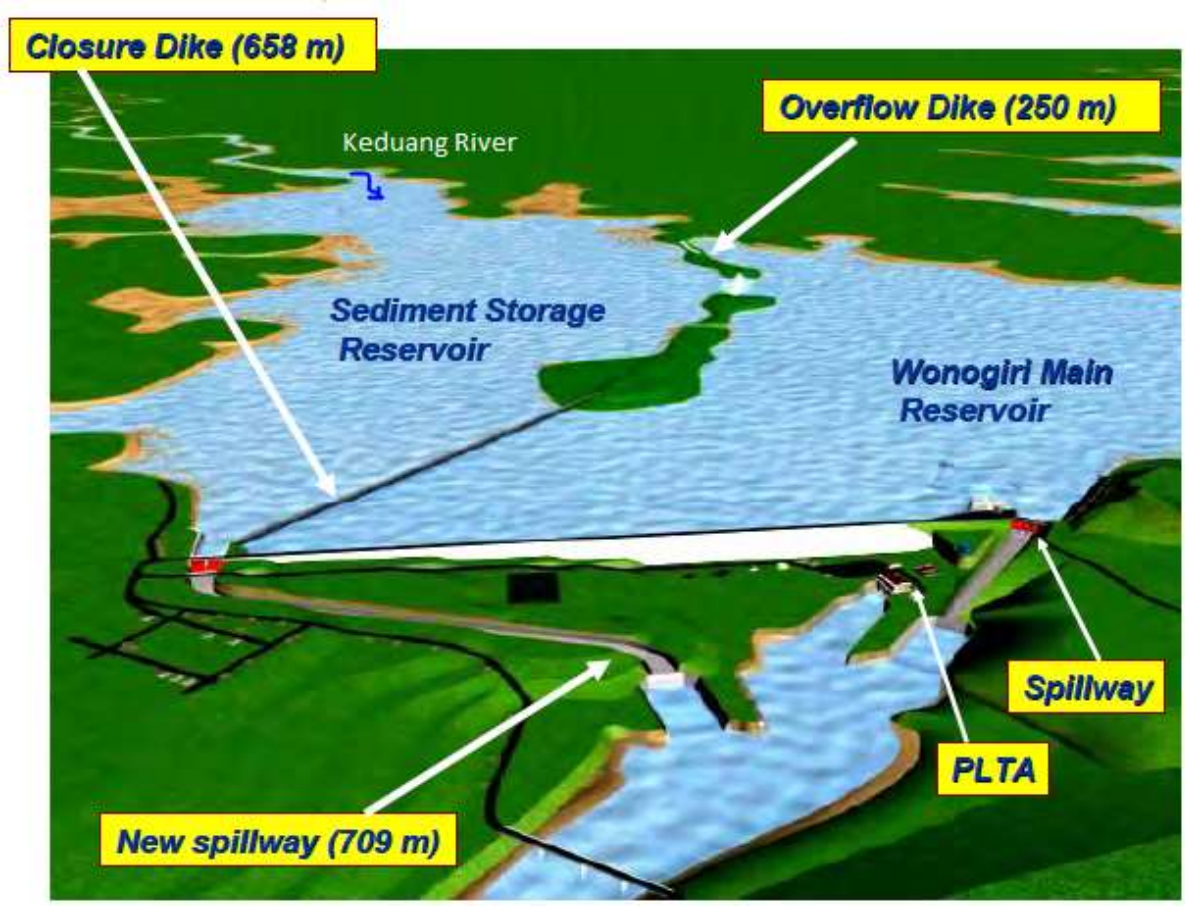

Figure 28 The concept of closure dike in Gajah Mungkur Reservoir (Japan International Cooperation Agency, 2007)

Along with dredging works on sediments that are retained on check dams, JICA in 2007 proposed another infrastructure to be constructed that was expected to help preventing more sediments, which was a closure dike (Japan International Cooperation Agency, 2007). The dike was planned to be constructed to divide Gajah Mungkur reservoir into 2 separate reservoirs, as can be seen on Figure 28. The closure dike would block the sediments, specifically from Keduang sub-basin, flowing to the main reservoir. A new spillway was planned on the Keduang part of reservoir, which Japan International Cooperation Agency (2007) named as sediment storage reservoir, to flush the sediment.

A study from an independent group of researchers was done to review the performance of this closure dike plan in Gajah Mungkur reservoir (Sardi et al., 2009).

Their research showed that the closure dike could lower the deposition of sediment in the main reservoir about 30.41% than in the condition without a closure dike. It also shows that the without a closure dike, a turbulence flow is happening in the reservoir that it flows with low velocity and going around in the reservoir, which helps the suspended sediments to be settled down in the reservoir. That is why many sediments had been deposited in Gajah Mungkur reservoir.

In 2011, the ministry of public work of Indonesia finally announced the construction plan of this closure dike. The construction was planned to start in 2012 with a total cost of about Rp 320 billion[3]. As of 5th March 2018, the construction of the closure dike had not finished, as can be seen satellite image taken from Google Earth (Figure 29). However, from the same figure the new spillway and the overflow dike can be already seen.

Figure 29 Gajah Mungkur Dam during wet season in March 2018 (Google Earth)

[3] It is about US$ 35,296,000 with the currency exchange rate on 1 January 2012.

6 STEEPLE analysis

Looking at some developed models on socio-hydrology, researchers only incorporated social element(s) that have direct relation(s) to the hydrology system, for example the model developed by Chen et al. (2016) which only incorporated human sensitivity into the model. However, it is also important to examine external factors that can affect in decision making processes.

The importance of analyzing external factors is very apparent in this research. Looking at the historical event analysis, there is much information missing that can explain on how an actor took a specific decision or action. For example, even though the over sedimentation had been identified in 1985, why it took about 20 years for BBWS Bengawan Solo to develop a grand design to solve the issue by hiring JICA.

In this chapter, all 7 elements of STEEPLE will be analyzed from different actors' point of view, based on their decision, action or behavior that have been explained on the previous sections.

6.1 Socio-cultural

The easiest way to obtain a general characteristic of people in a certain area is to check its Human Development Index (HDI). HDI is a statistical tool used by United Nations Development Programme (UNDP) for assessing the development of a country from people point of view. HDI was created because the development of a country cannot be assessed only based on economic growth alone, but it can also be assessed by looking at the people. HDI of all countries are published annually in the Human Development Report.

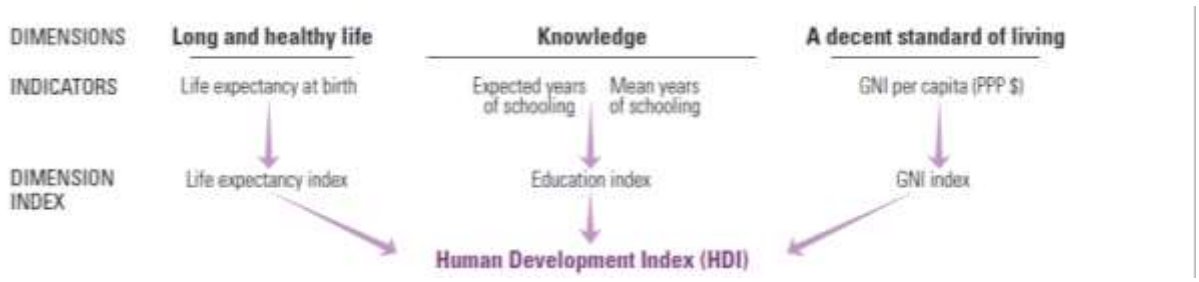

Figure 30 The principle of HDI (UNDP)

HDI consists of 3 different dimensions which are the key dimensions of human development: long and healthy life, knowledge and standard of living (Figure 30). The

long and healthy life dimension is assessed by looking on life expectancy at birth. The knowledge dimension is measured by mean of years of schooling for adults aged 25 years and more and expected years of schooling for children of school entering age. The standard of living dimension is measured by gross national income (GNI) per capita.

Not only UNDP, Statistics Indonesia also publishes HDI numbers of provinces and regencies in Indonesia. However, there are differences in the method of obtaining HDI number done by Statistics Indonesia. Instead of income per capita, Statistics Indonesia uses expenditure per capita as the indicator for the standard of living dimension. Not to mention, the currency used by Statistics Indonesia is Indonesian Rupiah instead of US Dollar. The other difference is in the formula, in which Statistics Indonesia has different value of maximum and minimum in the calculation (e.g. the minimum and maximum expenditure).

In this socio-cultural section, only the knowledge dimension will be observed. Later in the economics section, the standard of living dimension will be observed. According to Statistics Indonesia, the mean years of schooling for adults aged 25 and more in Wonogiri was only 6.68 years, which made Wonogiri ranked at 96 of 119 regencies in Java Island only[4]. Just looking at the ranking, it can be said that education level in Wonogiri is bad. That number means that in average, adult people there only graduated elementary school. For reference, in Indonesia it takes 12 years to graduate high school normally, and 16 years to obtain a bachelor degree normally. This number is bad, especially in Indonesia, it had been known for long to have a campaign that everyone must at least have 9 years of formal education, which is until middle school[5].This was even lower than the average of all regencies in Java Island, which was 8.03 years.

It is important to note that the number applies for the whole Wonogiri, not only area that is in the Keduang sub-basin. However, this low number seems to really reflect on the people in Keduang sub-basin. It has been mentioned several times

[4] To make a fair comparison, only regencies in Java Island are taken into account, as areas outside Java Island in general have lower quality in many aspects such as education, facilities and infrastructures.

[5] Since Joko Widodo became the president in 2015, the government started a new campaign that people must have 12 years of school education.

before that people in Keduang sub-basin have low environmental awareness. This is one of the results of the low education level there. It is also identified that other than formal education, people in Keduang sub-basin do not keen on learning something from other sources. People in Keduang sub-basin have low interest in reading magazines, newspapers or other sources of media (Praptadi, 2013).

The low willingness to learn something new is most probably the main reason why many river basin programs have not been so successful. Some solutions to solve the land use issue that causes over sedimentation in Keduang sub-basin include changing the behavior of farmers, such as planting other types of crops and changing crop cycle. The fact that people have low education level and low willingness to learn something new, makes it hard to change their behavior. Especially, looking at their low formal education level, it is most likely that their activities, especially agriculture activities, do not come from advanced agriculture studies, but come from traditions which most probably have been done since thousands years ago, as an evidence can be found in Borobudur temple, which is believed to be constructed in around 770, that one of the reliefs shows a farmer plowing a rice field. It is indeed difficult to suddenly change a tradition that has been done for a very long time.

Other than low education, people in Keduang sub-basin also have low confidence (Indrawati, 2016). This low confidence makes it even harder to change their behavior, because it means they cannot be easily taken out from their comfort zone. On the other hand, low confidence can also mean that they would trust people with higher experience or education than them, thus it also shows that their participation level on counseling or workshop is moderately high (Indrawati, 2016; Praptadi, 2013). But still, without guidance, after a program is finished they will go back to their previous behaviors, due to the low of confidence and also supported with low education level.

One other thing that explains why people there still do the same agriculture practice, even when their economy condition is bad, is their creativity is also low (Indrawati, 2016). Low creativity, supported with low knowledge, makes farmers can only farm for their income. They cannot do something else even though their economy becomes worse. That is why instead of changing to another work, people there prefer to expand their agriculture area, something that they are capable of.

There is another component of knowledge dimension of HDI, which is expected years of schooling for children of school entering age. In contrary, this number in Wonogiri is high, which is 12.44 years. It means that the present and future generation is expected to have at least 12.44 years of formal education. Does it mean that the socio-cultural characteristic of people in Keduang sub-basin will change? Most probably it will remain the same or just change slightly, because a research found that young generation in Keduang sub-basin, who have a better education, tend to move to bigger cities to pursue better career (Kusumaningsari, 2013).

6.2 Technological

Technology is a very important factor in the decision making process, especially in developing infrastructure. Technology affects the decision on the type and features of infrastructure, for example the invention of pump made Dutch people abandoned windmills for transporting water from downstream to upstream. However, talking about the sedimentation issue, technology is not an important aspect. First of all, there has been no new technology regarding sediment control in a river. Infrastructures like check dam and slope terraces have existed since long ago. Thus, technology is not a relevant aspect from infrastructure point of view.

From land management point of view, however, technology can be very relevant. For example, with wireless technology, a monitoring system consists of cameras and alarm can be installed for monitoring forests. However, such things do not exist. It means, even though there is a new technology that can be implemented, it does not affect the land management.

Figure 31 A pile of firewood can be found in front of a house in Jatiroto sub-dstrict (Google Street View)

There is one interesting technology related thing that is very relevant to the sedimentation issue, which is cooking technology. It turns out that most people in Keduang sub-basin still use firewood for cooking, which demands people to cut trees regularly (Wiryanto, 2014). Wiryanto (2014) stated that there was a case where green belt trees were planted by a government body, but not long after that they were gone because people cut them down for cooking. It is understandable why people do that. With the not so good economy condition there, they better get firewood for free than paying for gas.

6.3 Economic

It has been mentioned before in the socio-cultural section that HDI can also be used to check the economy of people, by looking specifically at its standard of living dimension. Statistics Indonesia uses expenditure per capita for standard of living dimension. According to Statistics Indonesia, in 2017 the average expenditure per capita in Wonogiri was Rp 8,765,000 per year, or about Rp 730,500 per month[6]. For this case, comparing it with other regencies cannot be done, as it is unfair to compare it with other area that composes of people that work on different sector. Not to mention,

[6] It is about US$ 53.99 with the currency exchange rate on 1 January 2012.

living cost varies in different regions. The closest thing that it can be compared with is to the average income stated in Afrianto (2017). In 2017, it was reported that in average farmers in Indonesia earned only Rp 1,000,000 per month[7], which was classified poor .(Afrianto, 2017). Poor describes a situation where someone is lacking sufficient resources to live at the standard living condition, which means that with income Rp 1,000,000, the actual needs to live in a comfortable condition cost more than that. Thus, according the HDI data from Statistics Indonesia, people in Wonogiri can be said to have way lower than the average income of farmers in Indonesia.

Yet again, the analysis done by Statistics Indonesia does not specifically represent only the area of Wonogiri in Keduang sub-basin. A more specific assessment on Keduang sub-basin must be done. Especially, it is too soon to say that the economy of people in Keduang sub-basin is bad, based on the comparison with the national average income of farmers. There are other variables that must be observed to assess the economy condition of people in an area, such as living cost and crops produced in case of farmers, as it is often that they consume their own crops entirely or partly instead of selling them all.

Kusumaningsari (2013) and Mandala (2013) did a poverty analysis in Keduang sub-basin. Both were done using 4 different methods, which are Sajogyo[8], World Bank, Food and Agriculture Organization (FAO) and Asian Development Bank (ADB). The only difference is Mandala (2013) analyzed each households, that it resulted in the ratio of people who are poor and not poor. On the other hand, Kusumaningsari (2013) used the average data, thus it only gave whether people in Keduang sub-basin are poor or not poor. The results of both poverty analyses are shown on Table 6.

[7] It is about US$ 73.90 per month with the currency exchange rate on 1 December 2017.
[8] Sajogyo is an Indonesian professor in sociology. He is often known as the father of rural sociology in Indonesia (https://id.wikipedia.org/wiki/Sajogyo).

Table 6 Poverty analysis of people in Keduang sub-basin

Method	Kusumaningsari (2013)	Mandala (2013)
Sajogyo	Not poor	6.67% poor 93.33% not poor
World Bank	Not poor	58.34% poor 41.66% not poor
FAO	Poor	73.33% poor 26.67% not poor
ADB	Not poor	38.34% poor 61.66% not poor

Table 6 shows that both Kusumaningsari (2013) and Mandala (2013) got the same result using FAO, that people in Keduang sub-basin are considered poor. Both also got the same result using Sajogyo and ADB, which in average people in Keduang sub-basin are considered not poor. The World Bank method, however, shows different results on both researches. What interesting is that, looking at the results of analysis by Mandala (2013), the ratio varies a lot on different methods. From this variation, the most possible conclusion can be made is that most people in Keduang sub-basin are located at around the poverty line. Even though almost all people in Keduang sub-basin are considered not poor based on the criteria in Sajogyo method, but it can be due to most of them are just slightly over the poverty threshold, so when they are assessed using different methods that have different criteria and threshold, some of them become classified as poor.

This conclusion can be considered valid, because it is supported by other findings from observation and another researches. As stated on the previous section, many people in Keduang sub-basin still use firewood for cooking. This condition also implies how bad the economy situation there is. Moreover, it has also been mentioned about the low possession of magazine or newspaper subscription. It turns out not only that, but in general people in Keduang sub-basin spend a very low amount money for tertiary needs such as entertainment (Praptadi, 2013). Nevertheless, many of them can still afford their primary and some secondary needs (e.g. vehicles), and some of them even own a proper house (Indrawati, 2016).

Still, even though many of them can afford their primary needs, they just barely live with a very minimum quality (e.g. firewood for cooking). Their position is close to the poverty threshold. This bad economy condition is believed to be one of the causes of poor land use in Keduang sub-basin. Poor farmers in Keduang sub-basin tend to do bad practice agricultures, such as expanding their area by doing deforestation, because they only care about short term profit, so that they can live (Mandala, 2013). Furthermore, due to their low awareness, they do not care about conservation at all, not to mention that conservation activity itself needs an additional cost, which is impossible to do for poor farmers (Kusumaningsari, 2013).

Economics aspect must be assessed also on the government side. Economy is definitely a big concern for government in making decision for river basin management. Especially after the over sedimentation was observed in 1980s, there was a financial crisis in Asia in 1997, in which Indonesia also faced the crisis. That is why it took about 20 years for the government of Indonesia to start doing a big progress in solving the sedimentation problem in Gajah Mungkur Dam, by re-hiring JICA as the engineering consultant.

6.4 Environmental

It is important to note than in STEEPLE analysis, only external factors are looked for. It has been some times the word environmental awareness mentioned in this research. However, the environment refers to the condition of the river and land in Keduang sub-basin, which is parts of the system. Thus, in this part other environmental elements are assessed, such as air pollution and climate.

Apparently, there is no external environmental factor that influence the action or decision making of actors in the system. Thus, this aspect can be ignored.

6.5 Political

Since the first development of Gajah Mungkur Dam in 1970ish, JICA has been chosen to be the main consultant in managing Solo River Basin in general, and Gajah Mungkur Dam in specific. This choice is not without any reason. Politics take role in this matter. In 1958, 14 years after Indonesia declared its independence, the bilateral diplomatic relations between Indonesia and Japan was officially established. After that Japan offered development aid to Indonesia for developing the country. One of the aid offered was to manage the problem in Solo River Basin. This development aid by

Japan, however, was facilitated through JICA. Not only for Solo River Basin management project, but also for other projects. To maintain good relation with Japan, Indonesia had no choice but to accept the aid and hired JICA as the consultant. Especially because in 1970ish Japan started to invest by building factories such as automotive and electronics in Indonesia, that was also important for Indonesia to improve its economy.

Other than international politics, local politics also take role in the management of upper Solo River Basin. After the resignation of President Soeharto in 1998, the political condition in Indonesia was not stable. Especially the resignation happened when the Asia Financial Crisis occurred. Not until 2004 when Susilo Bambang Yudhoyono, the first president of Indonesia that was chosen by direct presidential election, the condition of Indonesia started to look better. From 1998 until 2004, Indonesia was focus on rebuilding its economy, but since 2004 more attention to non-economy sector has been initiated. As mentioned on the historical event analysis section, RHL started to be more organized in 2004, which was a result of a more stable politics. The next year, in 2005, GN-KPA was initiated, a further step to give more attention to river basin management in Indonesia, which also includes Keduang sub-basin.

6.6 Legal

In order to prevent deforestation, the government of Indonesia established Law no. 18 year 2013 about prevention and eradication of forest destruction. In the regulation, it clearly states that cutting trees in forests is prohibited, unless a permission granted by the government.

But as expected from the low education level of people in Keduang sub-basin, not all people know the regulations. From the sampling on 3 villages, only about 24% of people in Keduang sub-basin know about the regulations (Indrawati, 2016). It means, legal aspect does not really affect the society's action in general because only small portion of people know it.

It is even worse, because there has been no punishment from the authority if a person violates the regulation (Indrawati, 2016). It means, it is not only the society that is ignorance towards the regulation, but also the local government in specific because indirectly they allow people to violet the regulation.

6.7 Ethical

The absence of sanction in regards to forest regulation violation may be related to ethical reason, specifically virtue ethics. It is wrong for the government to "encourage" its people to violate the regulation. However, in this case of Wonogiri regency that have many people who are below the poverty threshold, it can be ethically wrong for the government, especially local government to stop their activity to earn money, because if they are stopped they will no longer live. This relates to virtue ethics, that the local government must possess a virtue that is helpful to its people. The government is morally responsible to keep its population living decently.

Interestingly, on a broader view there is an ethical dilemma. Talking about utilitarianism ethics, the government should do something that would gain the highest profit. Forcing the law to farmers that would make them suffer most probably would result in a way higher profit, because the cost for infrastructure work is not cheap. Not to mention, if flood occurs on the downstream the damage can be very high.

It is like a trolley dilemma introduced by Philippa Foot in 1967, where a person is conflicted whether to pull the lever to save 5 people but will kill a person, which is related to utilitarianism ethics because it would produce the best possible outcome, or not to pull the lever and let the trolley hit those 5 people, which is related virtue ethics because as a good human being, one should not kill other human beings.

Nevertheless, it seems like virtue ethics is more dominant in the case of Keduang sub-basin, that the government seems to allow farmers to continue doing bad agriculture practice, and will not give punishment if someone violates the regulations.

7 Socio-hydrology system of Keduang sub-basin

After analyzing the actors, the actions and the external factors, what missing is to combine them all, along with the conceptual socio-hydrology process on sedimentation issue to get a better understanding on the whole socio-hydrology system in Keduang sub-basin. Those 3 analysis are still scattered that they need to

be assembled into one descriptive model, which then will answer the research questions of this research.

In this chapter, the whole of socio-hydrology system in Keduang sub-basin will be explained into two parts. First, a conceptual socio-hydrology model is presented. The next part will explain the dynamic and co-evolution of human and water in the system, which is the basic objective of any socio-hydrology studies.

7.1 Conceptual model

First of all, to give an easier overview of how the socio-hydrology system works in Keduang sub-basin regarding the sedimentation issue, it can be summarized into a system diagram, by expanding the conceptual socio-hydrology diagram shown in Figure 11 and adding the information from stakeholder, actions and external factors analysis. The system diagram can be seen in Figure 32 below.

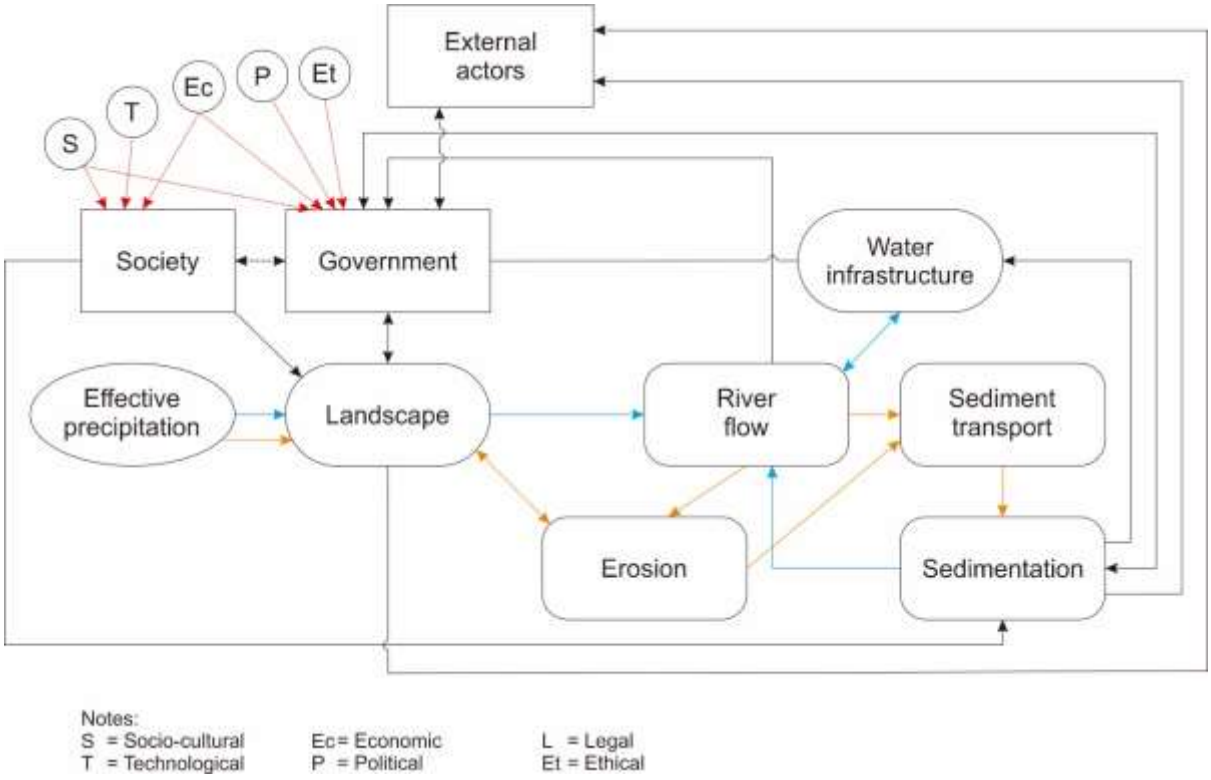

Figure 32 The socio-hydrology system of Keduang sub-basin on sedimentation issue

The first notable difference from the diagram presented in the methodology section is the groundwater element is removed. The reason of this removal is because apparently in Keduang sub-basin groundwater does not have any significant role in this matter. Even though people there mainly use groundwater for their daily needs, but because the area is not densely populated, it does not show any big impacts

especially on the river stream. It could be significant if groundwater extraction there is intense that it significantly changed the groundwater table. Thus, in Keduang sub-basin the groundwater element can just be ignored.

Another simplification can also be observed in Figure 32, which is the government. Even though in the stakeholder analysis there are many actors explained, specifically the government agencies, but those agencies can actually be simplified into only government, for present condition. However, such simplification could not be made for the past condition before 2005. The reason is because in 2005 GN-KPA was introduced, which united all related stakeholder, in this case all government agencies, to a one big integrated water management program. This program aims to reduce conflicts between stakeholders when someone wants to make a decision that is related directly or indirectly to water resources. Every program now is formulated together through a coordination that is hoped to be better than before. It was different before 2005 that every agencies worked independently that they created the programs on each own.

In the end, the actors in the system are only 3, which are the government, the society (which is mainly farmers) and external actors. Note that the connection between society and government in the conceptual model is different with the one in formal network, which is only one way relation. In the formal network, it shows that the government does something to the society, but the society does not do something to the government (e.g. protest or consult). However in the conceptual model, it shows a negative feedback loop mechanism, thus it has a 2 way connection. The government makes programs to the society, such as counseling, based on what the society has. These programs would have an impact that might change the society behavior. The change then would influence the government for the upcoming programs.

In the system, the government has 3 main actions toward Keduang sub-basin that related to the sedimentation issue. The first one is dredging sediment, or in other word removing the sediment that deposited in either Gajah Mungkur Dam or check dams in Keduang sub-basin. The second one is working on land management, which includes several works such as plating trees and making terraces. The third one is developing infrastructures such as check dam. Other than that, the government also works on the sedimentation issue by educating farmers by conducting counseling sessions and workshops. The government also has a connection to external actors.

This connection includes engaging researchers to give technical suggestions on solving the issue and engaging donators to do development project in Keduang sub-basin.

These actions done by the government are influenced by several factors. The most obvious one is the amount of sediment deposited in Keduang sub-basin and Gajah Mungkur Dam. If there is no sediment deposited, the government will not do some works such as dredging and building check dams. The next factor is the river flow. Check dams and terraces were developed by the government to prevent erosion that is caused by the river flow. Not only river flow, in order to reduce erosion, some works the government has done was also influenced by the landscape of Keduang sub-basin. Programs like creating community forests and planting green belt trees were responds to the condition of Keduang sub-basin that having less and less forest area overtime.

Other than those 3 factors, which are internal factors, actions by the government are also influenced by some external factors, which are socio-cultural, economic, political and ethical. The strongest influence can be said comes from economic factor. Economic clearly takes a very big portion of attention in the government decision making process. Even though the sedimentation issue had already identified in 1985, but a big action was initiated only in 2007 by hiring JICA as a consultant, where the economy condition of Indonesia had become better. Furthermore, it took also quite some time to implement the proposal made by JICA in 2007. The construction of additional features in Gajah Mungkur reservoir started 5 years later. The most possible reason why it took 5 years is finance. Unlike other infrastructure such as roads, this construction is done in the reservoir that does not need a land acquisition, which often takes a long time. Thus the only reason should be financial reason, as the construction costed high.

Socio-cultural of people in Keduang sub-basin also influences the action done by the government. For example, the agriculture counselling was created because most of the people in Keduang sub-basin were farmers. However, the influence from socio-cultural is not very strong. The government failed to understand in details the socio-cultural characteristics of the people. This can be explained from the top-bottom approach that the government often came up with something that were not suitable with the people, for example gave seeds of crops that the farmers had no idea how to

grow them. Still related to socio-cultural, the government action is also influenced by ethical factor, specifically on giving no sanction for people who cut down trees, due to the poor economic condition of the people. The other factor that influences the government actions is political factor, especially bilateral relation with Japan. Because of this, all major works are done by hiring JICA as the consultant, not to mention the development aid is also from Japan. The las factor that influences the government is external actors, especially researchers. Researches can give advice in the decision making process done by the government. One example is the agreement of constructing the closure dike proposed by JICA followed the results from a research done by a local university.

There are two actions done by the society toward Keduang sub-basin, especially related to the sedimentation issue. The first one is actions that change the landscape, which mostly is cutting down trees. The second one is throwing off domestic waste to the river that becomes a new form of sediment. Their actions are greatly influenced by external factors, especially their socio-cultural characteristic and economic condition. However, for littering to the river, it is also influenced by the quality of the river. They started to litter when the sediments in the river became high that the river became dirty. Other than the water quality of the river, it is also influenced by socio-cultural factor, which is the low environmental awareness. Low environmental awareness also influences their action of cutting down trees. They do not aware about the impacts of cutting down trees, especially to the river. Another big influence is the economic condition. The bad economic condition makes farmer cutting down trees for agriculture expansion, or other bad agriculture practices that can trigger higher erosion. They mostly only think about short term profit when making decision. Interestingly, the technology that the society has also influences their actions. There is another reason they cut down trees, which is because many of them still use firewood for cooking instead of gas stove.

From STEEPLE analysis, it turns out that legal factor does not have a big influence in the socio-hydrology system of Keduang sub-basin. Thus, it is not included in the system diagram.

7.2 Dynamics of human and water

The first change of the socio-hydrology system in Keduang sub-basin can be observed when the construction of Gajah Mungkur dam began in the late 1970. Many people especially who lived in around Nguntoronadi sub-district had to move because the area would be submerged in the reservoir. That was the first interaction between government and local society, as the government created a transmigration program to relocate those affected people to outside Java Island. The respond is 50-50, as some people did not want to join the program, instead they just moved to nearby villages. At this point, the first interaction between human to water system happened. People who moved nearby then started to change the land use by building houses and agriculture fields.

After the completion of the dam, there was no significant dynamic occurred. People just did what they always did. People used water from the river to water their fields and also for washing. In around 1985 it changed. The water in the river became filled with more sediments that researchers started to begin analyzing the sediment content in the river, as long as predicting the remaining operational age of Gajah Mungkur dam. There were also responds from both local people and governments. People stopped washing their bodies or clothes in the river because the water became not clean. Instead, they started to throw away trash, thinking because the river would never be clean again. On the other hand, governments responded in a good direction, that they tried to reduce the sediment in the river and the dam. Many programs started to come up since then from different agencies, such as MDM, RHL and PUKLT. BPDAS Solo with forestry agencies tried to do reforestation as much as it could. Also they tried to educate people with making counselling sessions. It was intensified in the late 1980 as deforestation issue in Indonesia had become bigger at that time. BBWS Bengawan Solo started to develop infrastructures such as check dam to prevent more erosion coming to Gajah Mungkur reservoir. In 1990, PJT I was created, hoping it can help to manage river basins upstream of Gajah Mungkur dam, so that the operational of Gajah Mungkur dam could be good.

From 1990 until early 2000s many small scale programs were conducted but because people especially farmers did not care much about sedimentation in the river, the programs were not effective. Even worse, in 1997 Asian financial crisis occurred that it affected budgeting on government programs.

In 2004 a big act to try solving the sedimentation issue in Gajah Mungkur reservoir began. It started with the making on GN-KPA which incorporating all related stakeholders in the case. It was the first integrated water management approach done to Keduang sub-basin. At that time local people especially farmers started to get more involved in the programs for reducing sedimentation. However, due to the characteristic of people, such as their economic condition and their awareness towards environment, the programs has not been 100% effective.

Along with smaller programs such as reforestation, dredging and counselling, in 2007 when the economy of Indonesia had got better, Indonesia hired JICA once again to give an input on solving the issue. The result of its consultancy service was a construction of closure dike that would divide the reservoir into 2 parts. Besides that, some other recommendations were also proposed such as planting more trees on upstream area and creating more check dams.

The construction plan began in 2012, 5 years after the study done by JICA, due to economic reason. Until March 2018 the construction had not been completely finished.

Despite having many actions to solve the sedimentation problem, it seems like there has been no significant changes on the hydrology system. It shows in a research that between 2013 and 2017 the sediment in Gajah Mungkur dam was still increasing. The changes of sediment during 1990ish could not be observed due to unavailability of data, but it can be observed indirectly from land uses. Despite Keduang sub-basin having some reforestation programs in the past, but forest area decreased instead.

To conclude, it clearly shows that there is indeed a feedback loop connection between human element and water element in the socio-hydrology system in Keduang sub-basin. Looking at the government, it always has a feedback loop reaction. As long as the sediment is still high in Keduang sub-basin or Gajah Mungkur reservoir, they will keep continue making programs to reduce the sediment, and of course their programs should affect the amount of sediment. However, the programs or actions do not entirely follow the amount of sediment. The higher sediment found in the reservoir does not guarantee the government to do much more intense action. There are many other factors that influence the decision making process. That is why it took about 20

years for the government to re-hire JICA to solve the problem even though the problem was already found out in 1985, indeed because of economic reason.

8 Discussion

After the socio-hydrology has been explained, one research question still remains. How well does qualitative case study approach describe the socio-hydrology of Keduang sub-basins?

First of all, this research focuses more on the social side of socio-hydrology. Therefore, the results of this research give a detail description on human actions in Keduang sub-basin. The description is detail that it also gives explanations on how such actions were done, whether the actions were responds of hydrological changes, or there are other external factors that influence the actions.

This qualitative case study approach is definitely different than the mathematical model approach. In terms of understanding, both give different kind of understanding. The case study approach gives more understanding on "why" aspect. It first gives the action that has actually been done, then explores all factors that influence the actions. Thus, for water managers, this kind of research can give an insight on what things that must be worked on to solve the issue.

Meanwhile, the mathematical model approach tries to mimic the actual river basin using numbers. By adding social variables into hydrology models, the relation between social and hydrology is estimated. Using historical data the model can be calibrated so that the model can give the same result as reality. In the end, mathematical model approach gives more understanding on casual relations between social and hydrology, for example if the awareness of people is at this level, how many sediments will be produced in the basin.

They both are different, so how about combining both approaches to give a more detailed socio-hydrology model? Making mathematical models based on the result of qualitative case study indeed sounds very nice. Imagine the diagram on Figure 32 but with numbers and equations for each elements and connections. However, it is very difficult to do so. As mentioned before in the introduction part, social elements are often very difficult to be incorporated in to mathematical models. For example, how one can incorporate political and ethical element into mathematical model. However, the combination of both approaches can still be done and can result in a better model, but not by taking all the findings from the qualitative case study and

only taking the important elements. At least, even though not all elements are considered, but all social elements that are added in the model are not assumed and reflect the actual condition, unlike the model in Di Baldassarre et al. (2013) that has been mentioned in the introduction part.

Another very powerful advantage of qualitative case study approach is, it can explain the dynamics when some uncertain things happen. In this case, other than regular pattern of feedback loops between human and water, there were some irregular events that could change the system completely, which in a mathematical model where it is full causal certain equations cannot describe. For example the Asian financial crisis in 1997. In this research this phenomenon is used to explain why it took so long until the government took a big action to reduce the sediment in Gajah Mungkur reservoir. But imagine in a mathematical model, unless the model can model a crisis in 1997, the results can be far from reality. Even if the model had a good economic growth model, but because it could not model this unexpected crisis, maybe the model would say the government would be able to make a big step in reducing the sediment by hiring JICA in before 2000, not in 2007, because without crisis the fund would be available by then.

The only problem found in the research is that there are lots of missing information in 1990ish. There was no recorded sediment measurement, as well as well documented government programs. Even though at the end it was found out that the sediment was still increasing in 2013 after a researcher did a measurement, but it can be very useful to know the details. What is known from many literatures is that government programs such as reforestation and counselling continued to run, but the sediment was still high. In the future, it will be nice if all actions and hydrology measurements are well recorded, so it can give a better understanding in the dynamics of the system.

9 Conclusion and recommendation

9.1 Conclusion

Socio-hydrology analysis using qualitative case study research is different than the mathematical model approach. Case study research focuses on reasoning, which means it can give a good understanding on why every actions or responds have been taken in the system. On the other hand, mathematical focuses on quantitative, that it can give a good understanding on causal relations between human and water using numbers. Hence, qualitative case study research is definitely better in giving more details on the social aspects of socio-hydrology analysis. Qualitative case study research works pretty well in describing the socio-hydrology system in Keduang sub-basin, regarding sedimentation issue.

There are 3 main actors in the socio-hydrology system in Keduang sub-basin: society, government and external actors. Society refers to people who live in Keduang sub-basin, and mostly are farmers. The government consists of many government bodies that before 2004 they independently did something to help solving the sedimentation problem. But in 2004 through GN-KPA all government bodies started to coordinate in one big program. This program aims to reduce conflicts between stakeholders, as now they must sit together in order to make a decision towards water related issues. External actors refer to people outside the system that have interest in the issue, such as researchers and donators.

The system clearly shows feedback loop connections, not only between people and water, but also between actor and another actor. The government respond to the high sediment in the system by making programs that can reduce the sediment, such as building infrastructures, reforestation and counselling. The action is not entirely based on the amount of sediment, the decision made by the government is also mainly influenced by socio-cultural of the local people, economic condition, politics and ethics. The government has also a feedback loop connection with society. There were programs that were made by considering the condition of society, e.g. agriculture counselling because most of them are farmers. Also some of the programs tried to change the character of society, e.g. counselling to increase awareness.

The society also has a feedback loop to the hydrology system. Unlike the government, the connection is a positive feedback loop. After the sediment is high, people started to throw trash to the river, which would make the sediment higher in the river. In addition, the bad river condition did not stop them to do bad agriculture practices. Their actions are mainly influenced by their low level of education and environmental awareness, low economy condition, and possession of old technologies.

As it turns out both the government and the society are heavily influenced with external factors such as economic and socio-cultural, a simplified mathematical model like the one which was developed by Di Baldassarre et al. (2013), which focused mainly on the hydrology part with low attentions to social aspects, might not be suitable to conduct in Keduang sub-basin. With variety of factors influence the system, a policy model approach which takes all factors into account without focusing on one of the factors will be more suitable. Furthermore, mathematical model which focus on one of the aspects tends to fail to model uncertain things, as it has a pattern.

One important conclusion is that it is very important to take into account is that socio-hydrology study especially for strategic management purposes must indeed include multidiscipline expert. As explained in the historical event part, there were some unexpected things happened in the system, such as the Asian financial crisis. If the goal of the system is only to understand how the system reacts based on different condition, this qualitative study is enough to answer such question. However, for future strategic management, it cannot be done without predicting the unexpected events, which can only be done only by a hydrologist. For this case in particular, at least economical and socio-cultural factors are the most important factors, thus to predict the future, an economic model and a socio-cultural studies and predictions must be done by the experts to give a good scenario based analysis.

9.2 Recommendation

Qualitative case study research is a good complimentary step before making a mathematical model of a socio-hydrology system. This way it can prevent pre-assumption in the result of the model. This research can be even better if it is done in a team consists of people from different expertise. The writer feels this analysis is a little bit limited in the social, economy, cultural and political aspect because the writer

is not the expert on those fields. Doing this kind of research with people who are expert on those fields could definitely give a broader view, yet more detail understanding in the dynamics of human and water in socio-hydrology systems.

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