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Integration of the Barabai Watershed Flood Channel with the Eco-Drainage System Concept of a Regulation/Retention Pond

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Abstract. Flood is a common problem for Indonesian people, especially during the rainy season. The water flow in the watershed experiences a natural hydrological cycle. The Barabai watershed is a tributary of the Negara River, in the Barito River Basin, South Kalimantan, Indonesia. Almost every year the river overflows, causing inundation and reach the city of Barabai. The flooding that occurred caused damage to river borders and inundated the city, causing the community's life activities to be disrupted. To reduce the flood discharge of the Barabai watershed that entered Barabai City, the Government built an Intake and Flood Channel to divide the flood discharge of the Barabai River (Q_5 years) of 79.79 m^3/s into two parts, namely one that passes through the Barabai Flood Channel of 40 m^3/sec and the other 39.79 m^3/sec continues to flow downstream of the Barabai River. The new intake is built with an intake elevation that is lower than the previous intake building, with the aim that Q2 flood discharge can enter the Flood Channel. However, this intake and flood channel was only able to cope with flooding up to Q_5 with a 62.75% reduction in flood inundation. The concept of integration of the existing flood channel (horizontal flood control system) with a vertical flood control system (regulation/retention pool) is expected to optimize the flood control system that has been built to reduce the peak time of flooding entering the city of Barabai by temporarily holding water in the regulation/retention pool.

Keywords: Barabai River, intake building, flood channel, regulation/retention pond, flood control

Introduction

Watershed management is a human effort to regulate the relationship between natural resources and humans in the watershed and all their activities, in order to realize the sustainability and harmony of the ecosystem and increase the benefit of natural resources for humans in a sustainable manner. Watershed management plans are prepared to maintain and restore their carrying capacity (Government Regulation Number 37 of 2012). An ecosystem is an ecological system consisting of components that are integrated with each other to form a unity. The main components of the Watershed (DAS) include vegetation, land and water, where water acts as a binder of linkages and dependencies between the main components of the watershed/sub-watershed (Asdak, 2010; Edward, 2015; Kenneth, 2015).

In the concept of flood control, flooding occurs when rainfall and runoff exceed the capacity of the river channel to carry the increased flow rate. Arsyad (2006) explains that floods that inundate urban/rural/agricultural areas during the rainy season occur as a result of not being accommodated by surface flows, namely water flowing on the ground surface by rivers and other waterways. Flood control is an action to reduce flood losses (flood damage mitigation). These actions can be reducing flood flow in a channel, decreasing the surface of the flood peak, diverting flood water, and the efforts to make flood resistance and reducing flood runoff.

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Specifically, flood control efforts can be carried out with two methods, namely efforts with buildings (structural method) and without physical buildings (non-structural methods). Structural flood control is principally carried out by building structures or water structures that can increase the capacity of the river's cross-sectional flow or reduce the flowing flood discharge.

Controlling the destructive power of water with the concept of conservation, in principle, is the use of water that falls to the ground as efficiently as possible and the timing accuracy, so that there are no destructive floods in the rainy season and there is enough water in the dry season. Water conservation can be done by; (a) increasing the utilization of two hydrological components, namely surface water and ground water; and (b) increasing the efficiency of irrigation water use (Arsyad, 2000; Kumari & Singh, 2016; Sadeghi, 2010).

The Barabai River in Hulu Sungai Tengah Regency is a tributary of the Negara River, the Barito Watershed has a catchment area of 550 km^2 and the length of the main river is 113.35 km. The existence of the Barabai River on Barabai City is very influential because it is one of the large rivers that flows and crosses the center of Barabai City. Barabai City almost every year experiences floods. In January 2021, there was another very big flood in Barabai City. The flooding that occurred was caused by the overflowing flood discharge of the Barabai River which flows through Barabai City, resulting in rising water levels to urban areas and causing damage to river borders. The floods that have occurred have caused considerable losses in terms of material, physical and non-physical and even fatalities. Frequent flooding in this city is very disturbing people's lives. The planning and implementation of regional development in Barabai City is hampered and causes massive damage and loss of property, especially to residential buildings (lost due to being washed away and damaged), infrastructure such as bridges and roads that require large costs for rehabilitation. In addition, damage to infrastructure buildings has isolated several residential areas, as a result the costs for evacuation and delivery of aid are difficult and expensive. Loss of livelihood in the long term causes economic paralysis of the people affected by the flood.

For handling the flood in Barabai City, the Government in 2004-2005, has built the Barabai Flood Channel which divides the flood discharge of the Barabai River (Q_5 years) of 79.79 m^3/s into two parts, namely through the Barabai Flood Channel of 40 m^3/s and 39.79 m3/sec continues to flow towards the downstream of the Barabai River where in the upstream part of the flood channel a regulatory building is made in the form of an Intake Building and a grounsill which functions to optimize the discharge that enters the Barabai Flood Channel. In 2015 - 2016, new intakes were added with lower intake elevations and rehabilitation/normalization of the Barabai River - Bangkau Lake - the National River as well as the normalization of small rivers that connect Bangkau Lake and Barabai flood channel to their outlets in the State River to reduce flood discharge through Barabai City.

According to Anam (2015) and Anam et al. (2020), flood events in the Barabai watershed have been caused by several factors, namely: (1) The occurrence of extreme rainfall in a long duration; (2) The amount of runoff that enters the Barabai River; (3) The existing capacity of the Barabai River and Barabai Flood Channel is no longer able to accommodate flood discharges; and (4) There is no area that functions as a retarding basin/flood absorption. The flood settlement methods that have been carried out such as making flood channels, normalizing rivers, making embankments, and all kinds of other civil constructions are still not optimal in reducing the flood problem of the Barabai watershed. So that flood control in the Barabai watershed must be planned more comprehensively by integrating the flood control system that has been built with the eco-drainage system flood control using a regulation/retention pool model, so that floods can be reduced continuously and gradually.

The research aims to conceptualize a flood management strategy in the Barabai watershed in reducing flood risk in Barabai City, by integrating conventional flood control methods that have been built with the eco-drainage system flood management method using a regulation/retention pool model.

Methods

Research Location

Research has been carried out in the Barabai watershed, Hulu Sungai Tengah Regency, South Kalimantan (Figure 1). Barabai is a sub-district as well as the administrative center of Hulu Sungai Tengah Regency, South Kalimantan Province, Indonesia. Barabai is located on the banks of the Barabai river and is 165 km north of Banjarmasin City, the capital city of South Kalimantan province.

Hulu Sungai Tengah Regency, with an area of 1,770.80 Km^2 or 177,080 Ha, or 4.57% of the total area of South Kalimantan Province, is the 4th smallest district out of 13 regencies/cities within the province of South Kalimantan with the capital city Barabai, mother distance the city of Hulu Sungai Tengah Regency with the capital city of Kalimantan Province Banjarmasin as far as ± 165 kilometers. The geographical location of Hulu Sungai Tengah Regency is at 2°27'5.213” - 2°46'54.559” South Latitude and 115°8' 56.965" - 115°53' 32.520" East Longitude.

The Barabai River is included in the Barito River Basin Unit, this river stretches from East to West which empties into the Batang Alai River and then on to the Negara River. The Barabai River crosses agricultural areas, settlements, and crosses the capital of the Hulu Sungai Tengah Regency, namely the city of Barabai. The condition of the river slope is relatively flat, causing the flow velocity to be slow and potentially overflowing if the river water discharge rises so that it has the potential for the inundation in the area around the river. During rainy season there are floods and puddles of water, especially in the area around the city of Barabai due to high fluctuations in the water level of the Barabai River during floods which cause backflow of water in the tributaries.

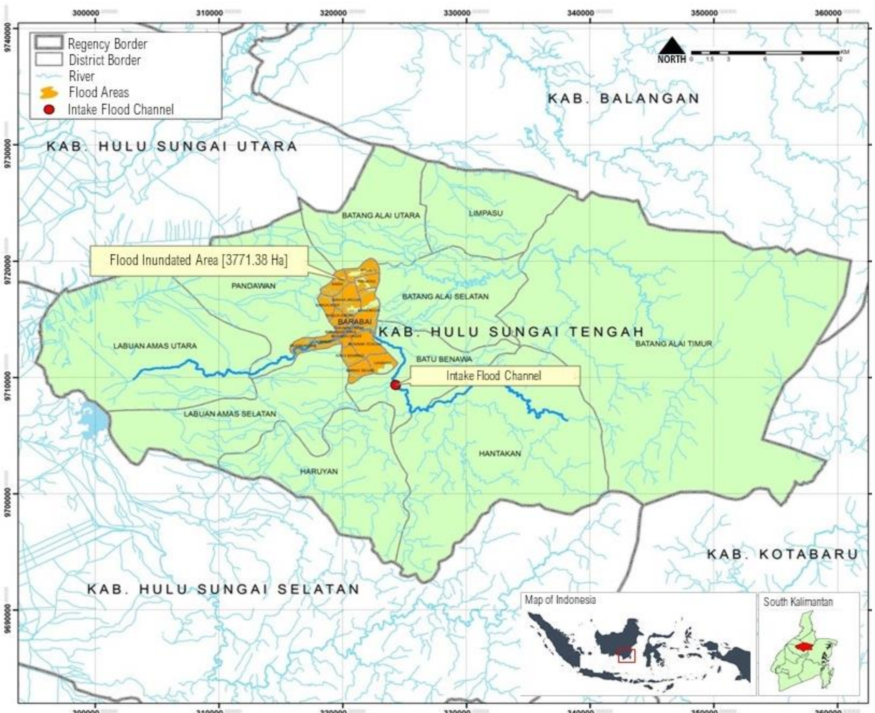

Figure 1. Research location; Barabai watershed, Hulu Sungai Tengah Regency, South Kalimantan

Methods

Surface water management includes (1) surface flow control; (2) water harvesting (water harvesting); (3) increase soil infiltration capacity; (4) tillage; (5) use of soil-clogging and water-repellent materials; and (6) lining the drains. Sub-surface water management can be done by (1) improving drainage; (2) control of deep percolation and sub-surface flow; and (3) changes to the subsoil structure. Improved drainage will increase the efficiency of water use by plants, because the loss of excess water will allow plant roots to expand more deeply into the deeper soil layers rather than being confined to the shallow top layer which will dry out quickly if the groundwater level decreases.

The control technology is designed to increase the entry of water into the soil through infiltration and filling of water pockets in the basin area and reduce water loss through evaporation. To achieve these two things, water conservation efforts that can be applied are water harvesting techniques and soil moisture management technology. The application of water harvesting technology is intended to reduce the volume of runoff water and increase groundwater reserves and water availability for plants. Thus, dry land management does not depend solely on rainwater, but can be optimized through the use of surface water and ground water sources.

In its application, the method for introducing water into the soil is adapted to the social, economic, geographical, morphology, surface geology, climate and rainfall characteristics of the region, as well as local wisdom in each region. Table 1 presents a summary of the application methods and targets that can be applied in various regions in Indonesia.

Table 1. Method of introducing water into the ground

Recommended methods	**Institution**		**Industry**		**Urban Community**		**Suburban and Rural Communities**		
	Office complex, educational facilities	Urban forest, park, trial garden	Factory, office, residential complex	Agricultural area, plantation, agro-industry	Residential area	Public area	Residential area	Public area	Agricultural area and moor
Rainwater collection pond	√		√		√	√	√	√	
Infiltration well	√		√		√	√		√	
Infiltration ditch		√		√			√		√
Rainwater infiltration area	√	√	√	√	√	√	√	√	
Yard embankment	√			√			√	√	√
Yard fence	√		√	√			√	√	√
Hole in the ground (jogangan)	√	√	√	√	√	√	√	√	√
Landscape modification	√	√	√	√	√	√	√	√	√
Groundwater conservation area		√		√					√
Rainwater conservation ponds (retention ponds/ regulation ponds/ retention ponds)	√	√	√	√	√	√	√	√	√
Revitalization of lakes		√		√					√

This study is a descriptive literature review. The first step is to identify the problem through a literature review, which is obtained from various information, namely:

1. Collecting information about the Barabai watershed and flooding at that location through survey activities;
2. Collecting study/study/research documents that have been carried out;
3. Collect scientific journals, theses, dissertations or handbooks that can provide information on integrated flood management and its application in various areas, so that it can be applied in the Barabai watershed;
4. Collecting information from print/electronic media;
5. Create an integrated concept of flood management in the Barabai watershed by analyzing existing information, so that results are obtained in the form of a framework and integration of the concept of flood management in the Barabai watershed by combining conventional flood control patterns that have been carried out with the concept of eco-drainage system water conservation.

Results and Discussion

Barabai Waterflood Hydrograph

The Barabai watershed has an area of +173.00 km2 with a river length of 40.73 km. The discharge data uses discharge data recorded at the Hantakan AWLR (Automatic Water Level Recorder) post which is located upstream of the By Pass Flood Channel inlet. From the calculation of the Barabai River AWLR hydraulics, it was found that the flood that occurred on June 6, 2013 was 608.54 m3/second (Anam, 2015).

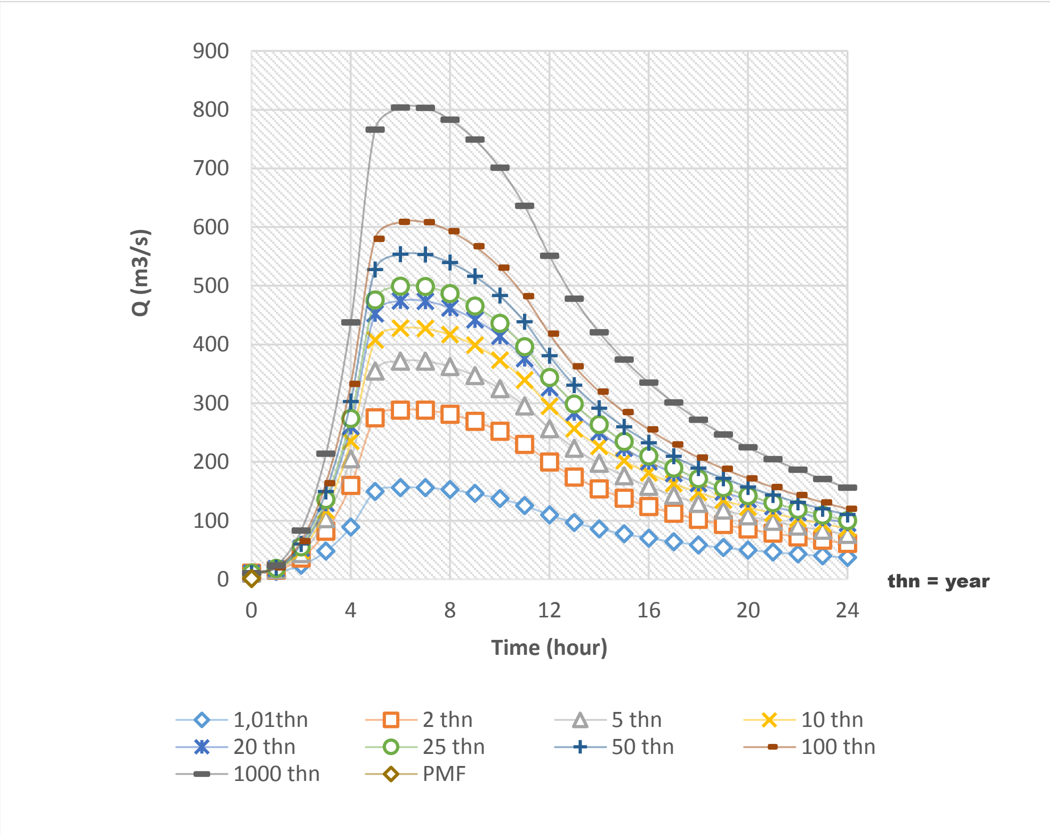

Figure 2. Barabai watershed design flood hydrograph

The figure above shows that the annual return flood discharge in the Barabai watershed is 156.25 m3/s, with a peak time of T 6 hours. With the existing flood channel capacity of 76.88 m3/s, so there is still 79.37 m3/s flowing in the Barabai River towards the downstream which has the potential to cause overflow and inundation in Barabai City. Figure 3 describes a scheme of Barabai flood channel – Bangkau lake – Country River.

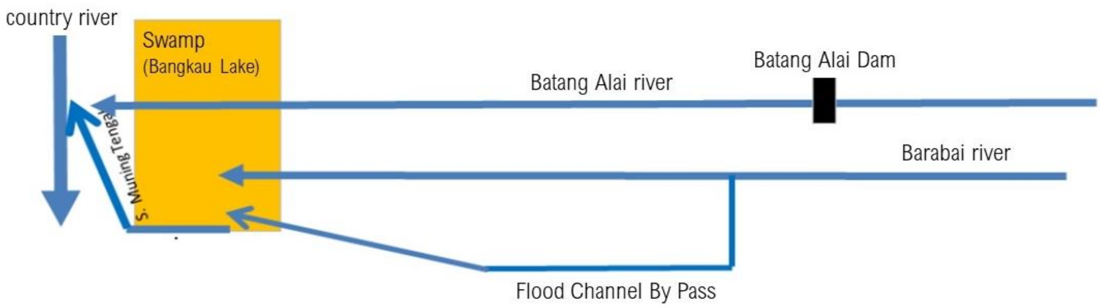

Figure 3. Scheme of Barabai flood channel – Bangkau lake – Country River

The existing condition of the downstream section of the Barabai River has narrowed the channel due to the development of urban areas, both for trade facilities and the development of residential areas. Likewise with the slope of the Barabai River, in the upstream and downstream parts of the river the difference is quite significant. The slope of the lower part of the river with a gentle profile is very different when compared to the upstream part which has a steep profile. The bottom slope of the Barabai River was in the upstream and downstream parts (Anam, 2015). Based on cross section data (2015 Planning Design), the cross-sectional area of the upstream river is 137.4 m2 and at the downstream is 40.57 m2.

Integration of Existing Conventional Concepts and Eco-Drainage System Concepts in Barabai Flood Control

The construction of a new intake and rehabilitation of the Barabai flood channel is only able to drain flood discharge with a return period of 1 to 5 years (336.99 m3/sec). To drain the discharge with a return period of Q10 to Q50. It is necessary to revitalize the Barabai River downstream, precisely in Barabai City which is experiencing a narrowing. to be able to drain a discharge of 476.56 m3/s (Table 2). Moreover, the normalization of the Barabai Flood Channel (By Pass) carried out in the rehabilitation activities aims to increase the river's storage capacity, from 40 m3/s to 76.88 m3/s with the prediction of inundation area that occurred in Barabai (Figure 4). The study shows that the reduction in inundated area (flooding) after controlling was 62.75% (from 36.6 km2 to 13.65 km2) or 33.53% of the area of Barabai District.

Table 2. Barabai river flood discharge with flood channel

Repetition	Old + New intake door		
	Water height in intake (m)	Q inflow (m3/s)	Q river (m3/s)
1	1.21	18.49	137.75
2	1.79	27.36	260.72
5	2.26	34.54	336.99
10	2.76	47.14	380.27
20	4.47	67.76	406.25
25	3.79	72.62	426.25
50	5.08	76.88	476.56
100	6.65	76.88	532.66

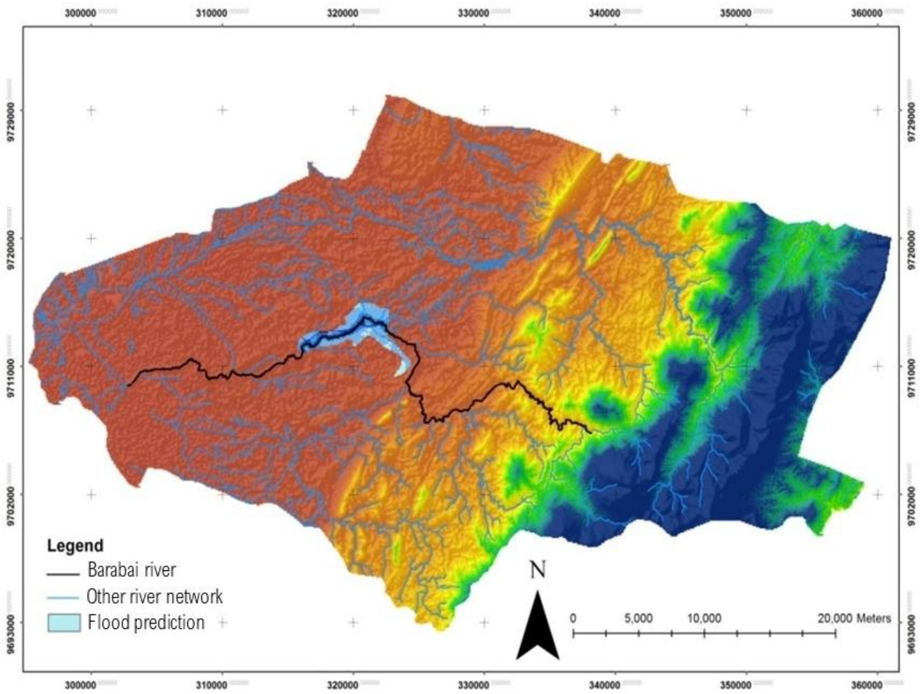

Figure 4. Prediction map of Barabai river flood after control

The flood management method in the Barabai watershed integrates the conventional flood management concept that has been built with the eco-drainage system concept of a storage pond (regulation/retention pool). The regulation/retention pool functions to store and hold water temporarily and absorb it and then flow it back after the peak of the flood has passed, so that the peak of flooding that enters the city of Barabai can be reduced. The extent of flood reduction depends on the characteristics of the flood hydrograph, the volume of the pond and the dynamics of several outlet buildings. The area used for the construction of a holding pond is usually in a low area. With good land use planning and implementation, retention ponds can be used as temporary rainwater reservoirs and water distribution or distribution. In addition to its main function as flood control, other benefits that can be obtained from retention ponds include as a means of water tourism and as water conservation because it can increase local groundwater reserves.

The regulation/retention pond also has a function as a conservation area. In accordance with the concept of a sustainable drainage system, the main priority of activities should be aimed at managing surface runoff by developing facilities to retain rainwater (rainfall retention facilities). Based on their function, rainwater retaining facilities can be grouped into two types, namely (1) storage types and (2) infiltration types. As an alternative to retaining rainwater, the Regulation/Retention Pool has both functions. This has caused the combination of existing conventional flood control in the Barabai watershed to be combined with the regulation/retention pond as an alternative in optimizing flood management and control in the Barabai watershed. So that inundation and flooding of shipments from upstream can be minimized. Regulation/Retention Ponds can also be infiltration facilities which can function to maintain ground water level elevation and also water quality.

This retention pond functions to control the parameters of the peak discharge and completion time, namely by cutting the peak discharge of the flood that occurs. Therefore, the retention pond has a good effectiveness in flood control. The use of regulation/retention ponds can control the magnitude of the peak discharge by suppressing or cutting off the peak of the flood that should have occurred. The concept of integrating conventional flood control and eco-drainage in the Barabai watershed is presented in the following figure.

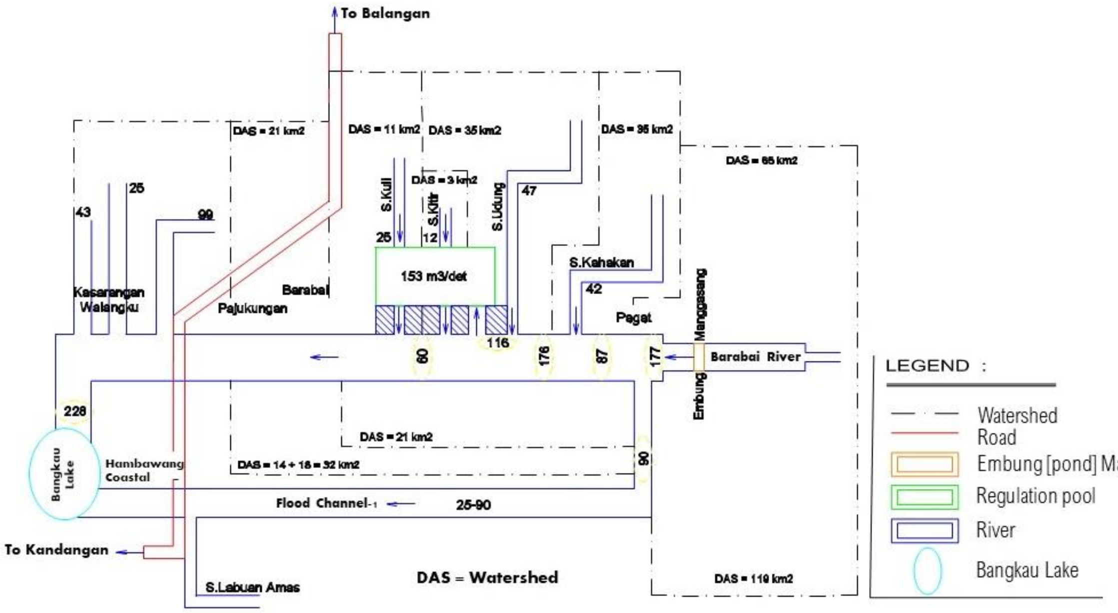

Figure 5. Barabai controller integration scheme with eco-drainage system

The concept of environmentally sound drainage (eco-drainage) is an effort to manage excess water by retaining and soaking it into the soil naturally as much as possible or flowing it into the river without exceeding the capacity of the river (Maryono, 2005a; 2005b; 2007; 2015). The basic concept of sustainable drainage development is to increase the usability of water, minimize losses and improve and conserve the environment (Suripin, 2004). Eco-drainage system has been implemented to minimize surface runoff by capturing and temporarily retain it (Kusumastuti et al., 2019). The Effectiveness of bio-pore as an alternative eco drainage technology to control flooding has been investigated and described that the load of the drainage channels can be reduced because bio-pore provide the function to accommodate and absorb rain water into the ground with rain water discharge capacity (Anggraeni et al., 2013).

There are 2 (two) patterns of eco drainage systems that are commonly used, namely; (1) the pattern of detention (holding water temporarily), for example by making a holding pond; (2) retention patterns (permeate), among others by making infiltration wells, infiltration channels, infiltration fields, and infiltration ponds.

The Retention/Regulation Pond model is to combine the concepts of the two patterns above, namely by storing water while waiting for it to fall when the flood peaks while soaking the reservoir water into the ground. This model is almost the same as the conservation pond concept. The conservation pond method is carried out by making water pools, either in urban areas, settlements, agriculture, or plantations or in watershed areas. This conservation pond is made to collect rainwater first, it is absorbed and the rest can be slowly flowed into the river. Conservation ponds can be created by utilizing areas with low topography, areas of ex-sand excavation or other excavated material, or extra made by excavating a certain area or section. Conservation ponds are also very beneficial if they are associated with the recreational needs of the community. For agricultural and plantation areas, this concept can be planned by making rainwater conservation trenches (ponds). This ditch is very important for dry season water reserves while increasing rainwater conservation in the upstream areas, as well as increasing the ecological carrying capacity of the local area. The construction of the trench is quite simple, in the form of elongated or longitudinal excavation in several places without a partner. The trench can also be used as a place for fish cultivation and others.

Conclusion

Based on the results of the study above, it can be concluded; (1) Barabai watershed flood control with the concept of integrating existing conventional flood control with the concept of regulation/retention pond eco-drainage system is expected to reduce the peak time of flooding that enters Barabai City during river revitalization to restore the large capacity of the Barabai River in Barabai City as a flood channel; (2) The concept of integration of regulation/retention pools with conventional flood control that has been carried out from 2004 to 2016 is expected to reduce the peak time of flooding in Barabai City so as to reduce the impact caused by flooding in the Barabai Watershed.

In order to handle flood discharges during the 100 year return period, it is necessary to build a dam/reservoir/dam in the upper part of the Barabai River as a larger reservoir and absorption function in controlling the Barabai flood discharge. Moreover, further studies are needed on the application of the absorption system in the Barabai city area itself so that more water entering the city can be absorbed when it reaches the Barabai urban area.

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References

Anam, S., Dermawan, V., & Dian, S. (2015). Evaluasi Fungsi Bangunan Pengendali Banjir Sungai Barabai Kabupaten Hulu Sungai Tengah Provinsi Kalimantan Selatan. *Jurnal Teknik Pengairan: Journal of Water Resources Engineering*, *6*(2).

Anam, S., Dermawan, V., & Sambah, A. B. (2020). Modeling Of Usbr Type Ii Energy Reducer To Improve Energy Reduction In Stilling Basins With Hydraulic Physical Model Test. *International Journal of GEOMATE*, *18*(70), 215-220.

Anggraeni, M., Prayitno, G., Hariyani, S., & Wahyuningtyas, A. (2013). The Effectiveness of Bio-pore as an Alternative Eco drainage Technology to Control Flooding in Malang City (Case Study: Metro Sub-Watershed). *J. Appl. Environ. Biol. Sci.*, *3*(2), 23-28.

Arsyad, S. (2006). *Konservasi Tanah dan Air*. Bogor: Institut Pertanian Bogor Press.

Arsyad, S. (2010). *Konservasi Tanah dan Air* (2nd ed.). Bogor: Institut Pertanian Bogor Press.

Asdak. (2010). *Hidrologi dan Pengelolaan Daerah Aliran Air Sungai* (Edisi Revisi Kelima). Yogyakarta: Gadjah Mada University Press. Yogyakarta.

Edwards, P. J., Williard, K. W., & Schoonover, J. E. (2015). Fundamentals of Watershed Hydrology. *Journal of Contemporary Water Research & Education*, *154*(1), 3-20.

Kenneth, N. B., Peter, F. F., & Joseph, A. M. (2013). Hydrology and the Management of *Watersheds* (4th ed.). John Wiley & Sons, Inc.

Kumari, M., & Singh, D. (2016). Water Conservation: Strategies and Solutions. *International Journal of Advance Research and Review*, *1*, 75-79.

Kusumastuti, C., Chandra, H. P., Wibisono, K., & Hartono, A. C. (2019). Eco Drainage System for Surface Runoff Reduction in Indonesia. *Civil Engineering Dimension*, *21*(1), 29-35.

Maryono, A. (2005a). *Eko Hidraulik Pembangunan Sungai* (2nd ed.). Thesis. Magister Teknik Program Pascasarjana. Gajah Mada University, Yogyakarta.

Maryono, A. (2005b). *Menangani Banjir, Kekeringan dan Lingkungan*. Yogyakarta: Gadjah Mada University Press.

Maryono, A. (2007). *Restorasi Sungai*. Yogyakarta: Gadjah Mada University Press.

Maryono, A. (2015). *Manajemen Air Hujan; Rainwater Harvesting*. Yogyakarta: Gadjah Mada University Press.

Sadeghi, M. A., Bajhestan, M. S., & Saneie, M. (2010). Experimental Investigation on Flow Velocity Variation in Compound Channel with Non-Submerged Rigid Vegetation in in Floodplain. *World Applied Sciences Journal*, *9*, 489-493.

Suripin. (2004). *Sistem Drainase Perkotaan yang Berkelanjutan*. Yogyakarta: Penerbit Andi.