IOP Conference Series: Earth and Environmental Science

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IOP Conf. Series: Earth and Environmental Science **622** (2021) 012007 doi:10.1088/1755-1315/622/1/012007

Analysis of peat wetting infrastructure on the peat hydrological units of Bentayan River - Penimpahan River Musi Banyuasin Regency

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Abstract. Peatland fires are a problem that always occurs every year in the dry season in Indonesia, especially in the South Sumatra region. Various efforts have been made to prevent peatland fires, one of which is peat rewetting to quickly restore the ability of the peat hydrological unity area (KHG). This research located in the KHG of Bentayan - Penimpahan River, Musi Banyuasin, South Sumatra. This study aims to analyze peat wetting infrastructure that is effective and efficient, as well as meeting the technical feasibility rules in the KHG Bentayan - Penimpahan River as an effort to overcome peatland fire. The research method used was a preliminary study, data collection in the field, mapping the KHG area, and analyzing the peat wetting infrastructure (IPG). The results showed that the suggestions and recommendations for IPG in the study location were in canal blocking. Based on the analysis of construction stability by calculating the bearing capacity of the cerocok gelam on the small concrete canal blocking, the bearing capacity of the cerocok gelam on the large concrete canal blocking, and the stability of the wooden canal blocking, it can be concluded that the planned canal blocking is safe from shifting and rolling.

1. Introduction

Utilization of peatlands is not only a hydrological regulator, conserving biodiversity, and a source of energy, but also has a more significant role as a controller of global climate change [1]. Peatlands have a function for conserving water resources, reducing floods, preventing seawater intrusion, supporting various kinds of biodiversity, and controlling climate, through their ability to absorb and store carbon [2]. The peatlands conversion to agricultural land, oil palm plantations and pulpwood is thought to have damaged peatlands with all their ecological functions [3]. Local community activities to prepare peatlands for agricultural land are usually carried out by burning.

Peatland fires are a problem that always occurs every year during the dry season in Indonesia, especially in Sumatra and Kalimantan. In 2015, 2.6 million hectares of burned forest and peatlands was concentrated in several parts of Indonesia [4]. According to [5], this condition has been occurring for 18 years ago, with the area of forest and land that has been burned has continued to increase. The losses incurred by the Indonesian government for forest and land fires in 2015 reached Rp. 221 trillion (16.1 US dollars) or the equivalent of 1.9% of GDP in 2015. This has resulted in impacts such as increased carbon emissions due to haze, losses in the agricultural and forestry sectors due to damaged infrastructure and equipment, and also resulted in a loss of biodiversity, damaged ecosystem services, and disruption of the transportation sector.

South Sumatra Province is one of the critical provinces in Indonesia, which is the priority target for implementing the peat restoration policy because there are 650 thousand hectares of damaged peatlands. Various efforts have been made to prevent peatland fires, one of which is by peat rewetting. Peat rewetting activities are carried out through the construction of peat wetting infrastructure such as canal blocking, canal backfilling, and deep wells, to quickly restore the ability of the peat hydrological unit to absorb and keep the water back. Making canal blocking in peatlands is intended to prevent drastic changes in land conditions, such as draining [6].

In this research, several efforts will be made to reduce the problem of peatland fires by analyzing the peat wetting infrastructure (IPG) that is suitable for the conditions of the study area. IPG can be in the form of drilled wells or canal blocks. With these barriers, a decrease in the water level in the peatlands can be prevented and the surrounding peatlands will remain wet and difficult to burn. Construction of canals in a canal (canal blocking) aims to keep water out of the peat so that the peat remains in a wet condition. The area that became the research location for the implementation of this peat wetting was the KHG Bentayan River – Penimpahan River, which is in the administrative area of Musi Banyuasin Regency, South Sumatra.

This study aims to analyze the effective and efficient peat wetting infrastructure (IPG), as well as fulfilling the technical feasibility principles to be applied in the peatland conservation area Bentayan - Penimpahan River as an effort to overcome the problem of peatland fires.

2. Methodology

2.1. Research procedure

This research is located at the peat hydrological unit Bentayan River - Penimpahan River, Musi Banyuasin Regency, South Sumatra Province (Figure 1). It is in Karang Agung village located in the administrative area of Lalan District, the division of Bayung Lincir District, Musi Banyuasin Regency, South Sumatra Province. The research stages carried out are a preliminary study, data collection, mapping the peat hydrological unit, and analysing the peat wetting infrastructure. The research flow chart shown in Figure 2.

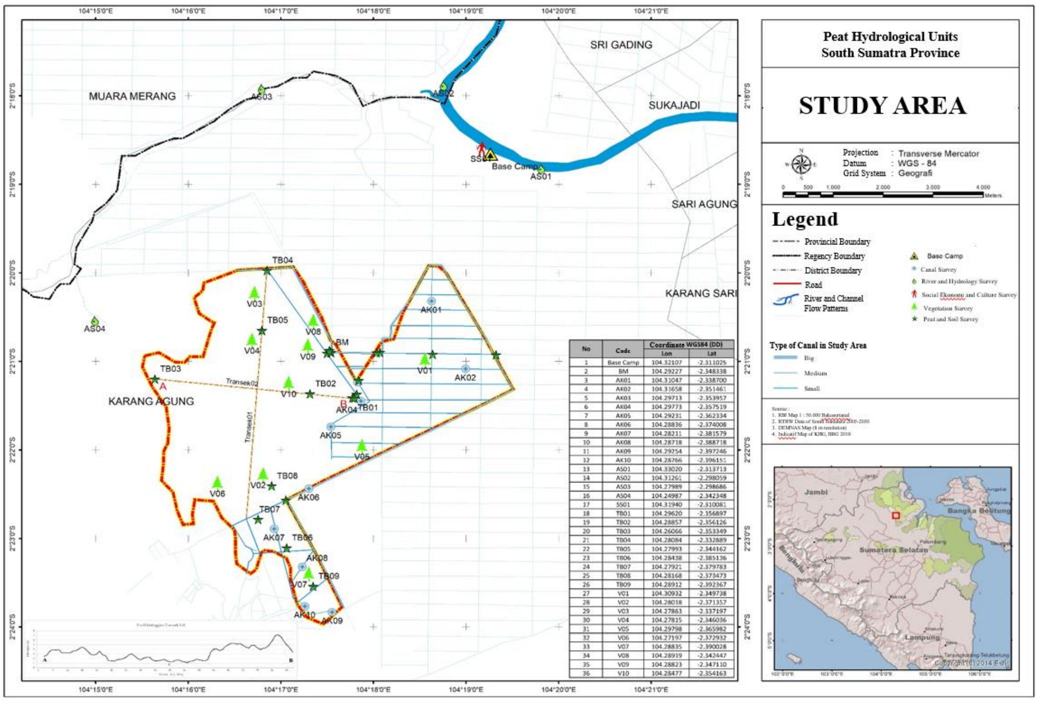

Figure 1. Research area in the peat hydrological unit Bentayan – Penimpahan river

2.2. Data
In this study, the data collected were primary and secondary data. Secondary data consists of daily rainfall data, earth map, the latest canal network map, and land cover map data. The primary data used are data obtained from collecting peat soil samples at the study site, peat depth data, and hydrometric data from canals such as canal length, width and depth, flow direction, flow velocity, and water discharge.

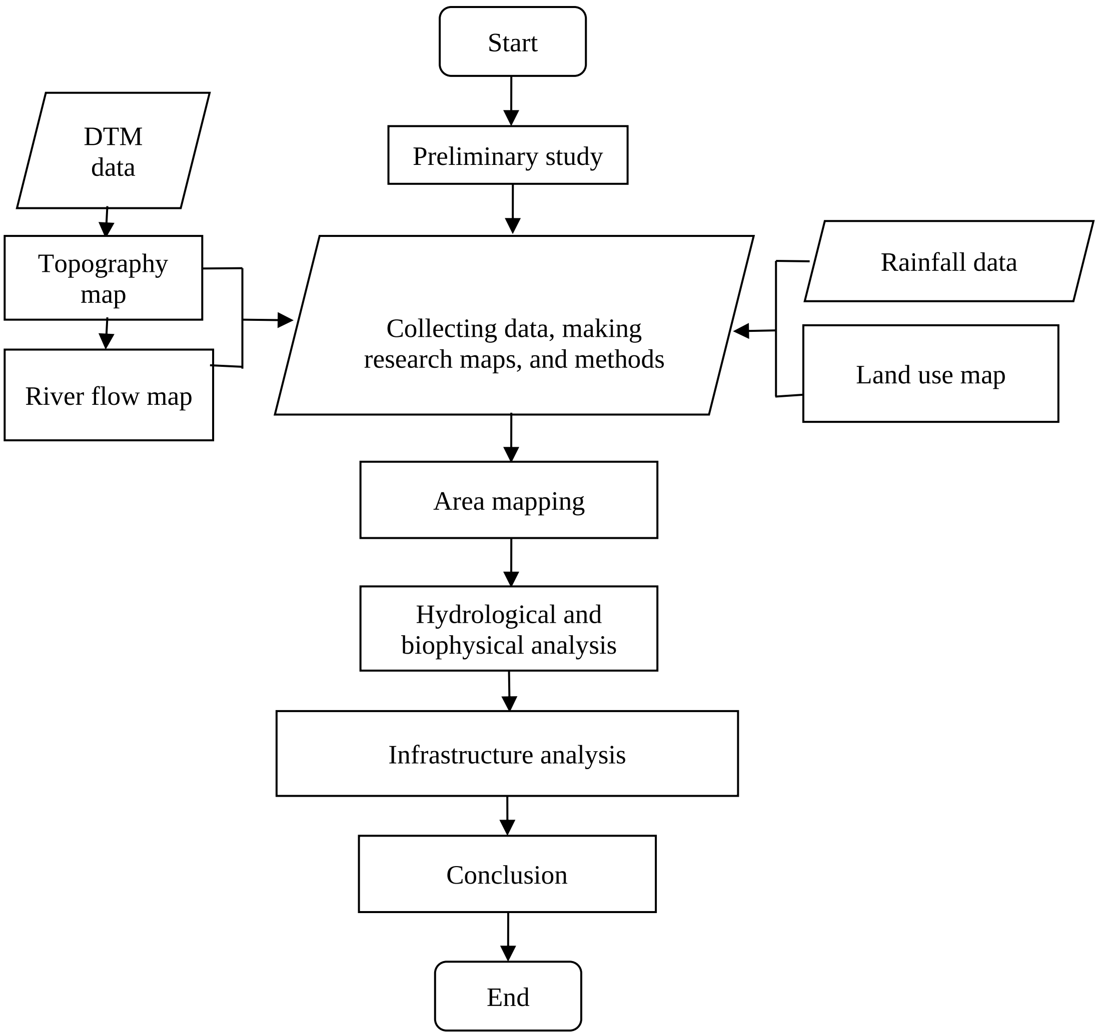

Figure 2. Research flowchart

2.3. Analysing the peat wetting infrastructure
In this study, the capacity reduction is expressed in terms of 'Pole Efficiency' is calculated using Converse - Labarre Formula as follow:

$$E_g = 1 - \theta \frac{(n'-1)m + (m-1)n'}{90mn'} \qquad (1)$$

Where :
E_g = pole efficiency
m = number of pole rows

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n' = number of poles in a row
θ = acrtg(d/s), in degrees
s = center to pole center distance
d = pole diameter (m)

To calculate the bearing capacity of a single pile according to the Caquot and Kerisel equation is as follows:

$$Q_t = ½ Z x P x C x \beta \qquad (2)$$

Where :
Q_t = single pole bearing capacity (t)
Z = pile depth (m)
P = circumference of the pole (m)
C = soil shear strength (t/m^2)
D = pole diameter (m)
β = effective friction coefficient between the soil and the pile

To find the value of β it can be found in Table 1 based on the value of the inner sliding angle (θ).

Table 1. β and θ relationship

Inner sliding angle	β
10	1,80
15	2,06
20	2,70
25	3,62
30	5,01
35	7,27
40	10,36
45	17,97

If $Q_t > t$; then the concrete canal bulkhead is safe against the bearing capacity of the cerocok pile group. Meanwhile, to analyze the stability of the wooden canal bulkhead, it is necessary to calculate the forces acting on the wooden canal bulkhead (*P*) and the shear resistance (*T*). If $T > P$, the bulkhead is safe against shifting. To analyze the stability of the roll, it is necessary to calculate the moment of rolling against the end of the bulkhead (M_{PA}) and the moment of rolling hold (M_{PGA}). If $M_{PGA} > M_{PA}$, the bulkhead is safe against rolling.

3. Result and Discussion

3.1. Hydrological and biophysical condition

Karang Agung village is one of 27 villages located in the administrative area of Lalan District. It is the result of the division of Bayung Lincir District, Musi Banyuasin Regency, South Sumatra Province. Karang Agung village is the largest village and is the main village of the villages in Lalan District. The study area is lowland with an altitude ranging from 0−12 m above sea level with a slope of 0−2%. Based on the indicative map of peat distribution, the condition of the study area is in the peat swamp area.

Based on the villager's information, the peat depth in Karang Agung Village, which previously had a depth of 1−4 m, is currently shrinking to only about 0.6−1 m, this is due to a large amount of peatland being converted into oil palm plantations both companies and by villagers.

Karang Agung village has a tropical climate and has two seasons, rainy and the dry season. The dry season lasts from May to October and the rainy season lasts from November to April with 2000−3000 mm of rainfall. Most of the soil types in Karang Agung Village are Organosol and Gley Humus type

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units because they are lowland areas and peat swamps that are not far from the tidal influence of the Lalan River. Some areas that are far from the influence of river flows tend to have Podzolic Red Yellow soil types [7].

Many rivers and swamps flank in Karang Agung Village. These small rivers empty into more significant rivers, namely the Bentayan River and the Lalan River. Most of the residential areas are located on the banks of the Lalan river. In addition to these rivers, the Karang Agung Village area has many canals made by the community and oil palm plantation companies, where these canals are used as waterways to reduce waterlogging on the plantation land and prevent oil palm plantations from being flooded.

3.1.1. Canal analysis

The study location is in the peat hydrological unit of the Bentayan River - Penimpahan River with a significant area of ± 2496.10 Ha. The total length of the canals in the study area is ± 64142.63 m which consists of 3 types of canals. In general, the dimensions of the canals showed in Table 2. Based on the analysis, the drainage density is ± 6.1 km/km^2 which indicates a moderate drainage density.

Table 2. The dimensions of the canals

Type of canals	Length (m)	Wide (m)	Depth (m)
Large	17096	8–10	2–3
Medium	38540	5–6	1.5–3
Small	8507	2–3	1.5

a) Primary canal

b) Secondary canal

c) Tertiary canal

d) Sluice

Figure 3. Condition of the existing canal and sluice which are the outlet in the study area

Figure 3 shows the large canal indicated located along the outer boundary of the study area to the east, the canal restricts the flow of water from the study area to the outside (the plantation area of an industrial company). The medium channel that stretches creates an East-West zonal line, and the small channel creates a North-South meridional line intersecting the secondary channel line. It is indicated that there is a sluice which connects the water network of the study area with the water network of the industrial company. Based on field observations, the study area is the primary source of water supply to the industrial company which is to the east during the dry season. This condition is quite alarming because it has an impact on the drying up of the study area, which results in most of the study areas being prone to forest and land fires.

3.1.2. Peat analysis

Based on the Indicative Peat map sourced from BRG 2016, the study area is a peat dome area categorized as Deep Peat (Figure 4), however after field checking the thickness of the peat indicates a depth of 10−196 cm with shallow peat and moderate peat criteria. Based on interviews and satellite image data with a confidence level of > 75% (data source LAPAN), the thinning of peat thickness in this zone occurred as one of the impacts of a large forest and land fires that occurred in 2015. The degradation of peatlands that occurs is not only caused by forest and land fires but also due to canalization and land clearing efforts by previous companies so that the area is currently indicated as peatland.

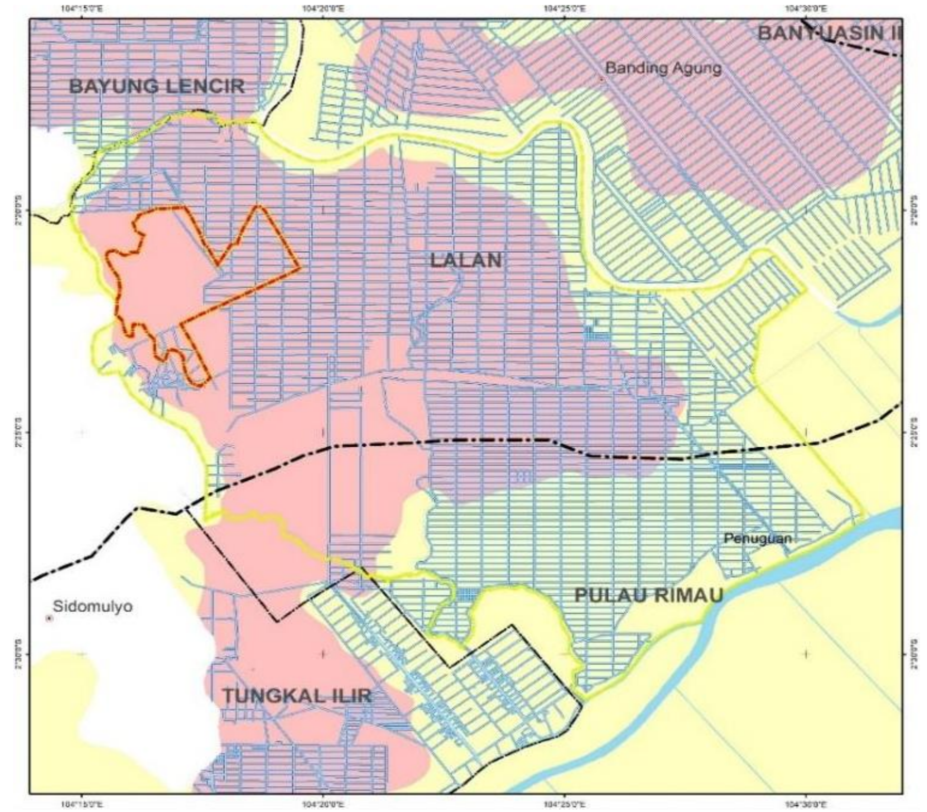

Figure 4. Indicative peat maps of peat hydrological unit Bentayan – Penimpahan river

The results of field observations also found traces of burns in all layers of peat and all observation points; these traces were in the form of charcoal in the peat layer. This indicates that the peatlands here have been burning for a long time because the charcoal burned tracks have been buried several meters below the surface of the soil. On the other hand, the vegetation conditions in the study area were all secondary forest and fern fields. There were no more trees with a diameter of > 20 cm. This indicates that the land is continuously burning. The area of ± 2496 ha is a shallow to medium peat area that is prone to forest fires. The fires themselves occur periodically and the land conditions are not cultivated, as well as the dominant vegetation and ferns.

3.1.3. Topography analysis

Based on data from DEMNAS (Digital Elevation Model Nasional) with a resolution of 8 m issued by the Geospatial Information Agency (BIG), the study area is a lowland with an altitude ranging from 0–12 m above sea level (DPL) with a slope of 0–2%. Spatially the altitude distribution at the study location showed in Figure 5. The blue colour (altitude < 4m) is a description that can describe areas that tend to be inundated during the rainy season.

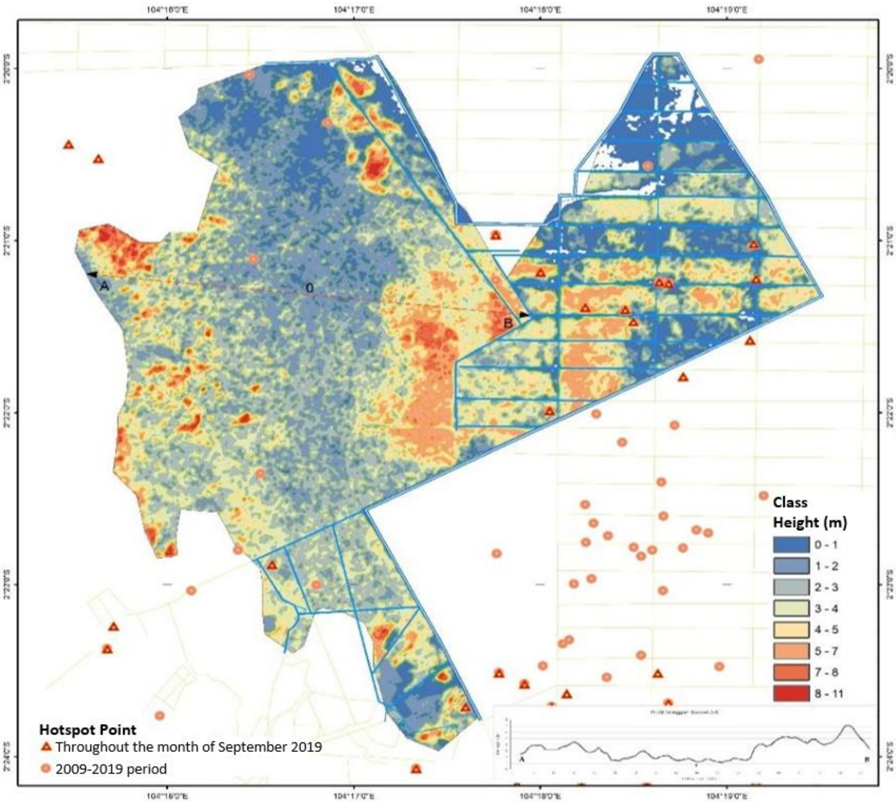

Figure 5. Contour maps and elevation classification in the research area compare with hotspot

In general, based on the incidence of forest and land fires in the study location, these originate from areas that have been channelled. The cause of the fire can be suspected to be related to the activities of the surrounding residents regardless of intentional or unintentional elements and negligence. Residents for plantation activities usually pursue areas that have been channelled. Zone A is an area that has not been channelized and tends to be safe from drought conditions because, at the time of the survey (dry season), the groundwater/peat conditions were still around 50 cm. However, because the wind direction during the dry season moved from the southeast/east to the west, the area it also becomes prone to burns.

3.2. Selection of construction type

Based on the study of wetting peat in the Peat Hydrological Unit (KHG) Bentayan River - Penimpahan River, it can be recommended that the development of the Peat Wetting Infrastructure (IPG) in the study location is as follows:

- Construction of 31 canal blockings, with a composition of 7 in large canals, 22 in medium canals and 2 in small canals. From several canal blockings, it is recommended to make permanent canal blocks on medium canal and large canal. The basis for making permanent type is due to large channels where the potential for water pressure is more significant (in terms of dimensions) so that a more muscular contour is required.

- The determination of canal blocking is based on the analysis of the slope level which is generally classified as flat with a slope of 0−2% and only a few ridge areas but still relatively flat. There are 62.28% of study area having a height of < 4 m which tends to be inundated during the rainy season. Therefore, based on the analysis of flow patterns, vegetation, community information, canal networks and hotspot data, the study area has the potential for drought and is prone to forest and land fires, especially in areas with an altitude of > 4 m (± 37.72%). Therefore, the location of the canal blocking is prioritized on the canal which is in the land area with a topography above 3 m. The development is located at the estuary or near the intersection of the two types of canals. This condition refers to the insulation criteria for canals with low slope every 1 km. However, due to the large area, for this study, insulation was carried out by taking a minimum figure of 2 km or based on a hydrotofographic pattern.
- Meanwhile, for the medium and small canals conditions, the canal blocking construction is sufficient with a composite material with wood as the primary material. This condition is because the water pressure is not too big so that the carrying capacity of the wood composite type construction is relatively safe.

Canal blocking have also been recommended by [8], [9], [10], [11], and [12] as strategies for hydrological restoration of degraded peatlands and peat fire prevention solutions. Canal blocking is considered the best method as strategy to restore peatlands and minimize land fires, haze, and carbon emissions. According to [13] there is a direct effect of canal blockings on hydrological conditions in peatlands. In addition, the water level in the downstream part of the canal blockings will be 10−20 cm lower than the upstream part. From the [12] study results proved that the construction of canal blocking as a solution to preventing peatland fires in Sungaitohor Village has been successful. This is proven by the decrease in hotspots in this village, even in 2016 there were no hotspots found in Sungaitohor Village. In addition, with the canal blocking, these peatlands are reorganized so that they can return to their function.

3.3. Construction stability analysis
The analysis results for bearing capacity of cerocok gelam on small concrete canal blocking showed that pole efficiency (E_g) is 0.76847, single pole bearing capacity (Q_t) is 230.605 t, and the load remains above the top pile group (t) is 161.9448 t. So, it can be seen that $Q_t > t$, then the small concrete canal blocking is safe against the bearing capacity of the cerocok pile group.

The analysis results for bearing capacity of cerocok gelam on large concrete canal blocking showed that pole efficiency (E_g) is 0.76533, single pole bearing capacity (Q_t) is 367.461 t, and the load remains above the top pile group (t) is 198.3888 t. So, it can be seen that $Q_t > t$, then the large concrete canal blocking is safe against the bearing capacity of the cerocok pile group.

The analysis results for wooden canal bulkhead stability showed that forces acting on the wooden canal bulkhead (P) is 3.92 t/m' and the shear resistance (T) is 18.3456 t/m'. Because $T > P$, then the bulkhead is safe against shifting. The moment of rolling against the end of the bulkhead (M_{PA}) is 23.52 t.m and the moment of rolling hold (M_{PGA}) 127.419 t.m. Because $M_{PGA} > M_{PA}$, the bulkhead is safe against rolling.

4. Conclusion
The recommendation for effective and efficient peat wetting infrastructure (IPG) is canal blocking. The determination of the canal blocking point is based on slope level analysis, and hydrological and biophysical conditions in the study area. The recommended composition of canal blocking is 7 in large canals, 22 in medium canals and 2 in small canals. From a number of canal blocks, it is recommended to make permanent canal blocking with concrete on medium and large canal. The determination of making a permanent type bulkhead is due to large canal where the potential for water pressure is greater (in terms of dimensions) so that a stronger construction is required. Based on the analysis of construction stability by calculating the bearing capacity of the cerocok gelam on the small concrete canal blocking, the bearing capacity of the cerocok gelam on the large concrete canal blocking, and the stability of the

wooden canal blocking, it can be concluded that the planned canal blocking is safe from shifting and rolling.

Acknowledgments
This research is a Science, Technology, and Arts Research (SAINTEKS) funded by Sriwijaya University. The authors also express the gratitude to the Peatland Restoration Agency (BRG).

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