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Groundwater Balance Evaluation for Groundwater Availability in Ngarawan Watershed, Belitung Timur Regency

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ABSTRACT

The balance between groundwater availability and soil water requirements should always be maintained, so that the quantity and quality of the ground water remains sustainable. The development of Manggar city located in Ngarawan watershed, it is feared will disrupt the balance of ground water. The decrease of ground water level has been felt by the community during the dry season, so that the ground water balance analysis is needed, to know the balance between the availability and the need of ground water in Ngarawan watershed. The research method consists of calculation of ground water balance, groundwater requirement, geometric method, and descriptive analysis. The results show that the condition of ground water balance in Ngarawan watershed is still surplus, with changes in ground water savings of 8,903,116.38 m^3 in 2016, but reduced to 3,468,570.18 m^3 in 2034. Reduced changes in groundwater storage, due to changes land use and increased groundwater demand.

1. Introduction

In Indonesia, groundwater is still a source of clean water for the needs of the community, one of them in the capital of Belitung Timur regency, Manggar city. As a newly formed district, development in Manggar city, as a center of government, is growing rapidly, followed by population growth. So the need for groundwater in the city of Manggar that entered the watershed (DAS) Ngarawan is increasing.

Increasing population makes the need for clean water will continue to increase. As one of the best sources for clean water, ground water continues to be intensively taken, to meet water needs. Often, groundwater extraction becomes uncontrolled and incompatible with availability, which may impact on quantity, quality and environmental carrying capacity of local aquifers.
Responding to these conditions, it is necessary to manage by conducting groundwater balance analysis, to avoid the risk of water scarcity for present and future. The groundwater balance is an analysis that describes the utilization of groundwater resources of an area based on the comparison of groundwater availability conditions and their needs (Wittenberg and Sivalan, 1999; Boisson, et al., 2014; Bonita and Mardyanto, 2015). The groundwater balance approach is used to estimate groundwater conditions in a region, whether the surplus or deficit for a given period of time.

The relationship between groundwater availability and demand is one of the most important aspects of ecological area protection. Therefore, knowledge of the groundwater balance system is a prerequisite for integrated land and water management (Batelaan, et al., 2003; Tuinstra and Wensem, 2014; Knuppe and Meissner, 2016; Tubau, et al., 2017).

The management of groundwater resources is a human

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challenge so that each generation can inherit sufficient groundwater resources of both quality and quantity to the next generation. Where the greatest challenge for natural resource management is creating to further maintain a balance between the fulfillment of human needs and the continued use and existence of natural resources (Asdak, 2014).

Appropriate groundwater resource management should be based on detailed and measurable water availability data, taking into account as much as possible the natural factors affecting it, including aspects of conservation and land use (Black, 1996 in Narulita, 2017), so that groundwater availability is guaranteed to be sustainable, its utility and availability for present and future.

2. Materials and Methods

Research Area

Ngarawan watershed is located in Belitung Timur, Bangka Belitung Province. Geographically Ngarawan watershed is located between longitudes 108°11'23" and 108°17'40" E and latitudes 02°51'40" and 02°55'39" S with the area 49,36 km^2. Upstream Ngarawan watershed is in Pancur area, Manggar District with elevation 25 m and downstream at Mudong beach.

The number of people living in the Ngarawan watershed in 2016 was 36,748 people with an average population growth rate of 2.04%.

Based on 2007-2016 data from BMKG rainfall recording station in Manggar, Ngarawan watershed has a monthly average rainfall of 53,3 – 251,1 mm/month (see Table 1). While the average annual rainfall of 2013,4 mm. Average monthly temperatures from 2007-2016 recorded at the BMKG Class 3 Meteorological Station are 22°C – 33,4°C.

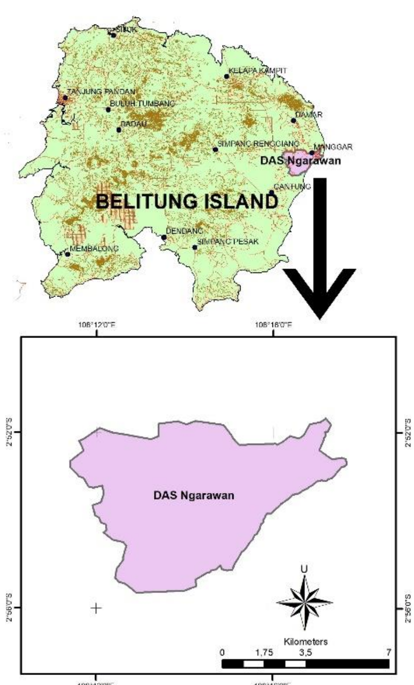

Figure 1. Map of Research Area

Table 1. Precipitation and Evapotranspiration

Month	Precipitation (mm)	Evapotranspiration (mm)
January	168.2	132.74
February	171.5	122.13
March	182.6	135.38
April	241.4	128.58
May	188.2	140.32
June	142.5	136.33
July	106.1	120.14
August	91.2	142.92
September	53.3	139.7
October	190.1	141.49
November	227.1	123.98
December	251.1	129.8

Data and Research Methods

Data used in this study include rainfall, air temperature, land cover map, population and number of social economic facilities in Ngarawan watershed. The land cover map is obtained from Google Earth satellite imagery processing in 2016, processed using ArcGIS 10.4 application, while the land cover projection of 2034 uses the spatial plan map of the Belitung Timur regency space pattern (See Figure 2)

Evaluation of spatial planning in Ngarawan watershed is done by comparing the results of ground water balance analysis in 2016 and 2034 based on current land use data and spatial pattern planning of Belitung Timur Regency 2014-2034. The groundwater balance is calculated using the equation:

$I - O = \Delta S$ ....(1)

where I is the volume of groundwater infiltration (input), O is the volume of groundwater demand (output), and ΔS is the change of groundwater storage. Ground water conditions are said to be surplus when the inflow is greater than in the water taken / out (outflow). The volume of groundwater infiltration and surface runoff volume is calculated using the Ffolliott method (Cristianingsih and Ariastita, 2012; Bonita and Mardyanto, 2015):

$R = (P - ET)(1 - C)A$ ....(2)

$Q = (P - ET)\ C\ A$..(3)

where, R is the volume of water absorbed into the soil (m^3), Q is the surface flow volume, P is the rainfall, ET is the evapotranspiration calculated by the Thornthwaite (1948) method, C is the average surface flow coefficient of the watershed (Forum DAS, 2017), see Table 2 and Table 3, and A is the watershed area. Surface runoff volumes are calculated to see the comparison of surface runoff in 2016 by 2034.

Calculation of domestic and non domestic water needs using the standards of the Directorate General of Human Settlements (2007). Future population projection is calculated by Geometric growth model.

Table 2. Land Cover Area and Average Surface Flow Coefficient of the Year 2016

Type of Land Cover	C	Land Cover Area (Ha)
Mining	0,70	938,70
Plantation	0,50	356,14
Settlement	0,60	581,52
Open field	0,50	2,83
Lake/river	0,01	104,95
Secondary swamp forest	0,02	1.041,90
Shrubs	0,07	1.275,00
Dryland Farming	0,50	635,31
Watershed Area		4936,34
Average Surface Flow Coefficient		0,35

Table 3. Land Cover Projection Area and Average Surface Flow Coefficient Year 2034

Type of Land Cover	C	Land Cover Area (Ha)
Mining	0,07	159,05
Plantation	0,50	360,44
Settlement	0,60	2.381,99
Rice field	0,15	307,31
Lake/river	0,01	196,74
Secondary swamp forest	0,02	400,70
Dryland Farming	0,50	1.130,11
Watershed Area		4936,34
Average Surface Flow Coefficient		0,49

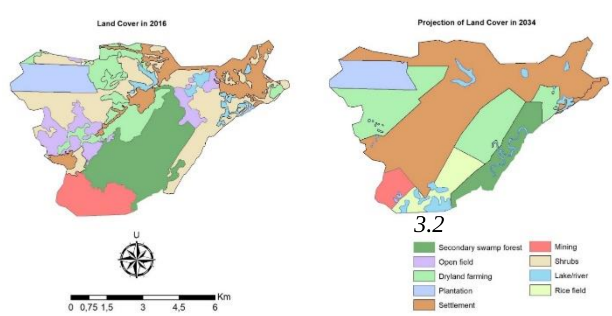

Figure 2. Ngarawan watershed land cover map
(*Source: Spatial plan map of Belitung Timur Regency of 2014-2034*)

3. Results and Discussion

Groundwater Demand

The calculation of groundwater demand shows the projected use of groundwater will increase from 1.938.060 m^3/year in 2016, to 3.419.160 m^3/year in 2034 (see Table 5), or an increase of about 4.25% every year. The biggest increase is the need for water for hotels and restaurants, because of the projected increase in tourist visits to Belitung Island, which will impact to the city of Manggar.

Table 5. Groundwater requirment for Domestic and Non Domestic in Ngarawan Watershed

Year	Domestic (m^3/month)	Non Domestic (m^3/month)	Total demand in a month (m^3/month)	Total demand in a year (m^3/year)
2016	132.293	29.212	161.505	1.938.060
2034	190.285	94.645	284.930	3.419.160

Groundwater Availability

Based on the calculation of groundwater recharge in Ngarawan watershed in 2016 of 10.841.176,39 m^3/year, while the projection of groundwater volume in year 2036 is 6,887,730.18 m^3/year, or down about 36,47 %. This decrease is to land cover change, due to the development of cities that affect the water cycle.

Table 6. Groundwater Recharge in Ngarawan Watershed

Month	Groundwater Recharge in 2016 (m^3)	Groundwater Recharge in 2036 (m^3)
JAN	1.137.788,22	892.726,14
FEB	1.585.288,33	1.243.841,62
MAR	1.515.301,83	1.188.929,13
APR	3.620.326,03	2.840.563,50
MAY	1.537.656,10	1.206.468,63
JUN	197.684,16	155.106,03
JUL	-694.112,84	-694.112,84
AGT	-2.553.924,58	-2.553.924,58
SEP	-4.266.072,14	-4.266.072,14
OCT	1.560.901,94	1.224.707,67
NOV	3.308.785,99	2.596.124,40
DES	3.891.553,34	3.053.372,62
Total	10.841.176,39	6.887.730,18

Groundwater Balance

The groundwater balance (ΔS) in Ngarawan watershed in 2016 and 2034 is calculated using the ground water balance equation, based on data on groundwater availability and demand.

Table 7. Ngarawan Watershed Groundwater Balance in 2016

Month	Groundwater recharge (m^3)	Groundwater demand (m^3)	Groundwater balance (ΔS) (m^3)	Expl.
JAN	1.137.788,22	161.505	976.283,22	Surplus
FEB	1.585.288,33	161.505	1.423.783,33	Surplus
MAR	1.515.301,83	161.505	1.353.796,83	Surplus
APR	3.620.326,03	161.505	3.458.821,03	Surplus
MAY	1.537.656,10	161.505	1.376.151,10	Surplus
JUN	197.684,16	161.505	36.179,16	Surplus
JUL	-694.112,84	161.505	-855.617,84	Deficit
AGT	-2.553.924,58	161.505	-2.715.429,58	Deficit
SEP	-4.266.072,14	161.505	-4.427.577,14	Deficit

OCT	1.560.901,94	161.505	1.399.396,94	Surplus
NOV	3.308.785,99	161.505	3.147.280,99	Surplus
DES	3.891.553,34	161.505	3.730.048,34	Surplus
Total	10.841.176,38	1.938.060	8.903.116,38	Surplus

Table 8. Projection of Ngarawan Watershed Groundwater Balance in 2034

Month	Groundwater recharge (m^3)	Groundwater demand (m^3)	Groundwater balance (ΔS) (m^3)	Expl.
JAN	892.726,14	284.930	607.796,14	Surplus
FEB	1.243.841,62	284.930	958.911,62	Surplus
MAR	1.188.929,13	284.930	903.999,13	Surplus
APR	2.840.563,50	284.930	2.555.633,50	Surplus
MAY	1.206.468,63	284.930	921.538,63	Surplus
JUN	155.106,03	284.930	-129.823,97	Deficit
JUL	-694.112,84	284.930	-979.042,84	Deficit
AGT	-2.553.924,58	284.930	-2.838.854,58	Deficit
SEP	-4.266.072,14	284.930	-4.551.002,14	Deficit
OCT	1.224.707,67	284.930	939.777,67	Surplus
NOV	2.596.124,40	284.930	2.311.194,40	Surplus
DES	3.053.372,62	284.930	2.768.442,62	Surplus
Total	6.887.730,18	3.419.160	3.468.570,18	Surplus

Based on the calculation of the groundwater balance, for the yearly ground water balance in 2016 and 2034 is still a surplus, despite a drastic reduction in the amount of groundwater savings, from 8,903,116.38 m^3/year to 3,468,570.18 m^3/year, amounted to 61,04%. In July, August and September in 2016 and June, July, August, and September in 2034 there is a deficit for the monthly water balance. In this situation there will be a decrease in the water table in Ngarawan watershed.

Ground water deficit occurs in months where the average monthly rainfall is smaller than the evapotranspiration value (in July, August, and September), which generally occurs during the dry season. Ground water deficit can also occur if the volume of groundwater affinity is less than the volume of groundwater demand, as in the projection for June 2036.

Seeing the development of this Ngarawan watershed area, then the opening of land for infrastructure development, settlement, public facilities and other sectors would inevitably not be avoided. Uncontrolled land use or land use will inevitably result in increased runoff, which may cause flooding. Land-hardening / land-use development or land use will also cause a reduction of the catchment area, which will affect the water system (Leveson, 1980).

According to Arsyad (1989), any treatment given on a plot of land will affect the water system in that place and the places downstream. Therefore, groundwater management is needed in the short and long term, to maintain the sustainability of ground water quality and quantity in Ngarawan watershed.

4. Conclusions

Ngarawan Watershed has sufficient ground water potential, based on yearly water balance calculations. But with the rapid development in the city of Manggar as the capital of Belitung Timur Regency, will have an impact on the increase in population and socio-economic facilities, as well as reduced land cover. The average groundwater storage potential will continue to decline until 2036, in the absence of groundwater management efforts.

Groundwater management that can be done is with the use of rainwater, which is making a pool/storage tank and absorption wells. Utilization of rainwater can reduce the potential for flooding during the rainy season, as well as maintaining water supply during the dry season, especially in June, July, August and September. Maintaining the quantity and quality of the remaining forests also needs to be done so that the groundwater absorption area is maintained.

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