Contribution of Groundwater to River Discharge in the Mampang Sub-watershed

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Abstract

Water is a necessity of human life. In fulfilling this need, the use of groundwater is often used. Groundwater is a non-renewable resource. Jakarta is a city traversed by many rivers and has a morphological dependence on the upstream watershed (DAS) in the Jabodetabek Region. The research location is in the Mampang Sub-watershed, which is in the Jakarta and Depok areas. The Mampang sub-watershed is geographically located at 106°48'44" - 106°49'59" East Longitude and 6°15'4" - 6°22'17" South Latitude. The problem in the research of the Mampang Sub-watershed often experiences floods every year with a height of between 10 cm - 50 cm. The aim of the study was to determine the groundwater-surface water interaction during a flood event at the study site. The method used is by collecting primary data and secondary data, then simulating using SWAT (Soil and Water Assessment Tools) and SWAT-MODFLOW. The SWAT MODFLOW simulation results obtained 874 river grids with Groundwater Surface Water Exchange Rates (GWSER) values in February 2020 between 52 m3/day to 353 m3/day and in September 2019 between -74 m3/day to 26 m3/day. The contribution of groundwater can be analyzed by comparing the river discharge in a certain month with the GSWER value for that month. The contribution of groundwater to the monthly peak discharge of the river at the study site ranges from 0.24% to 5.27%, and the average contribution of groundwater is 2.48%.

Keywords: *Groundwater, Mampang Sub-watershed, River Discharge, Groundwater Surface Wate, Exchange Rates.*

A. INTRODUCTION

Water is a necessity of human life; in fulfilling this need, the use of groundwater is often used. Groundwater is a non-renewable resource. The location of this research is in the area of Jakarta. The city of Jakarta is one of the cities that is traversed by many rivers and has a morphological dependence on the upstream watershed (DAS) in the Greater Jakarta area. Some of the Jakarta aquifer sources (Herlambang & Indriatmoko, 2005; Cook, 2013; Sun et al., 2021) come from Depok and Bogor. Groundwater management in a groundwater area is named Groundwater Basin. With this morphological dependence, the Presidential Decree of the Republic of Indonesia No. 26 of 2011 states that the Jakarta Groundwater Basin (CAT Jakarta) is a cross-provincial groundwater basin covering three provinces, namely Jakarta, West Java, and Banten.

If there are land use changes in Depok and Bogor that will affect the presence of groundwater in Jakarta, land use changes that occur upstream (Depok and Bogor) will affect Jakarta's hydrological conditions so that an integrated and holistic watershed management concept is called the concept of one watershed one management (Sabar & Plamonia, 2011; Santos et al., 2013; Guo et al., 2020). Groundwater - surface water, especially around the banks of rivers/streams, have a relationship with each other and has an impact on the pattern of groundwater-surface water both in quantity and water quality.

The research location is in the Mampang Sub-watershed with an area of 3,122 Ha and is in the Jakarta and Depok areas with a geographic location at 106°48'44" - 106°49'59" East Longitude and 6°15'4" - 6°22'17 "South latitude. The Mampang sub-watershed in the DKI Jakarta 2030 RTRW includes areas that are prone to inundation during the rainy season and has a flood-prone status (Provincial Government of DKI Jakarta, 2022). The aim of the study was to determine the groundwater-surface water interaction during a flood event at the study site. Problems in the research of the Mampang Sub-watershed often experience floods every year with a height of between 10 cm - 50 cm (DSDA Jakarta 2022). The research will discuss the interaction of groundwater-surface water in certain months every year during the research period.

B. METHOD

In order to be able to analyze the pattern of groundwater-surface water interaction, the method used is to collect primary data and secondary data. In this study, collecting river discharge for six months, taking groundwater levels at 15 points, collecting other data such as climatology data, DEM data, land use data, soil type data, infiltration data, and other supporting data, then proceeding with a SWAT simulation (Soil and Water Assessment Tools) and SWAT-MODFLOW. From the simulation results, the results of groundwater-surface water exchange rates (GSWER) will be obtained.

C. RESULT AND DISCUSSION

1. The Condition of the Mampang Sub-Watershed

The geological conditions of the study site from the Geological Map of Jakarta and the Thousand Islands Sheet (Turkandi, 1992; Batlle et al., 2014; Bishop et al., 2017) are alluvium fan (Qav) consisting of silt, sandstone, and gravel and alluvium (Qa) consisting of clay, silt, gravel, and cobblestone. Based on the Hydrogeological Map sheet of Jakarta (Soekardi, 1986), the Hydrogeology of the Mampang Sub-watershed is dominated by productive aquifers and a broad distribution where groundwater flows through gaps and spaces between grains. The type of soil in the study location is Latosol (Water Resources Service, 2020), which has the property of absorbing water. For infiltration rate based on Kohnke. 1968, the Mampang Sub-watershed has a slow infiltration classification ranging from 10 - 50 mm/hour (Water Resources Service, 2020). The rapid economy and population growth rate are one of the causes of changes in land use. These changes can have an impact on the contribution of groundwater. It can be seen in Figure 1. The largest land use for the Mampang Sub-watershed is Settlements and Activity Sites, which is around 77%.

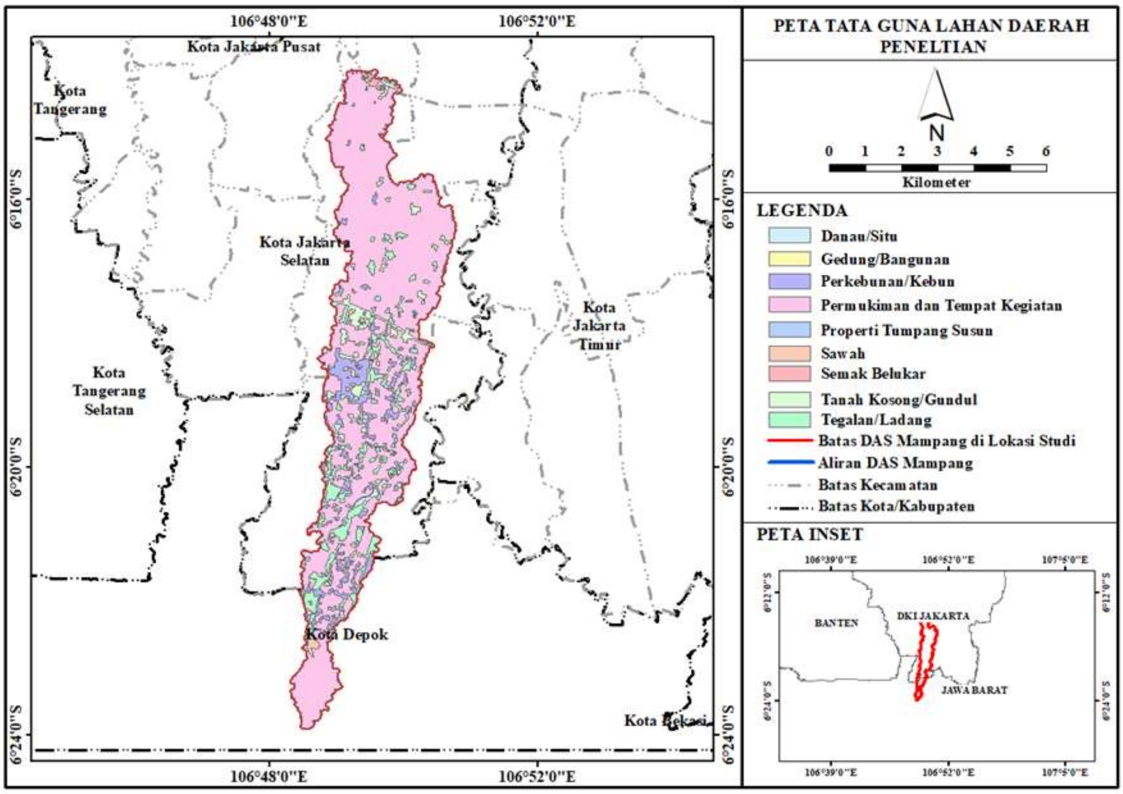

Figure 1. Land Use Map

2. Climatology Data

Climate data for research locations were obtained from the Meteorology, Climatology and Geophysics Agency (BMKG, 2022) for the period 2012-2022; the data obtained included average rainfall of 188.69 mm/month, the monthly average temperature of 28.36 oC, and 13.27% solar radiation. The Mampang sub-watershed has 2 (two) seasons, namely the rainy season and the dry season every year.

3. Simulation of Soil and Water Assessment Tools (SWAT)

SWAT modeling in this study was carried out using ArcSWAT 10.4.21 software on ArcGIS 10.4.1. The modeling process includes several stages, namely watershed delineation, division of HRU (Hydrological Response Unit), the input of climatology data, then simulation and calibration.

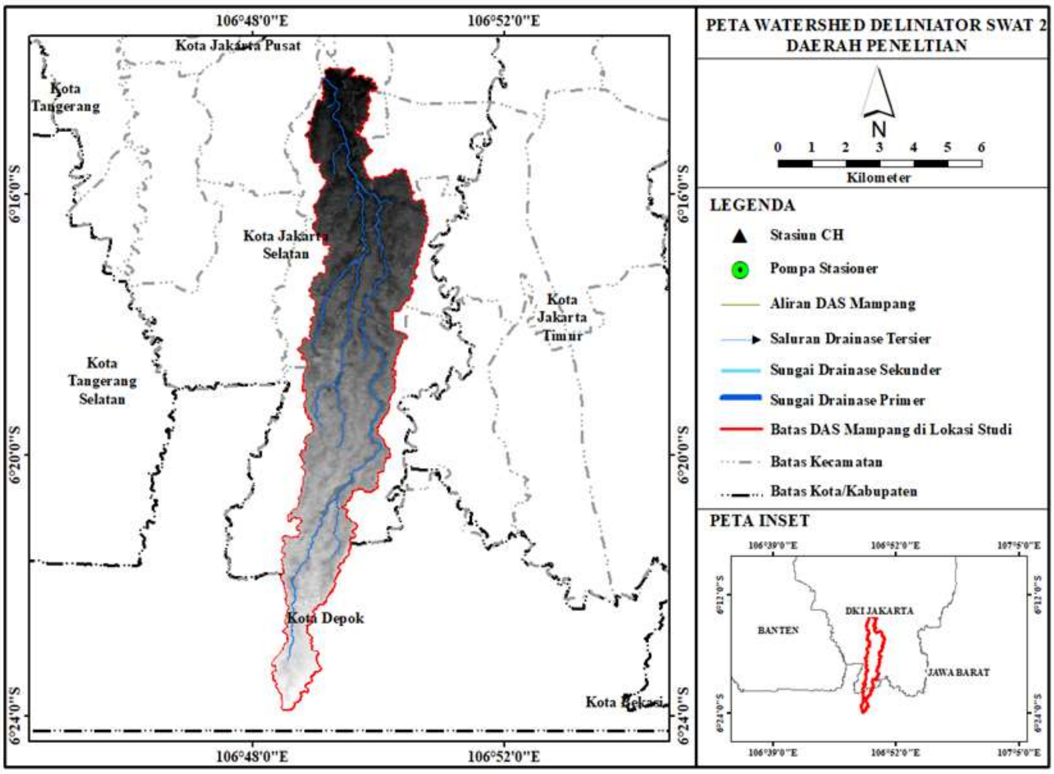

Figure 2. SWAT Delineation Result Map

The data used in the SWAT simulation are Digital Elevation Model (DEM) Data, Land Use Data, Climatological Data, Soil Type Data, and River Discharge Data. One of the simulation stages is the delineation of watersheds, determining the formation and number of main river networks and their tributaries, which then form the number of sub-watersheds. HRU Overlay Stage is a reclassification of soil types according to SWAT standards. The stage of entering weather data in *.txt form represents the station. The shape of the results of the Mampang Sub-watershed delineation (Figure 2).

The hydrological cycle scheme is used to divide the HRU in calculating the water balance from the results of land use, soil type, and slope of a watershed (Bailey et al., 2016), with the following equation:

$$SW_t = SW_0 + \sum_{i=1}^{t}(R_{day} - Q_{surf} - E_a - w_{seep} - Q_{gw}) \quad (1)$$

After the HRU distribution is complete, it is continued by entering climatological data and then simulating it. Next is the calibration process by comparing the discharge from the SWAT simulation results with the observation discharge at the same time and place. Calibration was performed using the SWAT-CUP software with the SUFI 2 algorithm (Sequential Uncertainty Fitting version 2). In this study, the river discharge collection point is at Jl. Poncol Gg 3 for six months. Then the calibration results give an R^2 value of 0.8707. Suppose the calibration results have a coefficient of determination (R^2) with a minimum value of 0.5. If it reaches this value, the model can proceed to the next simulation stage (Moriasi et al., 2007; Wang et al., 2021; Luijendik et al., 2020).

4. **SWAT-MODFLOW Simulation**

The next stage of the SWAT-MODFLOW simulation is the hydrological model by combining ground surface parameters, river hydrological processes, which are simulated using SWAT, and groundwater hydrogeological processes, which will be simulated. Two methods of rivers interact with groundwater, namely by filling the river with groundwater (gaining stream) and filling the groundwater (losing stream) (Winter, 1998; Rengarajan & Sarma, 2015) (Figure 3).

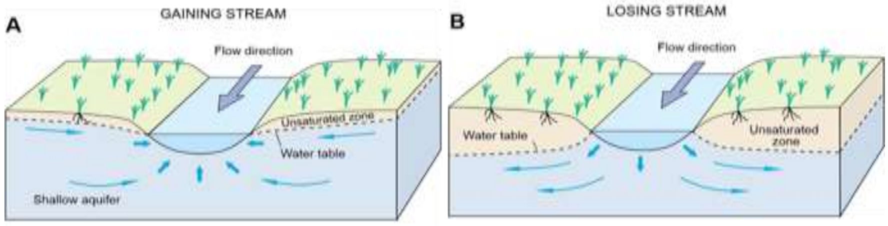

Figure 3. Interaction of groundwater and river water (Winter et al., 1998)

The river package equation in MODFLOW, the interaction of groundwater and river water is calculated as follows:

$$Q_{leak} = K_{bed}(L_{str}P_{str})\left(\frac{h_{str} - h_{gw}}{z_{bed}}\right) \qquad (2)$$

From the equation above, if the results are obtained with a negative discharge (Q) value, it means that the groundwater fills the river (gaining stream), while a positive discharge (Q) value means that the river water fills the groundwater (losing stream) (Bailey et al., 2016; Atkins et al., 2013; Santos et al., 2021). The calibrated and verified SWAT modeling results are connected to MODFLOW to model the interaction of groundwater and river water. Furthermore, the data needed in SWAT-MODFLOW is groundwater elevation maps from primary data interpolated and converted to a raster format, DEM data, and aquifer parameters consisting of specific storage (Ss) values of 2.3x 10-4 ft (Morris & Johnson, 1967; Zhou et al., 2019), the thickness of the aquifer was 30 m (Facri, 2002), the specific yield value (Sy) in the form of sand, medium was taken as 32%, and the conductivity value was taken as 0.232 m/day (Maathuis, 1996).

Then entered the SWAT-MODFLOW software. The SWAT MODFLOW results form a grid of 874 rivers, each grid having a value of groundwater-surface water exchange rates (GSWER) per day for the period 2015 – 2022. The output obtained is “swatmf_out_MF_gwsw” with file contents in the form of exchange volume (m^3/day) between river water with aquifers in each river grid which was previously processed in a spreadsheet, and the river grid was then entered into ArcMap. SWAT – MODFLOW simulation results can be displayed in the form of a GSWER map. To find out changes in groundwater–river water interactions in the study area, which are displayed on the GSWER map (Figures 4 and 5), select February 2020 for rainy season with the results of the largest SWAT simulation monthly average discharge values, with GSWER values ranging from - 52 m^3/day (gaining stream) up to 353 m^3/day (losing stream). For the dry season, September 2019 was chosen with the smallest SWAT simulation monthly average discharge value, with GSWER values ranging from -74 m^3/day (gaining stream) to 26 m^3/day (losing stream).

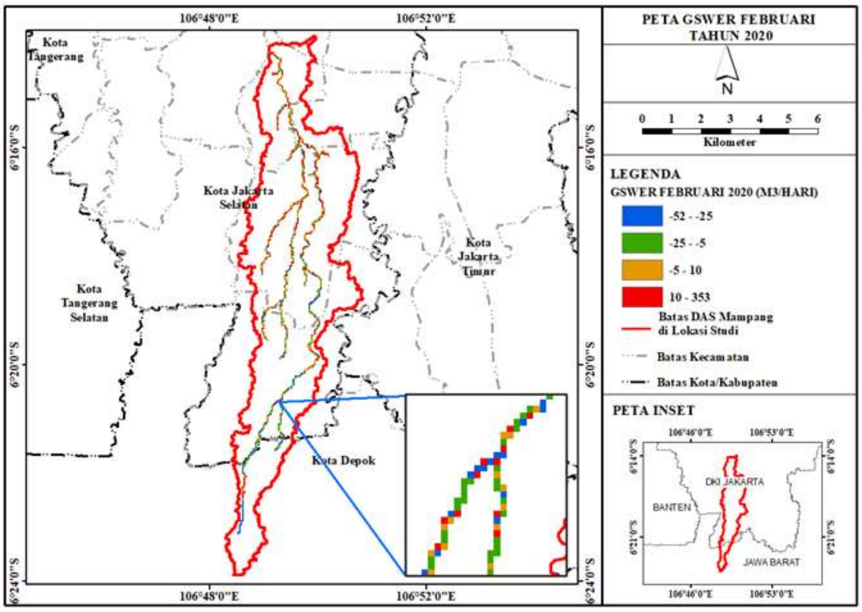

Figure 4. GSWER Map for February 2020

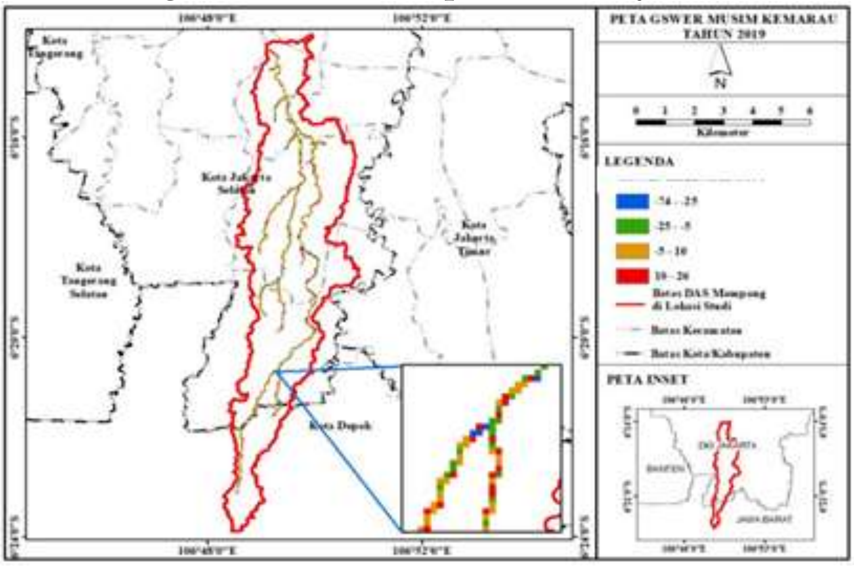

Figure 5. GSWER Map for September 2019

To determine the interaction contribution of groundwater and river water to the monthly peak discharge of the river. From 2015 to 2022. By adding up the GSWER (Groundwater Surface Water Exchange Rates) values of the Mampang River from upstream to the observation point on Jl. Poncol Gg 3, then compared with the simulated discharge of the river. The choice of the month is taken from the largest SWAT simulation discharge each year, and that month experiences flood events. The results show that the contribution of groundwater to the monthly peak discharge of rivers in the study locations ranges from 0.24% to 5.27%, and the average contribution of groundwater is 2.48% (Table 1).

Table 1. Contribution of groundwater to the monthly peak discharge of the river

Year	Month	River Flow Discharge (m^3/s)	GSWER Value (m^3/s)	Groundwater Contribution (%)
2015	February	9.94	0.10	1.03
2016	February	4.55	0.24	5.24
2017	February	4.82	0.01	0.24
2018	February	3.94	0.04	1.09
2019	March	2.53	0.05	1.83
2020	February	10.06	0.23	2.25
2021	February	5.65	0.30	5.27
2022	January	3.30	0.10	2.93
Average				**2.48**

D. CONCLUSION

Based on the results of the study, it can be concluded that the interaction of groundwater and Mampang River water consists of 2 (two), namely gaining streams and losing streams. Each river grid has a different GSWER value; in February 2020, the values ranged from 52 m^3/day to 353 m^3/day, and in September 2019, they ranged from -74 m^3/day to 26 m^3/day. The contribution of groundwater to the monthly peak discharge of the river in the study area ranges from 0.24% to 5.27%, and the average contribution of groundwater is 2.48%; the results obtained are not too significant, the possibility of the cause of the flooding is dominated by rainwater which becomes runoff or narrowing. River. In this study, there are still many shortcomings, so it requires other methods to complete in producing accurate values.

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