Analysis using the F. J. Mock Method for calculation of water balance in the Upper Konto Sub-Watershed

Dian Chandrasasi¹, Lily Montarcih Limantara¹, Riska Wulan Juni¹

¹Water Resources Engineering Department, Faculty of Engineering, Universitas Brawijaya, Malang, Indonesia

E-mail: labelledian@ub.ac.id

Abstract. A study of water balance in the Upper Konto sub-watershed was carried out to determine the potential for water availability and its use in the multisector water needs. Rainfall was converted into discharge using the F. J. Mock method, compared with the observed discharge, and calibrated with the Relative Error, Root-Mean-Square Error (RMSE), Nash-Sutcliffe Efficiency (NSE), and Correlation Coefficient (R). The potential for water availability was calculated based on an 80% dependable flow using the Weibull probability method with an amount of 22.41 m³/sec, equivalent to 706.622 million m³/year. The amount of water demand within a period of 25 years in scenario 1 (calculated based on data and increasing according to the growth rate) is 95.090 million m³/year, while in scenario 2 (based on the assumption that domestic, non-domestic, and industry demand increased while fishery, agriculture, and livestock demand remained constant) is 93.419 million m³/year. The results of the water balance analysis showed that the potential for water availability is sufficient for all multisector water needs, or indicates a surplus condition for 25 years (2017-2042).

Keywords: Upper Konto Sub-Watershed, F. J. Mock, water availability, water needs, water balance.

1. Introduction

Water is the most important component of living things and is a natural resource that will not run out. Approximately 80% of the surface of the Earth is covered by water, consisting of 96% seawater and 2.5% fresh water. Of the freshwater supply, polar ice caps make up approximately 68.7% and the remaining 31% is groundwater. Of the entire available water supply on Earth, only approximately 0.8% is used for human needs. The purposes of this study are to find out the results of discharge calculation using the F. J. Mock method in the Upper Konto Sub-Watershed, to find out the amount of water availability in the Upper Konto Sub-Watershed, to find out the magnitude of water demand and its projections for the next 25 years in the Upper Konto Sub-Watershed, and to find out the condition of the water balance in the Upper Konto Sub-Watershed.

The Brantas River Basin is the second longest river in Java. The Brantas River Basin has an area of 11,800 km². The Brantas watershed has several tributaries, one of which is Konto River. Konto River is a
The river originating from the Argowayang-Anjasmoro Mountains in Malang Regency and is a part of the Brantas River Basin with an area of approximately 568 km² and a total length of 168.34 km². Administratively, the Upper Konto Sub-Watershed is located in the sub-districts of Pujon and Ngantang.

The Upper Konto sub-watershed has the Konto River as its main river; the Selorejo Reservoir within the river flow, which is in Ngantang District, functions as a provider of water for irrigation, fisheries, and hydropower.

Of the various problems, the development of important facilities is to be prioritized to prevent the degradation of water resources.

2. Material and Methods

2.1 Study Location

This research was conducted at the Upper Konto Sub-Watershed in Malang Regency, Province of East Java. The Upper Konto Sub-Watershed has an area of approximately 234.29 km² and is geographically located at the coordinates of 112°14'1" – 112°30'31" East Longitude and 7°45'49" – 7°50'8" South Latitude. There are four rain stations, which are the Pujon, Ngantang, Kedungrejo, and Sekar rain stations, and there is an AWLR device at Konto II, located in the Selorejo Reservoir.

![Figure 1. Upper Konto Sub-Watershed](image-url)
2.2 Required Data
The data needed for this research consist of the following:

a) Rainfall data over a period of 10 years (2008-2017)
b) Daily climate data over a period of 10 years (2008-2017) from the Karangploso Climatology Station
c) Daily average discharge data of inflow into Selorejo Reservoir over a period of 5 years (2008-2012)
d) Data on population (2010-2017), fisheries (2015-2017), and animal husbandry (2013-2017)
e) Data on discharge springs
f) Map of irrigation network scheme
g) Map of Malang Regency administration boundaries
h) Map of Upper Konto Sub-Watershed boundaries
i) Map of land use and soil types

2.3 Steps of Study Completion
This study requires several systematic procedures. The following are the steps of study completion:

a) Collection
   All secondary data needed for the study were gathered from various related agencies.

b) Statistical Testing
   Statistical testing of the data was performed to find out the consistency and quality of the data to be used. The utilized consistency test is the double-mass curve test. Data quality testing used the absence-of-trend test (Spearman rank correlation method) and stationary testing [1].

2.4 Average Rainfall Analysis
Rain that falls in each region vary widely; the rainfall of a region is obtained from the average rainfall from several rain stations. In this study, the Thiessen polygon method was utilized to obtain the influence value for the watershed (Kr).

a) Potential Evapotranspiration
   The process of water changing into vapour and moving from the surface of the soil and bodies of water is called evaporation. Evaporation that occurs from plants is called transpiration. If both processes occur simultaneously, the process is called evapotranspiration. In general, the magnitude of potential evapotranspiration will increase when temperature, solar radiation, humidity, and wind speed increase [2]. This research utilized the Modified Penman method.

b) Calculation of Discharge with the F. J. Mock Method
   - Preparation of required data, including average regional rainfall (P), potential evapotranspiration (Eto), number of rainy days (n), groundwater recession flow factor (k), and infiltration rate coefficient (i)
   - Determining limit of evapotranspiration
   - Determining the amount of rain at ground level (Ds)
   - Determining the amount of soil moisture (SMC)
   - Determining infiltration (i), between 0-1
   - Determining excess water in soil (water surplus)
   - Determining groundwater content (Vn)
   - Determining changes in groundwater content (DVn)
   - Determining base flow and direct flow
   - Determining the available discharge of the river

c) Calibration of Discharge Data
   Model calibration is the process of optimizing the model parameter values to obtain a set of parameters that gives the best estimate of the observed river flow (AWLR). The most commonly used
testing methods for calibration are the Relative Error Test, the Root-Mean-Square Error Test (RMSE), the Nash-Sutcliffe Efficiency (NSE) Test, and the Correlation Coefficient Test (R).

- Dependable Flow Analysis
  Dependable flow is discharge that is available for 100 years with a certain risk of failure. In this study, the method of using the curve of the duration of the discharge using Weibull probability was based on SNI No. 6738 of 2015 regarding the calculation of river reliability analysis with the discharge duration curve [3].

- Calculation of Area Percentage and Projection Methods
  Article 62 of Law No. 7 of 2004 concerning Water Resources states a 25-year long-term projection, which was then used as the projection reference in this study. Population projection methods include geometric, arithmetic, and exponential methods.

d) Calculation of Water Needs

- Domestic Water Needs
  The domestic water needs of each region differ depending on the number and growth of population, climate, water prices, water quality, and changes in environmental issues.

| No. | Clean Water Needs (litres/day/person) | City Category | Total population (people) |
|-----|--------------------------------------|---------------|--------------------------|
| 1   | 150-200                              | Metropolitan  | >1,000,000               |
| 2   | 125-150                              | Large City    | 500,000 – 1,000,000      |
| 3   | 100-125                              | Medium City   | 100,000 – 500,000        |
| 4   | 90-100                               | Small City    | 20,000 – 100,000         |
| 5   | 60-90                                | Village       | – 20,000                 |

- Non-Domestic Water Needs
  Non-domestic water demand is assumed to be between 15-30% of the total clean water needs in households. Larger and denser populations will tend to have more commercial and social areas, which results in greater water needs.
  In the planning for the study, water needs for urban areas in Indonesia are assumed to be 30% of the household clean water needs with a constant value for each planning stage, and thus the projected value of water demand will remain equal to 30% [4].

- Industrial Water Needs
  Industrial water needs includes the needs for production activities, covering raw materials, workers, the industry, and other forms of support for industries. Due to data limitations, industrial water needs can be calculated using the standards from the Directorate of Sanitation Engineering of the Directorate-General of Development, which is that industrial water needs for industry is taken to be approximately 10% of domestic water consumption [5].

- Fishery Water Needs
  Fishery water needs are calculated based on the size of fish pools or ponds with the standard water requirement for fisheries. The standard average freshwater needs for fishery is based on SNI 6728: 2015 [4].

- Agricultural Water Needs
  Water taken from a river or reservoir are to be channelled through the irrigation network system. In this study, irrigation water needs are obtained directly from the discharge scheme for the Konto River Irrigation Area.
Animal husbandry water needs depend on the number or population as well as types of livestock. In general, livestock water needs can be estimated by multiplying the number of livestock by the level of water needs [4].

2.5 Water Balance Analysis

The water balance illustrates the principle that, over a certain period of time, the total water input equals the total water output plus the change in reserve water amount. The concept of water balance is the amount of potentially available water that is subtracted by the total amount of water needs for various sectors. This will allow the discovery of water surpluses and deficits for current and future conditions.

3. Results And Discussion

3.1 Consistency Test (Double Mass Curved)

Rainfall data from stations – Pujon, Ngantang, Kedungrejo, and Sekar – were examined for their consistency to find out whether the value of \( \alpha \) (alpha) of the rainfall data is consistent or inconsistent.

| Rain Station | \( \alpha \) Before Correction Method 1 | \( \alpha \) Before Correction Method 2 | \( \alpha \) After Correction Method 1 | \( \alpha \) After Correction Method 2 | Results |
|--------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|---------|
| Pujon        | 38.51                                | 38.95                                | 44.55                                | 45.00                                | Consistent |
| Ngantang     | 57.62                                | 57.11                                | 45.00                                | 44.44                                | Consistent |
| Kedungrejo   | 34.73                                | 34.47                                | 44.43                                | 44.15                                | Consistent |
| Sekar        | 46.22                                | 46.70                                | 45.86                                | 46.33                                | Consistent |

3.2 Data Quality Test

a) This was performed to check for trends in periodic series.

| Rain Station | \( T_{critical} \) | \( T_{count} \) | Notes               |
|--------------|--------------------|----------------|---------------------|
| Pujon        | 1.960              | 1.147          | \( H_0 \) accepted (no trend) |
| Ngantang     | 1.520              | 1.540          | \( H_0 \) accepted (no trend) |
| Kedungrejo   | 1.625              | 1.625          | \( H_0 \) accepted (no trend) |
| Sekar        | 0.960              | 1.540          | \( H_0 \) accepted (no trend) |

b) Stationary Testing

This was performed with the F-test to find out the stability of data variance values, and with the t-test to find out the stability of the average values.

| Rain Station | \( F_{count} \) | \( \alpha \) | \( F_c \) | Notes               |
|--------------|-----------------|-------------|----------|---------------------|
| Pujon        | 0.747           | 5%          | 1.540    | Stable variance value |
| Ngantang     | 1.316           | 5%          | 1.540    | Stable variance value |
| Kedungrejo   | 0.889           | 5%          | 1.540    | Stable variance value |
| Sekar        | 0.892           | 5%          | 1.540    | Stable variance value |
Table 5. Summary of t-test results

| Rain Station | t-value | α | t-critical | Notes |
|--------------|---------|---|------------|-------|
| Pujon        | -0.236  | 5%| 1.960      | Stable average value |
| Ngantang     | 0.695   | 5%| 1.960      | Stable average value |
| Kedungrejo   | 0.393   | 5%| 1.960      | Stable average value |
| Sekar        | -0.266  | 5%| 1.960      | Stable average value |

3.3 Average Regional Rainfall

Analysis of regional average rainfall was performed to obtain the rainfall value that can represent the overall value for the Upper Konto Sub-Watershed. The utilized rain stations were the Pujon, Ngantang, Kedungrejo, and Sekar rain stations. The following are the results of the effect area values (Kr) for the four rain stations:

Table 6. Thiessen polygon effect areas of the rain stations

| Rain Station | Area (km²) | Kr |
|--------------|------------|----|
| Sekar        | 55,393     | 0.236 |
| Kedungrejo   | 62,963     | 0.269 |
| Ngantang     | 39,732     | 0.170 |
| Pujon        | 76,203     | 0.325 |
| **Total**    | **234,291**| **1.000** |

The Kr value was multiplied by rainfall data to obtain the average monthly rainfall.

Table 7. Summary of Average Regional Rainfall Calculation

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 2008 | 513.85 | 596.39 | 695.68 | 262.52 | 107.19 | 13.39 | 0.00 | 8.57 | 26.41 | 181.32 | 307.43 | 287.38 |
| 2009 | 648.33 | 670.00 | 296.17 | 174.58 | 244.39 | 73.36 | 0.00 | 0.43 | 7.92 | 60.31 | 265.59 | 192.76 |
| 2010 | 728.83 | 547.97 | 421.33 | 443.46 | 143.56 | 90.84 | 0.00 | 16.28 | 50.96 | 498.48 | 391.43 | 473.80 |
| 2011 | 507.06 | 294.05 | 414.05 | 260.91 | 286.85 | 12.63 | 3.85 | 0.00 | 16.28 | 50.96 | 498.48 | 391.43 |
| 2012 | 545.06 | 525.10 | 347.16 | 155.68 | 64.24 | 16.40 | 0.00 | 0.00 | 0.70 | 82.95 | 337.41 | 425.40 |
| 2013 | 961.64 | 525.77 | 389.85 | 468.12 | 197.00 | 73.56 | 43.03 | 16.31 | 39.09 | 104.32 | 354.91 | 430.84 |
| 2014 | 691.25 | 617.97 | 319.45 | 199.89 | 206.02 | 69.43 | 131.39 | 255.97 | 623.99 | 406.06 | 713.34 |
| 2015 | 319.00 | 357.73 | 415.45 | 197.38 | 232.06 | 47.33 | 19.63 | 7.56 | 144.12 | 444.76 | 373.78 |
| 2016 | 319.00 | 357.73 | 415.45 | 197.38 | 232.06 | 47.33 | 19.63 | 7.56 | 144.12 | 444.76 | 373.78 |
| 2017 | 319.00 | 357.73 | 415.45 | 197.38 | 232.06 | 47.33 | 19.63 | 7.56 | 144.12 | 444.76 | 373.78 |
| **Average** | **550.91** | **521.74** | **420.42** | **259.65** | **184.38** | **73.56** | **43.03** | **16.31** | **39.09** | **104.32** | **354.91** | **430.84** |

3.4 Evapotranspiration Potential

The calculation of evapotranspiration potential in the study used the modified Penman method. The utilized data included monthly average temperature, relative humidity, wind speed, and length of sun exposure.

Table 8. Summary of evapotranspiration potential calculation results

| No | Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|----|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1  | 2008 | 4.38 | 3.89 | 3.40 | 3.29 | 3.41 | 3.07 | 3.42 | 3.72 | 4.95 | 5.07 | 4.18 | 3.70 |
| 2  | 2009 | 3.36 | 3.86 | 4.03 | 3.55 | 2.93 | 3.39 | 3.46 | 4.00 | 4.72 | 3.89 | 5.03 | 4.39 |
| 3  | 2010 | 3.64 | 3.91 | 3.87 | 2.76 | 2.70 | 2.80 | 2.87 | 3.75 | 4.05 | 4.28 | 4.26 | 3.46 |
| 4  | 2011 | 3.84 | 3.91 | 3.42 | 2.72 | 2.87 | 3.05 | 3.27 | 4.07 | 4.88 | 4.59 | 3.83 | 3.42 |
| 5  | 2012 | 3.26 | 4.01 | 3.56 | 3.12 | 3.05 | 2.88 | 2.73 | 3.55 | 4.60 | 4.84 | 4.26 | 3.47 |
| 6  | 2013 | 3.50 | 2.88 | 3.85 | 3.02 | 3.07 | 2.81 | 2.92 | 3.89 | 4.97 | 5.27 | 4.47 | 3.65 |
| 7  | 2014 | 3.67 | 3.85 | 4.15 | 3.06 | 3.35 | 3.11 | 2.74 | 3.81 | 5.12 | 5.66 | 4.58 | 3.47 |
| 8  | 2015 | 3.81 | 4.28 | 3.87 | 3.11 | 3.35 | 3.22 | 3.44 | 4.14 | 5.46 | 6.67 | 5.35 | 4.15 |
| 9  | 2016 | 4.61 | 3.63 | 3.98 | 3.38 | 3.27 | 2.94 | 3.24 | 4.06 | 4.85 | 4.68 | 4.16 | 3.81 |
| 10 | 2017 | 4.62 | 4.16 | 3.86 | 3.07 | 3.29 | 2.96 | 2.87 | 3.89 | 5.09 | 5.09 | 3.78 | 3.84 |
| Average | 3.77 | 3.84 | 3.80 | 3.11 | 3.13 | 3.02 | 3.10 | 3.89 | 4.87 | 5.00 | 4.39 | 3.74 |
3.5 F. J. Mock Discharge Method

The results of the calculations for average monthly regional rainfall and evapotranspiration potential were then used for discharge simulation analysis using the F. J. Mock method. Calculation of discharge using the F. J. Mock method was performed using a monthly period. The following is the summary of results for discharge calculation using the F. J. Mock method:

Table 9. Summary of discharge calculation results with the F. J. Mock method

| Year | Discharge (m³/s) | Total  | Average |
|------|----------------|--------|---------|
|     | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |       |
| 2008 | 12.22 | 24.11 | 31.32 | 21.99 | 13.99 | 10.52 | 7.55 | 5.60 | 4.30 | 3.09 | 2.95 | 8.35 | 145.98 | 12.17 |
| 2009 | 26.69 | 43.33 | 25.50 | 15.51 | 14.35 | 6.48 | 2.85 | 1.29 | 0.60 | 0.27 | 0.12 | 0.05 | 137.05 | 11.42 |
| 2010 | 11.85 | 16.14 | 14.82 | 18.13 | 17.45 | 14.53 | 11.88 | 10.21 | 10.44 | 11.38 | 16.21 | 17.94 | 170.97 | 14.25 |
| 2011 | 21.47 | 19.88 | 23.76 | 19.54 | 18.40 | 6.86 | 2.57 | 1.00 | 0.40 | 0.15 | 0.10 | 0.04 | 0.95 | 20.45 | 125.32 |
| 2012 | 27.16 | 35.34 | 23.74 | 11.52 | 3.70 | 1.52 | 0.59 | 0.23 | 0.10 | 0.04 | 0.09 | 0.95 | 20.45 | 125.32 |
| 2013 | 35.24 | 28.36 | 19.60 | 25.86 | 12.90 | 13.96 | 11.86 | 7.26 | 4.97 | 3.76 | 2.60 | 1.92 | 137.05 | 11.42 |
| 2014 | 22.80 | 29.81 | 14.97 | 12.15 | 6.35 | 4.70 | 2.30 | 2.57 | 1.92 | 1.69 | 0.94 | 0.23 | 10.99 | 10.44 |
| 2015 | 19.54 | 17.45 | 14.53 | 11.88 | 10.21 | 10.44 | 11.38 | 16.21 | 17.94 | 170.97 | 14.25 |
| 2016 | 15.70 | 19.00 | 21.25 | 15.69 | 12.68 | 9.73 | 8.42 | 8.13 | 8.02 | 8.62 | 9.81 | 10.94 | 145.98 | 12.17 |
| 2017 | 13.70 | 17.37 | 17.15 | 17.05 | 17.88 | 17.85 | 11.21 | 9.35 | 8.51 | 8.20 | 8.09 | 12.34 | 11.38 | 156.79 |

3.6 Discharge Data Calibration

a) Comparison of calculated and measured discharges

Due to limited data, the utilized discharge for observation is the average daily inflow discharge into Selorejo reservoir from 2008-2012.

The following are the results of comparing calculated discharge and observed discharge:

Table 10. Summary of calculated discharge and observed discharge from 2008-2012

| Year | Discharge (m³/s) | Total  | Average |
|------|----------------|--------|---------|
|     | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |       |
| 2008 | 13.70 | 17.37 | 15.21 | 21.25 | 13.69 | 12.48 | 12.31 | 12.48 | 12.31 | 10.07 | 7.47 | 5.64 | 4.70 | 2.85 | 1.29 | 0.60 | 0.27 | 0.12 | 0.05 | 137.05 | 11.42 |
| 2009 | 15.47 | 19.88 | 15.12 | 14.97 | 12.15 | 6.35 | 4.70 | 2.30 | 2.57 | 1.92 | 1.69 | 0.94 | 0.23 | 10.99 | 10.44 |
| 2010 | 15.80 | 18.62 | 17.84 | 18.62 | 17.84 | 17.85 | 11.21 | 9.35 | 8.51 | 8.20 | 8.09 | 12.34 | 11.38 | 156.79 |
| 2011 | 17.37 | 22.38 | 15.21 | 12.48 | 12.31 | 10.07 | 7.47 | 5.64 | 4.70 | 2.85 | 1.29 | 0.60 | 0.27 | 0.12 | 0.05 | 137.05 | 11.42 |
| 2012 | 19.54 | 17.45 | 14.53 | 11.21 | 9.35 | 8.51 | 8.20 | 8.09 | 12.34 | 11.38 | 156.79 |

b) Data calibration test method

The following are the results of calculations using the 5-year discharge data calibration test method (2008-2012):

Table 11. Recapitulation of Method Results Calibration Test

| Test Method | Value | Interpretation |
|-------------|-------|----------------|
| Relative Error | 0.4324 |               |
| RMSE         | 6.6236 | -              |
| NSE          | 0.5651 | Satisfactory   |
| R            | 0.9001 | Very Strong    |

7
c) Dependable flow
A dependable flow of 80% was calculated by adding the result of the discharge from the F. J. Mock simulation method to the spring availability, and probability was then calculated using the Weibull method.

| Table 12. Availability of springs in the Upper Konto Sub-Watershed |
|---------------------------------------------------------------|
| **Pujon and Ngantang Sub-Districts**                          |
| No | Village  | Discharge (l/s) |
|----|---------|-----------------|
| 1  | Pandesari | 57.30          |
| 2  | Pujon Kidul | 7.00           |
| 3  | Sukomulyo  | 78.30          |
| 4  | Pujon Lor  | 18.75          |
| 5  | Bendasari  | 63.30          |
| 6  | Ngroto    | 0.30           |
| 7  | Wiyurejo  | 12.80          |
| 8  | Madirejo  | 69.10          |
| 9  | Ngabab    | 15.60          |
| 10 | Tawangsari | 16263.00      |
| 11 | Mulyorejo  | 20.88          |
| Total (l/s) | 16606.33       |
| Total (m³/s) | 16.61          |

| Table 13. Total discharge from the sum of F. J. Mock calculated discharge and spring discharge |
|------------------------------------------------------------------------------------------------|
| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total (m³/s) |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------------|
| 2008 | 28.83 | 40.71 | 47.93 | 38.59 | 30.59 | 27.13 | 24.16 | 22.21 | 20.90 | 19.69 | 19.55 | 24.96 | 345.26       |
| 2009 | 43.29 | 59.94 | 42.10 | 32.12 | 30.96 | 23.09 | 19.45 | 17.90 | 17.21 | 16.87 | 16.73 | 16.66 | 336.33       |
| 2010 | 28.46 | 32.74 | 31.42 | 34.74 | 34.05 | 31.13 | 28.48 | 26.81 | 27.05 | 27.98 | 32.82 | 34.54 | 370.24       |
| 2011 | 38.08 | 36.49 | 40.37 | 36.15 | 35.01 | 23.47 | 19.18 | 17.60 | 17.01 | 16.76 | 27.27 | 36.15 | 343.53       |
| 2012 | 43.77 | 51.94 | 40.33 | 28.12 | 20.30 | 18.13 | 17.19 | 16.84 | 16.70 | 16.46 | 17.56 | 37.06 | 324.60       |
| 2013 | 51.85 | 44.97 | 36.20 | 42.46 | 29.51 | 30.57 | 28.46 | 23.86 | 23.06 | 21.97 | 24.91 | 48.14 | 405.96       |
| 2014 | 39.40 | 46.42 | 31.58 | 28.76 | 22.96 | 22.25 | 21.30 | 20.65 | 20.20 | 19.59 | 19.26 | 38.85 | 331.21       |
| 2015 | 14.70 | 31.00 | 31.90 | 29.06 | 22.53 | 20.69 | 20.00 | 19.53 | 19.20 | 18.77 | 18.53 | 23.55 | 269.47       |
| 2016 | 25.79 | 47.48 | 38.98 | 26.42 | 26.22 | 27.95 | 23.09 | 21.58 | 21.02 | 22.36 | 31.84 | 32.27 | 345.01       |
| 2017 | 22.80 | 30.86 | 32.90 | 26.18 | 27.27 | 21.31 | 20.52 | 19.97 | 19.60 | 19.10 | 26.91 | 31.81 | 299.22       |

| Table 14. Calculation of 80% dependable flow using the Weibull method |
|---------------------------------------------------------------|
| **Data** | **Prob. (%)** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** | **Average** |
|---------|----------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|------------|
| 1       | 9.09           | 51.85   | 59.94   | 47.93   | 42.46   | 35.01   | 31.13   | 28.48   | 27.05   | 27.98   | 32.82   | 48.14   |            |
| 2       | 18.18          | 43.77   | 51.94   | 42.10   | 38.59   | 34.05   | 30.57   | 28.46   | 23.86   | 23.06   | 22.36   | 31.84   | 38.85   |            |
| 3       | 27.27          | 43.29   | 47.48   | 40.37   | 36.15   | 30.96   | 27.95   | 24.16   | 22.21   | 21.97   | 21.97   | 37.06   | 322.27  |            |
| 4       | 36.36          | 39.40   | 46.42   | 40.33   | 34.74   | 30.59   | 27.13   | 23.09   | 21.58   | 20.90   | 19.60   | 26.91   | 36.15   |            |
| 5       | 45.45          | 38.08   | 44.97   | 38.98   | 32.12   | 29.51   | 23.47   | 21.30   | 20.65   | 20.20   | 19.59   | 24.91   | 34.54   |            |
| 6       | 54.55          | 28.83   | 40.71   | 36.20   | 29.06   | 27.27   | 23.09   | 20.52   | 19.97   | 19.60   | 19.10   | 22.25   | 32.27   |            |
| 7       | 63.64          | 28.46   | 36.49   | 32.90   | 28.76   | 27.27   | 23.09   | 20.92   | 19.60   | 19.10   | 18.77   | 21.97   | 31.84   |            |
| 8       | 72.73          | 25.79   | 32.74   | 31.90   | 28.12   | 22.96   | 21.31   | 19.45   | 17.90   | 17.21   | 16.87   | 18.53   | 24.96   |            |
| 9       | 81.82          | 22.80   | 31.00   | 31.58   | 26.42   | 22.53   | 20.69   | 19.18   | 17.60   | 17.01   | 16.76   | 17.56   | 23.55   |            |
| 10      | 90.91          | 14.70   | 30.86   | 31.42   | 26.18   | 20.30   | 18.13   | 17.19   | 16.87   | 16.70   | 16.64   | 16.73   | 16.66   |            |
| Q       | 80%            | 23.40   | 31.35   | 31.64   | 26.76   | 22.62   | 20.81   | 19.23   | 17.66   | 17.05   | 16.78   | 17.75   | 23.83   | 22.41      |

From Table 14, the result of average 80% dependable flow from January-December is 22.41 m³/s, or equivalent to 706,623 million m³/year. The result indicates the potential availability of water that will be used in the water balance calculation.

d) Water needs
- Percentage of Area-Region and Projection-Selected Method
To find out the area and the number of residents in the Upper Konto Sub-Watershed, it is necessary to calculate the sub-district area percentage. Based on Law No. 7 of Year 2004 on Water Resources, the long-term projection is for 25 years. The selected projection method used in this study is the Arithmetic Method with the smallest standard deviation and the highest $R^2$ values.

**Table 15. Percentage of sub-district areas in the Upper Konto Sub-Watershed**

| Sub-District | Sub-District Area | Sub-District Area within the Upper Konto Sub-Watershed | Percentage |
|--------------|-------------------|--------------------------------------------------------|------------|
|              | km²               | km²                                                    | %          |
| Pujon        | 151.40            | 143.59                                                 | 94.84      |
| Ngantang     | 129.08            | 90.76                                                  | 70.32      |
| Total        | 280.48            | 234.35                                                 | 165.16     |

**Table 16. Total population of the Upper Konto Sub-Watershed**

| Sub-District | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|--------------|------|------|------|------|------|------|------|------|
| Pujon        | 62041| 62483| 62893| 63274| 63663| 64020| 64351| 64667|
| Ngantang     | 39249| 39355| 39441| 39505| 39574| 39621| 39650| 39671|
| Total        | 101290| 101838| 102333.8682| 102778| 103238| 103641| 104001| 104338|

**Table 17. Summary of population projection methods**

| Method          | SD   | $R^2$ |
|-----------------|------|-------|
| Geometric       | 4361.03 | 0.9998 |
| Arithmetic      | 4142.84 | 1      |
| Exponential     | 4370.78 | 0.9998 |

**Water Needs Scenario 1**

The calculation of domestic, non-domestic, and industrial water needs was based on the population growth rate of 0.42%. The growth rate of fish pools or ponds is 0%, and thus it was assumed that the projected water needs are constant. Agricultural water needs were obtained directly from the discharge data of the irrigation area scheme, which was considered to be constant for every year of projection. The water needs of livestock are 1.31% for cattle/buffaloes/horses, 19.72% for goats/sheep, 0% for pigs, and 7.29% for poultry. The average discharge is 95.090 million m³/year.

**Table 18. Summary of total water needs for various fields for 2017-2024**

| Total Water Needs | Discharge (million m³/year) |
|-------------------|-----------------------------|
|                   | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
| Domestic Water Needs | 4.760 | 4.861 | 4.962 | 5.064 | 5.165 | 5.266 |
| Non-Domestic Water Needs | 1.428 | 1.458 | 1.489 | 1.519 | 1.549 | 1.580 |
| Industrial water needs | 0.476 | 0.486 | 0.496 | 0.506 | 0.516 | 0.527 |
| Fishery Water Needs | 0.049 | 0.049 | 0.049 | 0.049 | 0.049 | 0.049 |
| Agricultural Water Needs | 80.543 | 80.543 | 80.543 | 80.543 | 80.543 | 80.543 |
| Animal Husbandry Water Needs | 5.888 | 6.715 | 7.551 | 8.387 | 9.222 | 10.058 |
| Total | 93.136 | 94.113 | 95.090 | 96.067 | 97.044 | 98.022 |
| Average | 95.090 |      |      |      |      |      |

**Water Needs Scenario 2**

In scenario 2, the calculation of water needs for various fields was performed based on the assumption that domestic, non-domestic, and industrial water needs will increase as in Scenario 1. Meanwhile, the water needs of fisheries, agriculture, and livestock were considered to have a
constant projection of water needs for the period of 2017-2042 in the future. The obtained average discharge was 93.419 million m$^3$/year.

**Table 19.** Summary of total water needs for various fields for 2017-2042

| Total Water Needs                  | Discharge (million m$^3$/year) |
|-----------------------------------|---------------------------------|
|                                   | 2017   | 2022   | 2027   | 2032   | 2037   | 2042   |
| Domestic Water Needs              |        |        |        |        |        |        |
| 4.760                            | 4.861  | 4.962  | 5.064  | 5.165  | 5.266  |        |
| Non-Domestic Water Needs          | 1.428  | 1.458  | 1.489  | 1.519  | 1.549  | 1.580  |
| Industrial water needs            | 0.476  | 0.486  | 0.496  | 0.506  | 0.516  | 0.527  |
| Fishery Water Needs               | 0.049  | 0.049  | 0.049  | 0.049  | 0.049  | 0.049  |
| Agricultural Water Needs          | 80.543 | 80.543 | 80.543 | 80.543 | 80.543 | 80.543 |
| Animal Husbandry/Livestock Water Needs | 5.880  | 5.880  | 5.880  | 5.880  | 5.880  | 5.880  |
| Total                             | 93.136 | 93.277 | 93.419 | 93.560 | 93.702 | 93.843 |
| Average                           | 93.419 |        |        |        |        |        |

**e) Water Balance Analysis**
Calculation of water balance is by subtracting the discharge for total water needs from the discharge for water availability. It is known that the total water availability discharge is 706,623 million m$^3$/year.

**Table 20.** Water balance analysis for scenario 1 in the for the Upper Konto Sub-Watershed in 2017-2024

| Year               | 2017     | 2022     | 2027     | 2032     | 2037     | 2042     |
|--------------------|----------|----------|----------|----------|----------|----------|
| Total water availability (million m$^3$/year) | 706.622  |          |          |          |          |          |
| Total water needs (million m$^3$/year)         | 93.136   | 94.113   | 95.090   | 96.067   | 97.044   | 98.022   |
| Water balance     | 613.487  | 612.509  | 611.532  | 610.555  | 609.578  | 608.601  |
| Information       | Surplus  | Surplus  | Surplus  | Surplus  | Surplus  | Surplus  |

4. Conclusion and Suggestions

4.1 Conclusion
Based on the results of calculations and analysis that had been carried out for the formulated problems in this study, it can be concluded that:

- Calculation of discharge using the F. J. Mock method for the Upper Konto sub-watershed conducted over a period of 10 years (2008-2017) resulted in a maximum monthly average discharge of 17.22 m$^3$/sec.

- The calculation of water requirements for the Upper Konto Sub-Watershed was performed for two scenarios. In scenario 1, the projected water needs within 25 years (2017-2042) always increases, except for the fisheries and agriculture sectors, which have fixed water needs; the projected average value of water needs per year is 95,090 million m$^3$/year. In scenario 2, the projected water needs within 25 years (2017-2042) are always constant except for the domestic, non-domestic, and industrial sectors, which are always increasing; the projected average value of water needs is 93,419 million m$^3$/year.
The following are the results of water balance analysis for the Upper Konto Sub-Watershed:

a. Total projected water needs in Scenario 1 is greater than in Scenario 2.
b. The projected water balance value in Scenario 1 is smaller than Scenario 2 because the water needs in Scenario 1 is greater.

4.2 Suggestions

Based on the results of water balance analysis for the Upper Konto Sub-Watershed in Malang Regency, which had been performed in this study, the following are suggestions that can be considered:

- Other tests should be carried out with more complete data from a longer period so that the analysis results are more accurate and precise.
- Other tests should be carried out using methods that are different from those in this study.
- Because the obtained AWLR data for the Upper Konto Sub-Watershed is not very accurate, such as the data for discharge, which increases drastically every year, this results in extreme comparative differences with a very large value of relative error. It is expected that further research can use more accurate and complete data.

References

[1] Soewarno 1995 Hidrologi: Aplikasi Metode Statistika untuk Analisa Data Jilid 2 [Hydrology: Application of Statistical Methods for Data Analysis, Part 2]. Bandung: Nova
[2] Asdak, Chay 2007 Hidrologi Dan Pengelolaan Daerah Aliran Sungai [Hydrology and Watershed Management]. Yogyakarta: Gajah Mada University Press.ISBN: 979-420-737-3
[3] Badan Standarisi Nasional SNI 6738:2015 Perhitungan Debit Andalan Sungai dengan Kurva Durasi Debit [Calculation of Dependable Flow with a Discharge Duration Curve]. Jakarta: Badan Standarisi Nasional
[4] Badan Standarisi Nasional SNI 6728.1:2015 Penyusunan Neraca Spasial Sumber Data Alam-Sumber Daya Air [Composition of the Spatial Balance of Natural Resources – Water Resources]. Jakarta: Badan Standarisi Nasional
[5] Triatmodjo B 2010 Hidrologi Terapan [Applied Hydrology]. Yogyakarta: Beta Offset Yogyakarta
[6] Chow, V T, Maidment, D R and Mays, L W 1988 Applied Hydrology. McGraw-Hill Book Company
[7] Indarto 2012 Hidrologi Dasar Teori dan Contoh Aplikasi Model Hidrologi [Fundamentals of Hydrology: Theories and Example Applications of Hydrological Models]. Jakarta: Bumi Aksara
[8] Montarcih, L 2018 Rekayasa Hidrologi [Hydrological Engineering]. Yogyakarta: CV Andi Offset
[9] Pechlivanidis, I G, Jackson, B M, McIntyre, N R and Wheater, H S 2011 Catchment Scale Hydrological Modelling : A Review of Model Types, Calibration Approaches and Uncertainty Analysis Methods in the Context of Recent Developments in Technology and Applications. Global Nest Journal. 13:193-214
[10] Setyawan, H W 2013 Studi Potensi Air Permukaan di Sub DAS Sumber Brantas [A Study of Potential Surface Water for the Sumber Brantas Sub-Watershed]. Unpublished undergraduate thesis. Malang: Universitas Brawijaya
[11] Wibowo, A C 2013 Studi Penentuan Kinerja Pengelolaan DAS di Sub DAS Upper Konto [Study on Determination of Watershed Management Performance of the Upper Konto Sub-Watershed]. Unpublished undergraduate thesis. Malang: Universitas Brawijaya
[12] Zulkipli 2011 Analisa Neraca Air Permukaan DAS Renggung untuk Memenuhi Kebutuhan Air Irrigasi dan Domestik Penduduk Kabupaten Lombok Tengah [Analysis of the Surface Water Balance of Renggung Watershed to Fulfill Domestic and Irrigation Water Needs of Residents of Central Lombok]. Jurnal Teknik Pengairan. III (2):89-90