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F.J Mock Method For Hydrological Moel In Water Reliability Study In Leuwi Padjadjaran II Reservoir

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Abstract

Padjadjaran University built the Leuwi Padjadjaran II Reservoir as a water harvesting facility and conservation area in the Cikeruh Sub-watershed area. This reservoir serves as a water reservoir before being channelled to other river branches and can be utilized as a water reserve collector. The water supply and the degree of water demand in the residential, non-domestic, agricultural, fishery, animal, and industrial sectors are impacted by land use changes and climate changes. This study aims to ascertain the state of the water balance in the Leuwi Padjadjaran II Catchment Area to know the deficit condition and calculate the reservoir serve. F.J. Mock Method was used to examine water availability based on climatology data. SNI 6728.1-2015, PUPR Minister Circular Letter (SE PUPR) Number 7 of 2018, and associated studies were used to analyze water demand. The findings revealed that total water demand was 133.506,09 m^3/year with an average of 11.125,5 m^3/month, and total water supply was 138.732,90 m^3/year with an average of 11.561,08 m^3/month. Throughout January-May and November-December, the water balance in the Leuwi Padjadjaran II Catchment Area was in surplus. Deficient water balance conditions occur from June-October, requiring water supply. Leuwi Padjadjaran II Catchment Area has a surplus of water, so it is sufficient to be utilized. Still, it is not evenly distributed, so there is a water shortage in several sectors, such as agriculture. To make the Leuwi Padjadjaran II Reservoir useful, conservation measures must be taken to manage the water demand.

Keywords – F.J Mock; Water Balance; Water Demand; Water Supply

I. INTRODUCTION

Universitas Padjadjaran (Unpad) Jatinangor Campus is one of the catchment areas that utilizes water for domestic and non-domestic needs [1]. Universitas Padjadjaran (Unpad) Jatinangor Campus is in the Cikeruh Sub-watershed area. Precipitation is the main factor controlling the hydrological cycle of a watershed [2]. In Indonesia, wet months occur from February to April and November to December [3].

The process of water flow generally comes from rainfall. The maximum rate of water movement into the soil is called the infiltration capacity, which occurs when rainfall intensity exceeds the soil's ability to absorb soil moisture. Infiltration involves three indirectly interrelated processes [4]. Potential evapotranspiration and actual evapotranspiration are essential components in hydrological models used to estimate water fluxes [5]. Several methods are used to calculate potential evapotranspiration values, one of which is the Penman-Monteith method [6].

Along with the rapid development in the Jatinangor Unpad Campus area, the demand for water and the supply of water has become unbalanced. Proper water management is needed to reduce excess or runoff water. Rainfall-runoff water must be accommodated to become water storage or reserves [7]. Water storage can use reservoir buildings. The soil texture in the Jatinangor Campus Unpad Catchment Area is clay. Jatinangor Campus Unpad has good potential in constructing rainwater harvesting ponds with a total area of 60.1 ha or 16.9% of the total area of Jatinangor Campus Unpad Catchment Area with a good location for rainwater harvesting in dryland agricultural areas. The construction of Leuwi Padjadjaran II Reservoir is the first step in controlling water availability problems. Leuwi Padjadjaran II Reservoir was built with the aim of water conservation.

Reservoirs have different catchment characteristics, such as land cover, slope, and others [8]. Land use changes in the Leuwi Padjadjaran II Reservoir's Catchment Area can disrupt the balance of water resources in the catchment area [9]. Land use change affects the amount of water intake and increases surface runoff. If this continues, it can cause a water crisis and land damage that causes erosion and sediment accumulation [10].

Various studies conducted worldwide on the effects of land use change [11] show that land use change profoundly impacts the magnitude of surface and subsurface flows that ultimately impact the long-term availability of water resources.

Land cover changes cause differences in river discharge in the dry and wet seasons and reduce the amount of water that can be stored. [12] Their study stated that land use significantly influences the amount of evapotranspiration, which rises and falls significantly with land use change. The difference in discharge is influenced by surface runoff [13]. Surface water flow is one of the factors for erosion and sedimentation [14]. As a water harvesting pond, Leuwi Padjadjaran II Reservoir is expected to be a useful rainwater harvesting structure and help meet the water needs at Padjadjaran University Jatinangor Campus. Unwise activities around the reservoir degrade the quality of reservoir services and cause a decrease in water availability and service life of the reservoir due to the sedimentation process [15].

The role of water in every process of the hydrological cycle is complex. As water moves through the hydrological cycle, it interacts with the process and dynamically with other components in the atmosphere. Estimating the value of each element of the hydrological cycle and its interactions is required in water balance calculations [16].

II. MATERIALS AND METHOD

The research object is Leuwi Padjadjaran II Reservoir, Padjadjaran University, located in Cikeruh Village, Jatinangor District, Sumedang Regency, West Java Province. Geographically, Leuwi Padjadjaran II Reservoir is located at the coordinates of 6°54'57.7"S 107°46'23.9"E. Analysis of regional rainfall using the Arithmetic Method, measurement of runoff coefficient using Cook's Method, analysis of water availability in the micro watershed of Leuwi Padjadjaran II Reservoir using the F.J Mock Method.

The Methodology of this study (Figure 1) consists of several steps, such as establishing the FJ. Mock model, calibration of model based on the objective function, and analyze water reliability using the water demand and water supply calculation result. F.J. Mock is widely used to determine the size of a watershed's primary discharge using the water balance principle. In practically every corner of the world, this model is commonly used to simulate discharge in watersheds or reservoirs [17]. FJ. Mock's hydrological model calculates rainfall and actual evapotranspiration data for the region. The standard used in each sector for water demand calculation is SNI 6728.1-2015 for domestic, non-domestic, and livestock sectors. PUPR Circular Letter Number 7/SE/M/2018 of 2018 for the agricultural sector. The fisheries sector uses Standards used are the results of the Frontiers Investment and Development Partners (FIDP) and Integrated Water Resources Development (IWRD) studies. Industry and fisheries use the results of research conducted by [18].

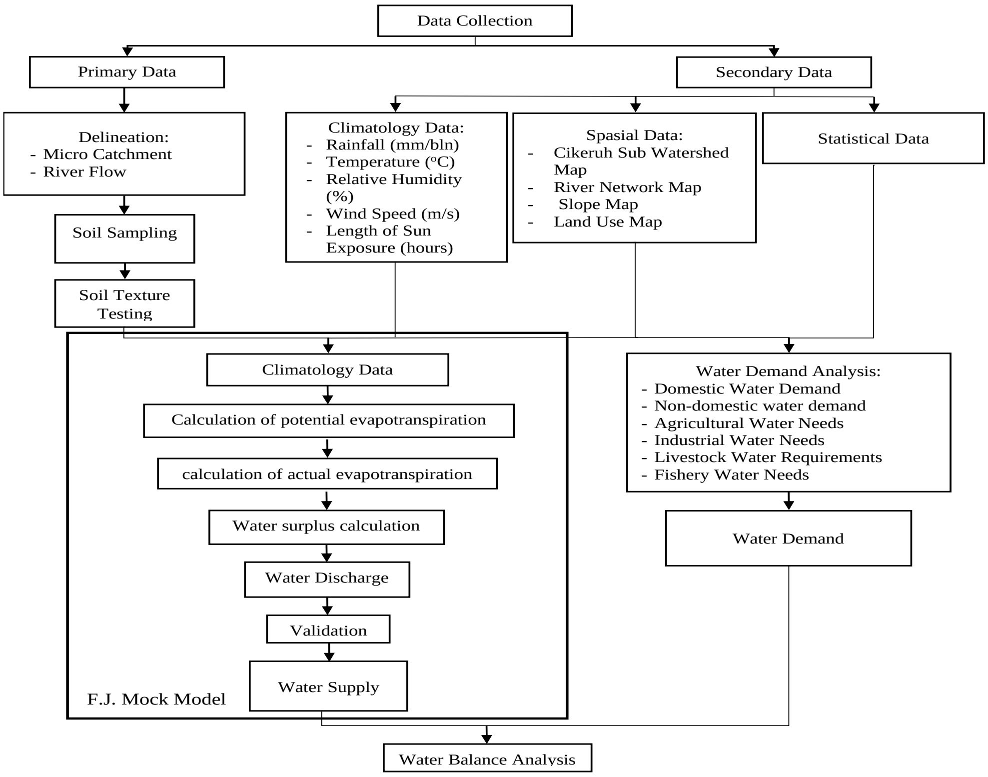

Fig. 1 Research Methodology

A. Monthly rainfall data of Jatinangor District from the Weather Station of Padjadjaran University

Table 1 Regional Rainfall Station

Year	Amount of Monthly Rainfall (mm)											
	Jan	Feb	March	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
2012	40	37	68	40	47	52	0	0	0	70	41	70
2013	52	54	43	40	48	41	0	0	0	0	41	41
2014	60,0	36	101	111	6	35	35	11	17	61	68	83
2015	72	66	35	69,5	26,5	4	0	0	0	6	38,5	40,5
2016	24	52,5	66	78	26,5	27	48,5	14	53	66	75,5	25,5
2017	38	42,5	36	37	46	26	6,5	8	19	39	84	88,5
2018	52,5	45	80	30,5	12,5	7,5	0	0	4	37	42	48
2019	85	45	59	17,5	0	0	0	0	25	22,5	67	0
2020	80	55	72	34	48	12,5	20,5	8,5	2	76	40	53
2021	99	30	70	12	53,5	28,5	6	7,5	11	18,5	91,5	0
Average (cm)	6,025	4,63	6,295	4,69	3,135	2,335	1,165	0,485	1,305	3,96	5,885	5,62

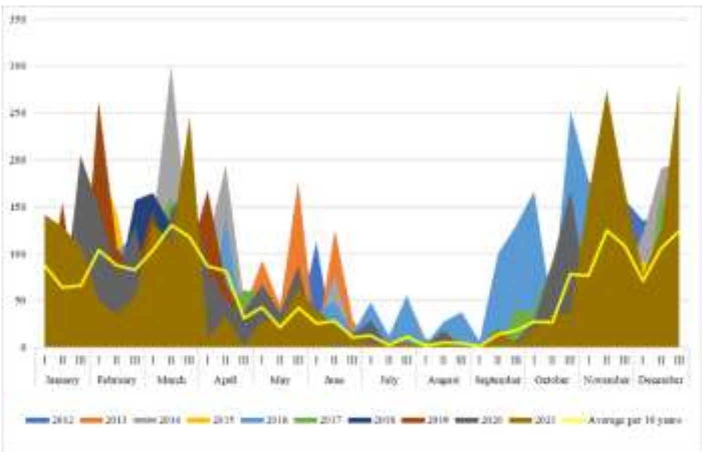

Fig. 2 Average Dasarian Rainfall of Leuwi Padjadjaran II Reservoir's Catchment Area 2012 – 2021

Precipitation or rainfall is the fall of water from the atmosphere to the surface of the earth and sea in different forms, namely rainfall in the tropics and subtropical rainfall, and snow in temperate climates [19]. The results of processing average rainfall data from 2012 - 2021 show that the highest monthly rainfall is in March

Dasarian II at 130 mm/month and the lowest average in September Dasarian I at 1.3 mm/month. A significant difference occurs between the month with the highest and lowest rainfall, 128.7 mm/month. Rainfall is one part of the water cycle. When it falls, there is direct evaporation before coming down to the earth's surface and up to its surface (soil) [20].

B. Land Map Unit

The land map was obtained from overlapping or overlaying between several maps, namely the land slope map and the land cover map. This land map unit has similar properties and is in the same observation area.

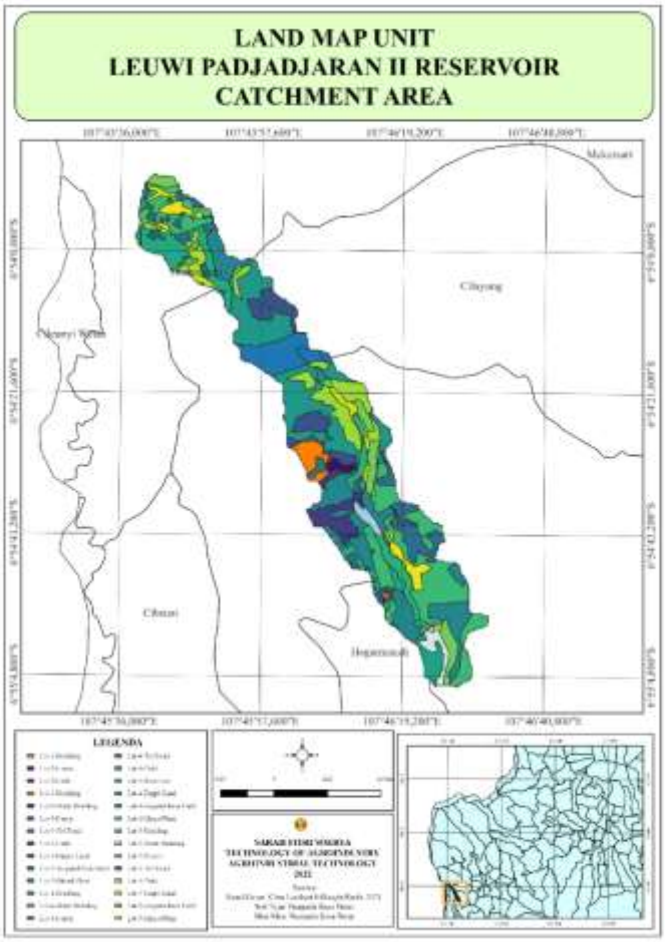

Fig. 3 Land Unit Map of Leuwi Padjadjaran II Reservoir Catchment Area

This map determines soil sampling and the amount of runoff on the land. The F.J. Mock Method considers the water runoff coefficient instead of the infiltration coefficient [21]. Land cover or land use in the Leuwi Padjadjaran II Reservoir's Catchment Area varies, including irrigated rice fields, fields, mixed crops, water and agricultural buildings, houses and office buildings, and vacant land. Over time, there was a change in land cover in 10 years, from 2012 to 2021, there were toll roads and industrial buildings associated with the construction of toll roads, causing a reduction in fields as well as the construction of Leuwi Padjadjaran II Reservoir which was previously wet rice fields and mixed crops.

III. RESULTS AND DISCUSSION

3.1 Water Supply Analysis

Water availability is a river's ability to supply a quantitative value throughout the year during the dry and rainy seasons to meet the number of designed outflow needs [22]. This discharge data is sought using rainfall data and potential evapotranspiration with the rainfall-runoff approach [23]. Based on the results of water availability data processing in the Leuwi Padjadjaran II Reservoir Catchment Area from Table 30, the highest water supply is in March, which is 17,975.1 m^3/month, the same as the highest rainfall and total runoff. The total average water supply of the Leuwi Padjadjaran II Reservoir Catchment Area based on the Mock Method from 2012 - 2021 is 138,732.9 m^3/year. Climate change also affects forest hydrologic systems, and the effects of climate change on water quality are unclear. Warmer climates will almost certainly result in more fires, accompanying erosion, and more frequent high-intensity downpour events [24].

Table 2: Results of Water Supply Analysis of Leuwi Padjadjaran II Reservoir Catchment Area

Month	**Mock discharge (m^3/s)**	**Water Supply (m^3/month)**
January	0,0049	13.046,2
February	0,0067	16.404,8
March	0,0067	17.975,1
April	0,0055	14.227,1
May	0,0040	10.591,1
June	0,0033	85.76,81
July	0,0021	5.716,78
August	0,0017	4.478,76
September	0,0018	4.578,9
October	0,0030	8.022,96
November	0,0067	17.407,1
December	0,0066	17.707,3
Minimum	0,0017	4.478,76
Maksimum	0,0067	17.975,1
Average	0,0044	11.561,08
Total	0,0529	138.732,9

Using the Mock Method, the results of the calculation of water availability in the Leuwi Padjadjaran II Reservoir Catchment Area show that in wet months, with average rainfall above 200 mm/month, water tends to be abundant, and dry months have little water available. The difference in water availability in the Leuwi Padjadjaran II Reservoir's Catchment Area each month shows uneven water distribution. The cause of the high contrast in water availability during the wet month or rainy season is the high percentage factor value, low infiltration coefficient, and SMC value. High total runoff forms a more significant water discharge into the reservoir.

3.2 Water Demand Analysis

The three principal uses of local water resources for a certain location are agricultural production, industrial production, and urban residential water [25]. This research uses Total water demand calculated from 6 sectors, which are:

Table 3 : Results of Water Demand Analysis of Leuwi Padjadjaran II Reservoir Catchment Area

No	Month	Water Demand (m^3/year)						Total
		Domestic	Non-Domestic	Agriculture	Fishery	Farm	Industry	
1	January	5.637,7	1.691,3	2.823,5	842,0	722,0	563,8	12.280,2
2	February	5.092,1	1.527,6	2.145,0	760,5	652,1	509,2	10.686,5
3	March	5.637,7	1.691,3	448,6	842,0	722,0	563,8	9.905,3
4	April	5.455,8	1.636,7	434,2	814,8	698,7	545,6	9.585,8
5	May	5.637,7	1.691,3	448,6	842,0	722,0	563,8	9.905,3
6	June	5.455,8	1.636,7	434,2	814,8	698,7	545,6	9.585,8
7	July	5.637,7	1.691,3	2.374,8	842,0	722,0	563,8	11.831,5
8	August	5.637,7	1.691,3	2.374,8	842,0	722,0	563,8	11.831,5
9	September	5.455,8	1.636,7	2.298,2	814,8	698,7	545,6	11.449,9
10	October	5.637,7	1.691,3	2.823,5	842,0	722,0	563,8	12.280,2
11	November	5.455,8	1.636,7	2.732,4	814,8	698,7	545,6	11.884,0
12	December	5.637,7	1.691,3	2.823,5	842,0	722,0	563,8	12.280,2
	Total	66.378,9	19.913,7	22.161,4	9.913,4	8.500,9	6.637,9	133.506,1
	Average	5.531,6	1.659,5	1.846,8	826,1	708,4	553,2	11.125,5

The total water demand for the Leuwi Padjadjaran II Reservoir's Catchment Area is 133.506,1 m^3/year, averaging 11.125,5 m^3/month. The sector with the highest water demand is domestic water demand which reaches 49.72% in terms of the population and environment of Padjadjaran University. The lowest sector is the industry, with one toll road construction industry needing 4.97% of the total water demand. The presentation of specific water requirements is depicted in Fig 4.

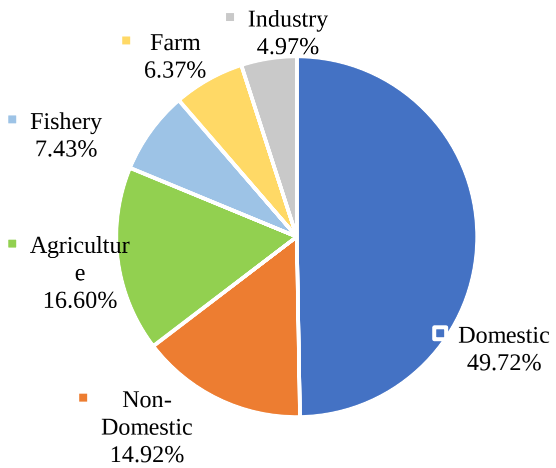

Fig. 4 Total Water Demand of Leuwi Padjadjaran II Reservoir's Catchment Area

The amount of water demand indicates the amount of water that must be met in its Utilization. Agriculture is the second largest water demand because in the Leuwi Padjadjaran II Reservoir's Water Catchment Area, the agricultural land is extensive, and the jobs in the Padjadjaran University Environment are farmers and breeders.

3.3 Water Balance Analysis

The results of monthly water balance calculations are surplus and deficit. Surplus values exist in January-May and November-December. The deficiency occurs from June-October. The highest surplus value falls in March at 8.069,79 m^3/month and the lowest surplus value in May at 685.78 m^3/month. The highest deficit monthly water balance occurred in August, namely 7.352,76 m^3/month, and the lowest deficit value was in June, with a value of 1,008.97 m^3/month. The total annual water balance of the Leuwi Padjadjaran II Reservoir's Catchment Area shows a surplus value or water needs are met.

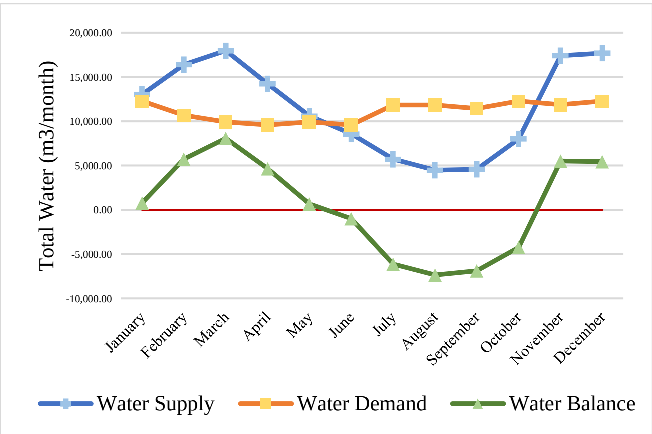

Fig. 5 Water Balance Analysis of Leuwi Padjadjaran II Reservoir's Catchment Area

The results of the water balance analysis of Leuwi Padjadjaran II Reservoir's Catchment Area show that water is abundantly available in March, which is a wet month. Directly proportional to rainfall, March has the highest availability of water. This surplus value can be an excess of water that can become surface runoff.

The water balance of Leuwi Padjadjaran II Reservoir's Catchment Area is surplus or excess water in the needs of each month. Four months is a deficit. This calculation shows that the distribution of water in the Leuwi Padjadjaran II Reservoir's Catchment is not evenly distributed according to the needs of each month. Dry months show very little water availability, and there is a deficit in some months, so it can become a water crisis. Water scarcity, particularly in arid and semi-arid countries, impedes agricultural productivity significantly [26]. Appropriate efforts need to be made to overcome the problem of water distribution so that it can be evenly distributed and not experience flooding during the rainy season and drought during the dry season so that it can be available throughout the year according to community needs.

The amount more than the water availability each year is 522.684 m^3 or 435,57 m^3/month. The excess water or surplus can be a water supplier for the Padjadjaran University Jatinangor Campus environment that is not included in the Reservoir's Leuwi Padjadjaran II Catchment Area. Water supply from the reservoir can be utilized for agricultural land, greenhouses, and fish ponds or needs in other buildings around Leuwi Padjadjaran II Reservoir. This reservoir's existing condition of water utilization is only used for greenhouses. Still, the high level of sedimentation causes turbid water and is rarely used for the irrigation of plants. Enhanced irrigation depth enhanced soil-accessible water in the root zone; however, over-irrigation was ineffective for soil water storage [27]. Overflow from the reservoir re-enters the river that passes through the Unpad Jatinangor Campus and Cikeruh Watershed.

The catchment area of Leuwi Padjadjaran II Reservoir consists of forests, irrigated rice fields, fields, mixed crops, toll roads, water buildings, and other buildings. The abovementioned elements influence crop development but are mostly influenced by humans [28]. The giant land cover is fields with an area of 24.2 Ha or 25.75%. The most significant slope is in the steep class, with an area of 57.8 Ha, 25%-40%. Forests control water cycles and prevent climate change [29]. This situation affects the size of the surface runoff coefficient or percentage factor (PF), which also affects the infiltration coefficient (if) and SMC value in the Leuwi Padjadjaran II Reservoir's Water Catchment Area. The Schmidt-Ferguson climate classification identified in Table shows that one year has eight wet months and four dry months and is determined as a wet climate. Low Percentage Factor (PF) and infiltration coefficient (if) indicate high surface runoff potential and low infiltration. The abundant water in the wet month will eventually become runoff that enters the waterways leading to Leuwi Padjadjaran II Reservoir.

Water harvesting at Leuwi Padjadjaran II Reservoir is one step in dealing with water shortages in dry months. Land in the catchment area with a height above the reservoir needs another water harvesting to be directly channelled. The interview results explained that farmers need permanent water channels that flow directly to their farming areas. Higher land also requires semi-permanent or permanent ponds to irrigate farmland. Jiabin Peng's research [30] recommends arid watersheds for efficient water conveyance measures (e.g., seepage prevention and underground channels).

The runoff causes erosion of the land surface in the catchment area, leading to more erosion rates and potential sedimentation in the Leuwi Padjadjaran II reservoir. Dry months are also a problem when there is a deficit in the Leuwi Padjadjaran II Reservoir's catchment area, so there cannot be sufficient water distribution. With the amount of sedimentation entering the reservoir, rainwater harvesting as a water reserve that enters the reservoir cannot be maximally accommodated.

Runoff management is the countermeasure or conservation effort that can be done from runoff problems. Runoff management is intended to reduce the risk of losses from water damage due to large Discharges of runoff or surface runoff and increase the usability of water. The results of interviews with the manager of Padjadjaran University Environment it is better to make small reservoir ponds on the water flow to reduce the runoff that is too large before entering the reservoir.

The results of the study in the field, many waters flow in the Leuwi Padjadjaran II Reservoir Catchment Area are covered by sedimentation deposits so that the volume of water is not maximized, and several waterways are not well channelled due to unmaintained canals. [31] Examined the impact of dam heightening on reservoir flood vulnerability changes and discovered that it enhanced adaptive capacity, which might increase the difference between inflow and outflow, reducing susceptibility.

The next effort is to repair the canals. The existing waterways along the Leuwi Padjadjaran II Reservoir Catchment Area are generally not yet permanent drainage channels, so they are easily damaged, and erosion often occurs, which causes landslides and becomes sedimentation. Permanent drainage channels can be a solution to reduce the potential for landslides due to the large amount of water discharge that overflows so that it can be appropriately accommodated. Scouring the reservoirs, rivers, and canals could increase the reservoir stability, reservoir life span, and storage capacity [32]. Water supplies in each link in the water cycle will influence water sources for vegetation growth. However, the water cycle processes in arid regions are distinct [33]. Mapping flood-prone areas due to dam failures can be one of the preventive solutions for water excess [34]. Increasing the storage capacity of suitable reservoirs may be a realistic alternative since total inflow will be available [35]. Balancing ecological and socio-economic water use will optimize the functionality of the reservoir [36]. Simplifying the development model by utilizing existing materials in the building environment can be a fairly efficient solution [37]. The reservoir can supply hydropower generators in good buildings and benefit the environment [38].

Estimating water deficit in agricultural land using traditional methods is a misinterpretation. [39] presented an agricultural drought assessment approach integrating hydrological and crop models (variable infiltration capacity-climate policy integrated environment, VIC-EPIC) to consider crop growth. The temporal and geographical fluctuation features of drought level may be evaluated in a typical large-scale drought occurrence in Jiangsu province. It might also use the cube modelling [40] built for both basins to anticipate hydrological changes and identify key basin features. The simulation of the research accurately predicted hydrological change and demonstrated that the contribution of basin geomorphology and land cover to change varies between basins.

IV. *C*ONCLUSION

The condition of the water balance of Leuwi Padjadjaran II Reservoir's Catchment Area is surplus with water availability of 138.732,90 m^3/year with an average of 11.561,08 m^3/ month and water demand of 133.506,09 m^3/year with an average of 11.125,51 m^3/month. There are months with deficit conditions that indicate that water distribution has not been evenly distributed according to needs. Conservation efforts can be made to fulfil water needs by loading permanent waterways and small ponds upstream of Leuwi Padjadjaran II Reservoir.

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