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| RESEARCH ARTICLE

Optimization of Irrigation Water Allocation at The Meninting Dam to Substitute The Water Discharge to The Jangkok - Babak HLD

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| ABSTRACT

Water resources are vital components for sustaining life and supporting economic development; therefore, their management must be carried out in an integrated and sustainable manner. The Lombok River Basin (WS Lombok), as one of Indonesia's National Strategic River Basins, comprises 197 watersheds (DAS), 52 of which have been utilized for water supply. The imbalance of water distribution between the western region (which tends to have a surplus) and the southern region (which faces a deficit) necessitates an efficient and equitable water management system. One of the key solutions developed to address this issue is the construction of the Meninting Dam, designed to balance water availability through the High-Level Diversion (HLD) Jangkok–Babak Channel. This study aims to simulate and optimize water allocation from the Meninting Dam to several major irrigation areas, namely D.I. Sesaot, D.I. Jurang Sate Hulu, D.I. Jurang Sate Hilir, and D.I. Jurang Batu. The methodology includes hydrological simulation and water allocation optimization using a trial-and-error approach to achieve flow balance between the supplying rivers (Meninting, Jangkok, and Sesaot) and the HLD as the receiving system. The results indicate that water availability in each irrigation area reaches 2,480 L/s for D.I. Sesaot, 10,049 L/s for D.I. Jurang Sate Hulu, 8,596 L/s for D.I. Jurang Sate Hilir, and 4,536 L/s for D.I. Jurang Batu, with a total inflow to the HLD system of 13,970 L/s. Following the operation of the Meninting Dam, irrigation efficiency (K Factor) increased from 85.6% to 98.3% in D.I. Sesaot, and from 86.3% to 87.7% in the Jurang Sate–Jurang Batu system. Water distribution also shifted, with 61.4% of the flow directed to the HLD system and 38.6% to D.I. Sesaot, as the dam fully meets the irrigation demand in D.I. Sesaot. These findings demonstrate that integrated inter-watershed water management through the operation of the Meninting Dam and the HLD system significantly improves water distribution efficiency and supports the enhancement of cropping intensity in southern Lombok.

| KEYWORDS

Meninting Dam, water allocation, inter-basin management, irrigation efficiency, Lombok

| ARTICLE INFORMATION

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1. Introduction

Water resources are one of the most essential elements for sustaining life and supporting economic development, thus their sustainable and integrated management is crucial. The Lombok River Basin (WS Lombok) is classified as a National Strategic Basin consisting of 197 watersheds, of which 52 have been utilized for water resource development (RAAT WS Lombok, 2025). The availability of water directly affects irrigation supply across the island, where perennial rivers provide year-round flows while intermittent rivers flow only during the rainy season. Southern Lombok faces limited and uneven water availability, with a generally dry climate and low annual rainfall—averaging about 1,517 mm/year in the west, 898 mm/year in central areas, and 836 mm/year in the east. Many river and irrigation systems in this region are interdependent, relying on inter-basin water transfers and irrigation return flows shared alternately. This forms the basis of the interconnected irrigation system characteristic of southern Lombok. To optimize water use, the High-Level Diversion (HLD) Jangkok–Babak channel was designed to transfer surplus water from western Lombok to central and southern areas. The development of the Meninting Dam is a key effort to address the island's uneven water distribution. The western region, particularly the Meninting watershed, has sufficient water resources, while the central–southern region has extensive agricultural potential but limited water supply. The dam aims to increase the supplemental discharge to the HLD Jangkok–Babak system, ensuring irrigation water for southern Lombok and stabilizing raw water supply for northern Lombok Barat, where spring discharges have been declining. Additionally, the dam's hydraulic head provides potential for hydropower generation, contributing to the energy supply of Lombok Island. This study focuses on simulating and optimizing irrigation water allocation from Meninting Dam to several major irrigation areas—D.I. Sesaot, D.I. Jurang Sate Hulu, D.I. Jurang Sate Hilir, and D.I. Jurang Batu—over one hydrological year. Optimization is carried out using a trial-and-error approach to achieve balance between the Meninting River as the main water supplier and the HLD system as the receiver. The research aims to determine water availability at each intake, optimize irrigation water delivery, and define the proper allocation percentage between the Sesaot Feeder Weir and HLD channel. The results are expected to serve as a reference for water resource planning within the Lombok River Basin, particularly for optimizing inter-basin water sharing between surplus and deficit regions, thereby improving irrigation efficiency and supporting sustainable agricultural development.

2. Literature Review

According to the Regulation of the Minister of Public Works and Public Housing of the Republic of Indonesia No. 04/PRT/M/2015, the Lombok River Basin (WS Lombok) is designated as a National Strategic River Basin consisting of 197 watersheds (DAS). The total area of WS Lombok is 4,560.50 km², with watershed sizes ranging from 0.47 km² (Sentelik DAS) to 578.62 km² (Dodokan DAS). The study focuses on the Meninting Dam Catchment Area and High Level Divertion Jangkok-Babak, located in West Lombok Regency, West Nusa Tenggara Province (NTB).

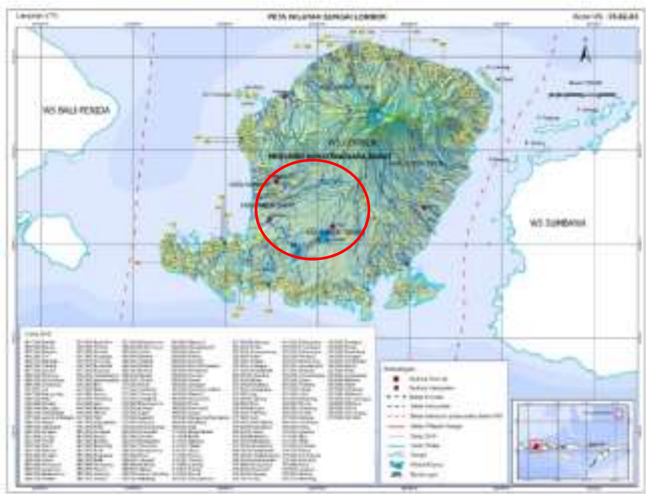

Figure 1. Map of the Lombok River Basin (Source: BBWS NT I, 2025).

The Jangkok–Babak High Level Diversion (HLD), also known as the Lower HLD, conveys water from the Jangkok Weir to the Jurang Sate terminal. This system supplies irrigation to the Jurang Sate and Jurang Batu Irrigation Areas (D.I.), as well as to Praya City and Central Praya irrigation zones, serving a total irrigated area of 14,885 ha. Administratively, the HLD passes through West Lombok and Central Lombok Regencies, consisting of: Jangkok–Terminal Section (±9.5 km) – constructed in 1987 to convey water from the Jangkok Weir to the Jurang Sate section. Jurang Sate Section (±20.5 km) – built in 1938 to irrigate the Jurang Sate area. Jurang Batu Section (±13.5 km) – supplies the Jurang Batu Irrigation Area downstream. However, sedimentation and reduced channel capacity, particularly in the Jurang Sate section, have decreased irrigation efficiency and limited water delivery to the service areas.

3. Methodology

The main diversion structures on the HLD system form an integrated network comprising the Jangkok, Sesaot, and Keru Weirs. Jangkok Weir: Located in West Lombok and constructed in 1984, this Ogee-type weir (65 m wide, 11.5 m high) is designed to pass a maximum flood discharge of 1,690 m³/s. Currently, sedimentation has reduced the effective discharge capacity from 6 m³/s to approximately 4.5 m³/s. Sesaot Weir: A Dutch-built broad-crested weir (53 m wide, 1.3 m freeboard), originally designed to deliver 1.5 m³/s. High sedimentation in both upstream and downstream channels has rendered the measuring structures non-functional. Keru Weir: Built with masonry, 40 m wide and 10.5 m high, designed for a design flood of 862 m³/s. It also supplied water to a 34 kW micro-hydropower plant, which is no longer operational after the 2009 flood event. Water resources on

Lombok Island are unevenly distributed, with the western region having abundant water but limited agricultural land, and the central–eastern regions having extensive farmland but insufficient water supply. To address this imbalance, the HLD Jangkok–Keru–Babak system was constructed to transfer water from surplus rivers (Jangkok, Sesaot, and Keru) in West Lombok to deficit areas in Central Lombok (Jurang Sate–Babak system). However, illegal water withdrawals—mainly for domestic and agricultural uses, and even irrigation of a 63 ha golf course—have reduced system performance and delivery efficiency.

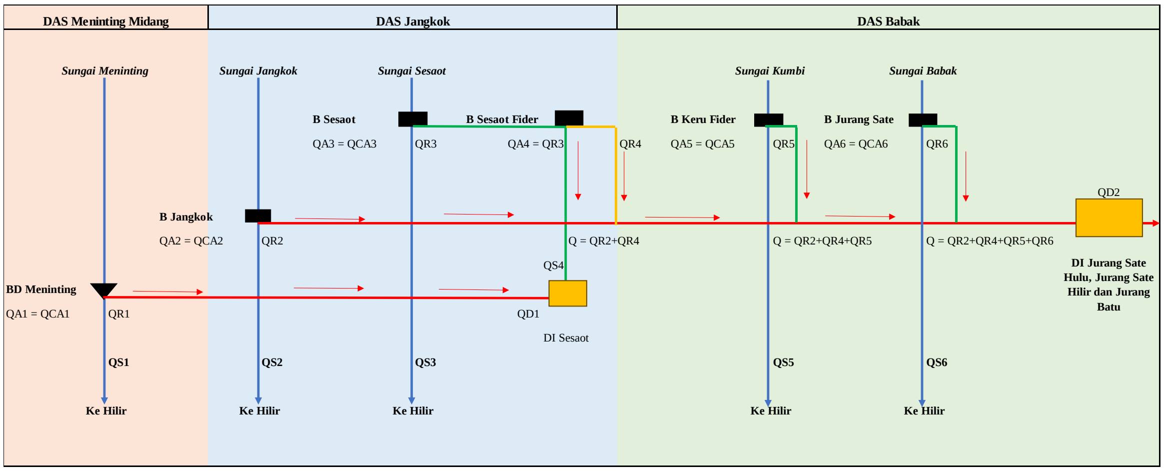

Figure 2. Schematic Diagram of Water Distribution Scenarios in the HLD Channel (Source: BBWS Nusa Tenggara I Mataram, 2025)

Rainfall Stations

Rainfall data were obtained from 17 rainfall stations (ARR) within WS Lombok managed by BWS NT I (2024). These include Aiknyet, Jurang Sate, Keru, Sesaot, Lingkok Lime, and others, distributed throughout the Jangkok, Babak, Dodokan, and Renggung watersheds. Spatial interpolation and Thiessen polygon analysis were used to determine representative rainfall for the Meninting catchment area.

Figure 3. Map of Rainfall Station Distribution in the Lombok River Basin (Source: BBWS Nusa Tenggara I Mataram, 2025)

Data Collection

a. Secondary Data

Secondary data were collected from the Balai Wilayah Sungai Nusa Tenggara I (BWS NT I), Mataram, including:

1. Rainfall records from ARR stations (1994–2022),
2. River discharge data from AWLR stations,
3. Physical watershed data (topography, land cover, hydrology shapefiles),
4. Existing weir discharge data (Jangkok, Sesaot, Keru, and Jurang Sate),

5. Existing irrigation data (cropping intensity, irrigation factor K).

b. Literature Review

Previous studies, theses, and journal articles related to irrigation optimization and water allocation from Meninting Dam to the HLD Jangkok–Babak system were reviewed to support the research framework and parameter selection.

c. Institutional Data Collection

Additional data were gathered from relevant government agencies, particularly the Water Allocation and Hydrology Units of BWS NT I and the Public Works Department of NTB Province.

Research Scope and Analytical Methods

The research employed a sequence of analytical steps integrating hydrological, spatial, and irrigation analyses:

a. Rainfall Data Processing:
   Quality control using the Double Mass Curve and RAPS methods.
b. Watershed Physical Data Collection:
   Compilation of watershed coordinates, river networks, contour maps, and irrigation boundaries using ArcGIS.
c. River Discharge Analysis:
   Utilization of AWLR discharge data for Mock model calibration and verification.
d. Weir Discharge Analysis:
   Evaluation of available water, irrigation supply, spillway overflow, and existing water demand at the Jangkok, Sesaot, Keru, and Jurang Sate Weirs.
e. Irrigation Cropping Intensity Analysis:
   Determination of irrigated area, planting seasons, and irrigation efficiency (K) for each irrigation area (Sesaot, Jurang Sate Hulu, Jurang Sate Hilir, Jurang Batu).
f. Hydrological Data Analysis:
   Processing rainfall and discharge data to establish dependable flow conditions.
g. Catchment Delineation:
   Defining rainfall-influenced catchment boundaries using ArcGIS spatial analysis.
h. Design Rainfall Analysis:
   Computation of rainfall probability for planning using frequency analysis.
i. Rainfall Distribution Testing:
   Statistical fitting to identify the most suitable rainfall distribution.
j. Regional Rainfall Estimation:
   Computation of areal rainfall using the Thiessen Polygon Method based on station weights.
k. Water Availability Simulation:
   Application of the Mock Model to estimate low-flow discharge after calibration with AWLR data.
l. Irrigation Water Requirement Calculation:
   Estimation using the Net Field Requirement (NFR) and effective rainfall data.
m. Optimization and Simulation of Meninting Dam Operation:
   Simulation of dam releases to determine optimal discharge for the Sesaot Irrigation Area.
n. Optimization and Simulation for HLD Jangkok–Babak System:
   Simulation of water allocation among the Jangkok, Sesaot, Keru, and Jurang Sate weirs to determine optimal irrigation discharge for Sesaot, Jurang Sate, and Jurang Batu irrigation areas.

5. Discussion

The hydrological analysis of the Meninting Dam Catchment Area (CA) provides a comprehensive understanding of rainfall distribution, evapotranspiration dynamics, water availability, irrigation demand, and optimization of water allocation both before and after the operation of the Meninting Dam. The integration of ArcGIS-based spatial analysis, the Penman evapotranspiration method, and the Mock rainfall-runoff model has yielded reliable insights into the hydrological behavior and water resource management potential of the study area.

Spatial Distribution of Rainfall and Thiessen Weighting

The Thiessen Polygon analysis, conducted using ArcGIS 10.8, identified two rainfall stations—ARR Gunung Sari and ARR Sesaot—as the main contributors to the rainfall regime within the Meninting Dam catchment. The weighted influence of these stations was determined to be 59.77% and 40.23%, respectively. This result indicates that the rainfall pattern over the catchment area is spatially heterogeneous, with the Gunung Sari region exerting greater hydrological influence due to its larger effective catchment coverage and higher elevation. These findings are consistent with regional climatological conditions, where topographic gradients significantly affect rainfall intensity and distribution.

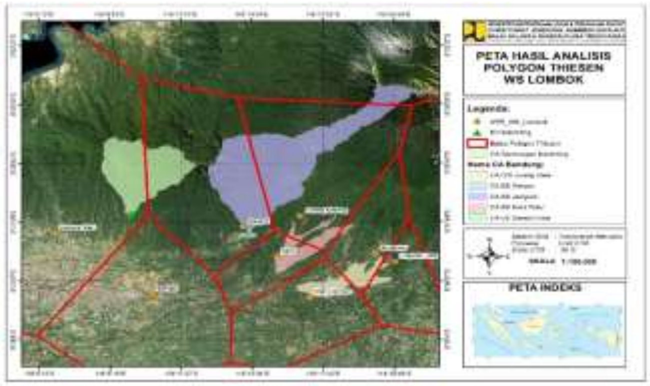

Figure 4. Thiessen Polygon Analysis of the Meninting Dam Catchment Area (Source: ArcGIS 10.8 Analysis)

Evaporation and Evapotranspiration Characteristics

Evapotranspiration (ETo) was calculated using the Penman method, recommended by FAO for regions with complete climatic data. The availability of comprehensive climate data at the Kopang climate station allowed for accurate computation of ETo, integrating temperature, relative humidity, wind speed, and solar radiation parameters. Spatial verification through ArcGIS confirmed that the Kopang station represents the dominant climatic influence over the Meninting catchment area. The calculated regional evaporation values reflect the semi-humid climatic conditions of Lombok, indicating a moderate atmospheric demand for water that aligns with the region's agricultural potential.

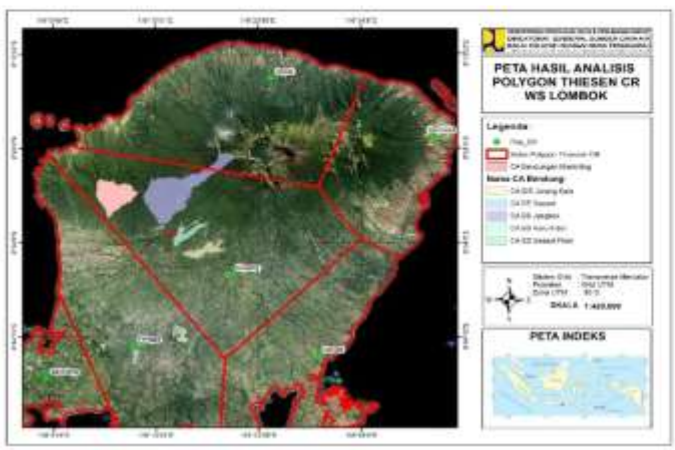

Figure 5. Map of Climate Stations (CR) in the Lombok River Basin (Source: ArcGIS 10.8 Analysis)

Water Availability Estimation using the Mock Model

For catchments lacking discharge records, such as the Meninting watershed, the Mock rainfall–runoff model was applied. Calibration of the model using the Orong AWLR data produced consistent coefficients: infiltration rate (rainy season) = 0.03, infiltration rate (dry season) = 0.95, recession constant = 0.98, initial soil moisture capacity (ISMC) = 100 mm, and maximum soil moisture capacity (SMC) = 120 mm. The resulting runoff for the first ten days of January (Dasarian I) was 251.67 mm, corresponding to a discharge of 9.71 m^3/s (9710 L/s). This simulated flow value aligns with hydrological expectations for the monsoon period, validating the reliability of the calibrated parameters for subsequent simulation periods.

Irrigation Water Requirement Analysis

Irrigation demand was assessed using existing cropping patterns—Paddy–Paddy–Secondary Crop—with the initial planting season occurring in early November. The Net Field Requirement (NFR) and Diversion Requirement (DR) were calculated based on FAO irrigation criteria, utilizing rainfall at 80% probability (R_{80}). For the Sesaot Irrigation Area, the NFR was determined to be 1.2 mm/day, equivalent to 0.14 L/s/ha, while the DR was 0.23 L/s/ha. These values indicate that during the initial planting period, the available rainfall and effective irrigation management can sufficiently meet crop water requirements, particularly with improved regulation from upstream water structures.

Optimization and Water Balance Simulation

The water balance analysis, performed under pre- and post-dam operation scenarios, demonstrated substantial improvements in irrigation reliability following the commissioning of the Meninting Dam. Before dam operation, the irrigation efficiency factor (K) averaged 85.6% in the Sesaot Irrigation Area and 86.3% across Jurang Sate Hulu, Jurang Sate Hilir, and Jurang Batu. After dam operation, these values increased to 98.3% and 87.7%, respectively. The improvement of approximately 12.7% in the Sesaot area underscores the dam's effectiveness in stabilizing irrigation supply during critical dry spells. The total inflow to the Headwork system reached 13,970 L/s, significantly enhancing water availability for the HLD Jangkok–Babak system. In the optimized post-dam scenario, the Meninting Dam contributed 1000 L/s directly to irrigation, while maintaining a spill flow of 2592 L/s to sustain downstream ecosystems and supplementary uses. The equitable redistribution of spill water—679 L/s for both the Sesaot and Jurang Batu irrigation areas—ensures balanced water sharing and mitigates potential water use conflicts in downstream regions.

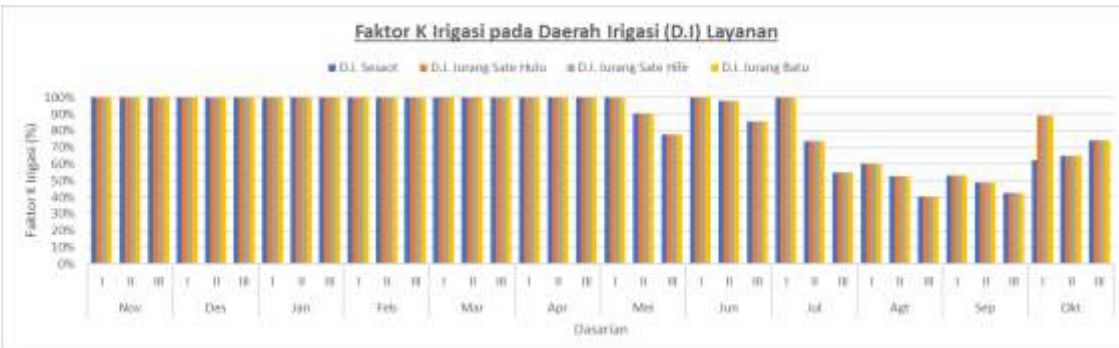

Figure 6. Irrigation Efficiency Factor (K) in the Service Irrigation Areas Before the Construction of the Meninting Dam.
Source: Analysis, 2025

Figure 7. Irrigation Efficiency Factor (K) in the Service Irrigation Areas After the Construction of the Meninting Dam.
Source: Analysis, 2025

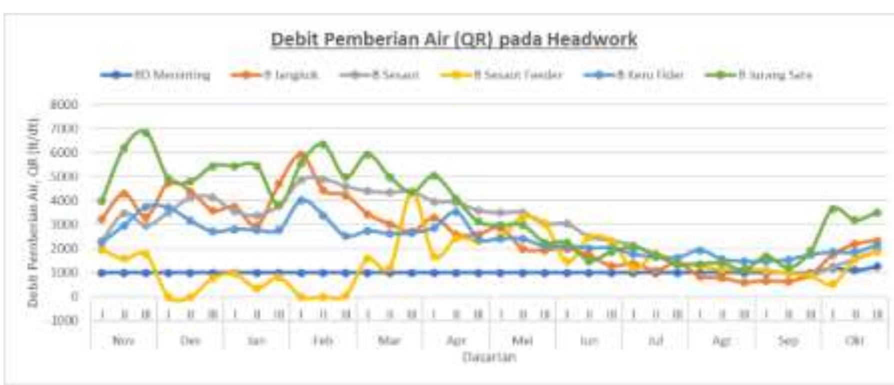

Figure 8. Water Supply Discharge (QR) at the Headwork After the Construction of the Meninting Dam. Source: Analysis, 2025

Implications for Integrated Water Resource Management

The simulation results reveal that the Meninting Dam substantially enhances the overall water balance across the interconnected irrigation network. By providing a consistent water supply and optimizing distribution, the dam supports both agricultural productivity and river ecosystem sustainability. The findings also demonstrate the value of integrating hydrological modeling (Mock), spatial GIS analysis (Thiessen polygons), and irrigation optimization in regional water resource planning. Furthermore, the improved irrigation factor (K) and higher water reliability after dam operation signify that the Meninting Dam can effectively mitigate drought risk and increase cropping intensity in the associated irrigation command areas. These improvements align with national objectives for sustainable agricultural intensification and water resource resilience in semi-humid tropical basins such as Lombok.

6. **Conclusion**

Based on the results of the analysis, the following conclusions can be drawn:

1. The available water in each irrigation area is as follows: 2,480 L/s for the Sesaot Irrigation Area (D.I. Sesaot), 10,049 L/s for the Jurang Sate Hulu Irrigation Area (D.I. Jurang Sate Hulu), 8,596 L/s for the Jurang Sate Hilir Irrigation Area (D.I. Jurang Sate Hilir), and 4,536 L/s for the Jurang Batu Irrigation Area (D.I. Jurang Batu).
2. The presence of the Meninting Dam has significantly increased irrigation water availability. The dam's water supply is capable of serving D.I. Sesaot, Jurang Sate Hulu, Jurang Sate Hilir, and Jurang Batu, with a total inflow to the Headwork (HLD) system amounting to 13,970 L/s. After the operation of the Meninting Dam, irrigation efficiency (K Factor) increased from 85.6% to 98.3% in D.I. Sesaot, and from 86.3% to 87.7% in D.I. Jurang Sate Hulu, D.I. Jurang Sate Hilir, and D.I. Jurang Batu. This improvement indicates enhanced irrigation system performance as a result of the reliable water supply from the dam.
3. The analysis of water distribution indicates the need for optimization to achieve a more equitable allocation between the Headwork (HLD) system and D.I. Sesaot. Prior to the construction of the Meninting Dam, 58.5% of the discharge was directed to HLD and 41.5% to D.I. Sesaot. After the dam became operational, the proportions changed to 61.4% for HLD and 38.6% for D.I. Sesaot. This shift occurred because the water demand of D.I. Sesaot was fully met by the Meninting Dam's supply, thereby allowing the Sesaot Feeder Weir to prioritize more water allocation toward the HLD system.

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