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Analysis of Water Losses in the Jimat Irrigation Area, Wonosobo Regency

Nasyiin Faqih[1], Fadhilah Ilham Ulumudin[2], Ashal Abdussalam[3], Mochammad Qomaruddin[4], Musthofa
[1234]Universitas Sains Al-Qur'an (UNSIQ) Wonosobo
[5]Universitas Bojonegoro (UNIGORO), Jawa Timur

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ABSTRACT

This study aims to analyze the actual irrigation water losses in the Jimat Irrigation Area, identify the factors causing irrigation water losses, and determine effective strategies to reduce water losses in the area. One of the important irrigation areas in this region is the Jimat Irrigation Area, which supplies water to 110 hectares of agricultural land. However, the effectiveness of water distribution is often hampered by significant water losses. The research methods used are descriptive evaluative and quantitative descriptive analysis. The descriptive evaluative method describes a study that evaluates the actual conditions of the study object. Meanwhile, the quantitative descriptive analysis method aims to accurately describe the characteristics of the study object.Based on the analysis and calculations, the Jimat Irrigation Area requires an actual irrigation water supply of 0.812 m³/second to serve its four tertiary canals, with the highest allocation going to Tertiary Channel 2 (0.465 m³/second) and the lowest to Tertiary Channel 4 (0.084 m³/second). However, only 54% of the initial discharge of the primary canal (1.702 m³/second at the Upstream Intake) actually reaches the agricultural land. A total of 46% of the water (0.686 m³/second) is lost along the primary network, with seepage accounting for 99.94% of the water loss, particularly in critical sections such as Primary Channel V, which lost 59% of its discharge. Meanwhile, the contribution of evaporation is minimal (0.06%) due to the limited water surface area and low daily evaporation rate (2.76 mm/day).

1. INTRODUCTION

Irrigation water is a crucial factor in supporting agricultural productivity, especially in regions that rely on irrigation, such as Wonosobo Regency (Faqih, 2020). One of the important irrigation areas in this region is the Jimat Irrigation Area, which supplies water for agricultural land covering 110 hectares. However, the effectiveness of water distribution is often disrupted by significant water losses (Adekalu et al., 2007).

The high rate of water loss in the Jimat Irrigation Area not only reduces the efficiency (Heibaum, 2014) of water resource utilization but also threatens agricultural water security (Srinivasarao et al., n.d.), particularly during the dry season when water availability is more limited (Faqih and Svajlenka, 2023). This issue can hinder efforts to improve food security (Veettil et al., 2019) in Wonosobo Regency, considering that many people depend on the agricultural sector for their livelihoods (Pope et al., 1992).

Therefore, it is important to conduct an in-depth study of the level of water loss in the Jimat Irrigation Area (Gao & Zhao, 2023). This analysis aims to measure the extent of water loss and identify the main causes of the problem. With the results of this study, it is hoped that practical solutions can be found to improve the efficiency of the water distribution system (Mushthofa et al., 2024), thus supporting sustainable agricultural productivity and food security in Wonosobo Regency.

This study shares similarities with previous research on irrigation water losses, particularly regarding seepage as

*Correspondence author.
E-mail: nasyiin@unsiq.ac.id (Nasyiin Faqih)
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the dominant factor reducing efficiency (Mwesigye et al., 2020). Earlier studies also emphasized that soil permeability and channel damage significantly affect water distribution performance (Nishigaki et al., 2017). Like them, this research aims to identify the causes and quantify the magnitude of losses to support efficient irrigation management.

The main difference lies in the specific focus and detailed analysis conducted in the Jimat Irrigation Area (Nishigaki et al., 2017), Wonosobo Regency. This study measures actual losses in each primary and tertiary channel, showing that infiltration accounts for 99.94% of the total 0.686 m^3/s water loss, while evaporation is only 0.06% (Hulley et al., 2010). It also introduces practical solutions such as installing impermeable linings, repairing cracks, and strengthening channel walls (Chirol et al., 2018). Moreover, this research proposes using IoT-based flow and water-level sensors with automated gates to monitor discharge in real time—an innovation not addressed in earlier studies.

Previous studies on irrigation efficiency have not provided localized (Heibaum, 2014), quantitative analyses with detailed measurement of losses per channel segment. This research fills that gap by assessing infiltration and evaporation rates in each section of the Jimat Irrigation Area and linking them to physical factors such as soil type (Pickup et al., 1993) and channel condition. In addition, earlier studies rarely integrated technology into irrigation management. This study bridges that gap by proposing IoT-based monitoring and control systems (Tomar, 2021), combined with infrastructure rehabilitation and institutional coordination, to improve water use efficiency and reduce losses (Prosdocimi et al., 2016).

2. METHODS

The research methods used are the Descriptive Evaluative method and the Quantitative Descriptive Analysis method (Hermawan et al., 2022). The Descriptive Evaluative method is used to explain the study that evaluates the conditions as they exist, according to the situation at the study object (Faqih et al., 2019). Meanwhile, the Quantitative Descriptive Analysis method is aimed at accurately describing the characteristics of a study object (Lyu et al., 2018).

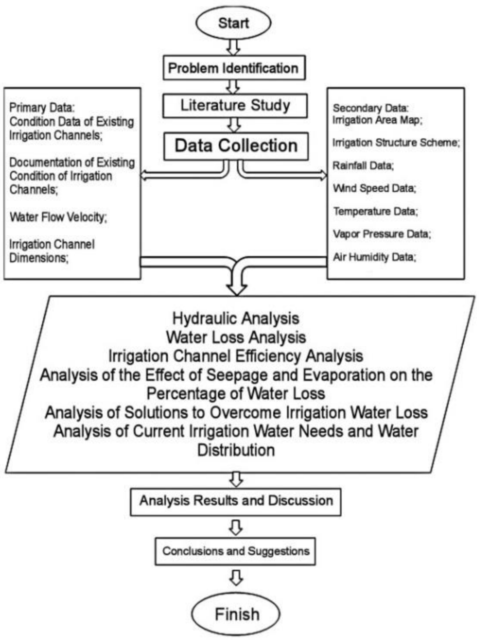
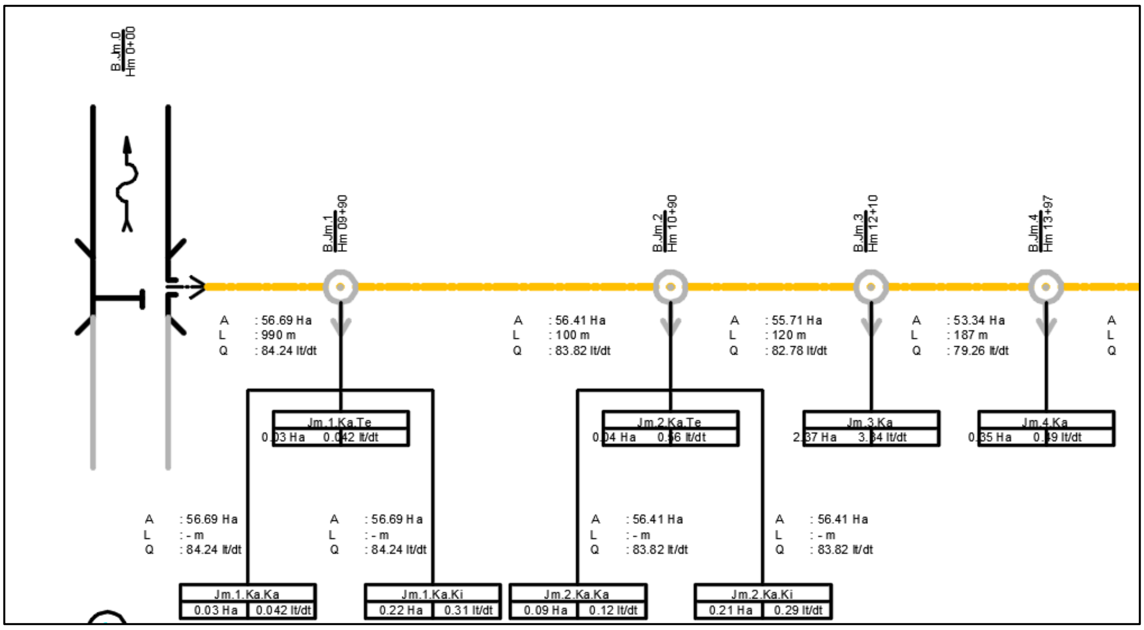


Figure 1. Water Diagram of the Study

3. RESULT AND DISCUSSION

Hydrological Analysis

a. Primary Channel Discharge Analysis



Picture 1. Scheme Building IN Amulet

Speed measured use lifebuoy (ball pingpong consequen ce limitations tool. Debit counted with formula:

$Q = V \times A$

with:

- V = speed flow (m/sec),
- A = wide cross section wet (m²),
- Q = debit (m³/second).

Table 2. Debit Channel Primary IN Amulet

No.	Name Channel And Tapping	V (m/sec)	A (m²)	Q (m³/second)
1.	Intake Hulu	0.851	2.00	1,702
2.	Intake Downstream	0.721	2.00	1,442
3.	Section II Tapping I Hulu	0.551	2.40	1,324
4.	Section II Tapping I Downstream	0.552	2.31	1,275
5.	Section III Tapping II Hulu	0.506	1.60	0.810
6.	Section III Tapping II Downstream	0.515	1.60	0.824
7.	Section IV Tapping III Hulu	0.447	1.52	0.679
8.	Section IV Tapping III Downstream	0.382	1.52	0.581
9.	Section V Tapping IV Hulu	0.195	2.55	0.497
10.	End Channel	0.102	2.00	0.204

b. Analysis Debit Channel Tertiary

The calculation of the discharge in the tertiary channels is carried out based on the difference between the downstream discharge of the previous channel section and the upstream discharge of the next channel section (Dewan et al., 2017). The result of this difference represents the volume of water conveyed to the tertiary channel for irrigation purposes (Hürlimann et al., 2019). The formula used is as follows:

$$Q_{tersier} = Q_{hilir} - Q_{next\ upstream}$$

Information:

- $Q_{tersier}$ = debit enter to channel tertiary (m³/second)
- Q_{hilir} = debit on downstream section previously (m³/second)
- $Q_{next\ upstream}$ = debit on upstream section channel after that (m³/second)

Table 4. 2 Debit Channel Tertiary IN Amulet

No.	Channel Tertiary	Q_{hilir} (m³/second)	$Q_{next\ upstream}$ (m³/second)	$Q_{tersier}$ (m³/second)
1	Tertiary 1	1,442	1,324	0.118
2	Tertiary 2	1,275	0.810	0.465
3	Tertiary 3	0.824	0.679	0.145
4	Tertiary 4	0.581	0.497	0.084

Analysis Lost Water

a. Analysis Lost Water Total

Formula calculation lost water :

$H_n = Q_{in} - Q_{out}$

Information:

- H_n = lost water per section channel (m³/second)
- Q_{in} = debit enter on beginning section (m³/second)
- Q_{out} = debit go out on end section (m³/second)

b. Analysis Evaporation

Calculation Detail Evaporation per Section Channel

Formula And Constants:

1. Wide surface water ()$A_{surface}$:

   $A_{surface} = B \times L (m^2)$

   Information:

   - $A_{surface}$ = wide surface water channel (m²)
   - B = wide channel (m)
   - L = long section channel (m)

2. Evaporation channel ():E_{Sal}

   $$E_{Sal} = \frac{E_d \times A_{surface}}{86.400.000} \ (m^3/detik)$$

   Information:

   - E_d = evaporation daily (2.76 mm/day)
   - Constant 86,400,000 = conversion mm/day to m³/second (1000 × 86,400 second)

c. Analysis Seepage

Step Calculation:

a. Seepage (S):

$S = H_n - E_{Sal}$

b. Rate Seepage per Long (q):

$$q = \frac{S}{L} \ (m^3/detik/m)$$

c. Rate Infiltration (I):

$$I = \frac{S}{A_{seep}} \times 1000 \times 3600 \ (mm/jam)$$

- $A_{seep} = P \times L$: Wide surface seepage (m²)
- $P = B + 2h$: Around wet channel (m)

Analysis Efficiency

Mark efficiency stated in percentage (%) And counted use formula as following:

$$\eta = \left(\frac{Q_{out}}{Q_{in}}\right) \times 100\%$$

Information:

- η = Efficiency channel (%),
- Q_{in} = Debit enter on beginning section channel (m³/second),
- Q_{out} = Debit go out on end section channel (m³/second).

Analysis Influence Seepage And Evaporation to Percentage Lost water

Based on the calculation results from the previous analysis, an evaluation was conducted on the contribution of infiltration and evaporation to the total water loss in the primary channel of the D.I. Jimat Irrigation Area. The total water loss (H_total) is 0.686 m^3/second and serves as the main reference. Meanwhile, the total evaporation (E_total), calculated using the Thornthwaite method, is only 0.00039193 m^3/second (Table 4.5). The total infiltration (S_total) is obtained by summing the infiltration per segment, resulting in the following value:

"S_total" = 0.25987 + 0.04894 + 0.09794 + 0.29296 = 0.69971 m^3/second.
Note: Primary Channel III is not included due to an increase in discharge (supplementary supply).

The percentage contribution of each component is calculated relative to the total water loss (H_total = 0.686 m^3/second).

1. Evaporation:
   $$\text{Persentase} = \frac{0{,}00039193}{0{,}686} \times 100\% = 0{,}06\%.$$
2. Seepage:
   $$\text{Persentase} = \frac{0{,}69971}{0{,}686} \times 100\% = 99{,}94\%.$$

Analysis Solution Overcome Lost Water Irrigation

Based on the findings, infiltration (99.94%) is the dominant cause of water loss in the D.I. Jimat Irrigation Area. The priority technical solution is the rehabilitation of the primary channel infrastructure by installing impermeable linings (such as concrete, geomembrane, or consolidated clay soil) on the sections prone to leakage, particularly in Primary Channel IV, which experiences extreme infiltration rates (540.86 mm/hour). The repairs should focus on segments with low efficiency (<85%), such as Primary Channels I, IV, and V, including crack sealing and strengthening the channel walls to prevent further erosion.

Analysis Need Water Irrigation Moment This And Di stribution Water

Based on the calculation results of the discharge in the tertiary channels (Table 4.2), the current irrigation water requirement in the Jimat Irrigation Area (D.I.) is allocated to four tertiary channels with a total discharge of 0.812 m^3/second. The allocation details for each tertiary channel are as follows:

- Tertiary 1: 0.118 m^3/second
- Tertiary 2: 0.465 m^3/second
- Tertiary 3: 0.145 m^3/second
- Tertiary 4: 0.084 m^3/second

Primary Channel II (Upstream Intake to Downstream Intake) experienced a significant decrease in water discharge from 1.702 m^3/second at the upstream to 1.442 m^3/second at the downstream, resulting in a water loss of 0.260 m^3/second (15.3%). The channel efficiency was recorded at 84.72%, with the dominant factor being high infiltration (0.25987 m^3/second).

Primary Channel III (Upstream Tap to Downstream Tap) recorded optimal performance with an efficiency of 96.30%, with only 0.049 m^3/second (3.7%) of the initial discharge of 1.324 m^3/second lost. This success was achieved due to the relatively short segment length (666 meters) and low infiltration rate (57.87 mm/hour).

Primary Channel III has a unique characteristic, as it experienced an increase in discharge from 0.810 m^3/second at the upstream to 0.824 m^3/second at the downstream, resulting in an efficiency of 101.73%. This phenomenon was caused by additional supply (supplementary water) from the Geblok Irrigation Area, which compensated for the water loss.

Primary Channel IV experienced a decrease in discharge from 0.682 m^3/second to 0.584 m^3/second, causing a loss of 0.098 m^3/second (14.4%). The main cause was high infiltration (0.09794 m^3/second) due to the characteristics of the alluvial soil, which has fast percolation with an infiltration rate of 166.67 mm/hour.

Primary Channel V is the critical point with the worst water loss: discharge dropped from 0.497 m^3/second at the upstream to 0.204 m^3/second at the downstream (59% loss), resulting in an efficiency of only 41.05%. Infiltration reached 0.29296 m^3/second due to the dominance of sandy soil with an extreme infiltration rate of 540.86 mm/hour.

Tertiary Channel 1 received the smallest discharge (0.118 m^3/second), allocated from the difference in discharge between the Downstream Intake of Primary Channel I (1.442 m^3/second) and the Upstream Intake of Primary Channel II (1.324 m^3/second). This limited allocation reflects its position near the upstream of the network, prioritizing water flow to the following primary channels.

Tertiary Channel 2 recorded the largest discharge (0.465 m^3/second), sourced from the difference in discharge between the Downstream Intake of Primary Channel II (1.275 m³/second) and the Upstream Intake of Primary Channel III (0.810 m³/second).

Tertiary Channel 3 maintained a stable discharge of 0.145 m³/second due to the influence of supplementary water from the Geblok Irrigation Area, which also impacted the increase in discharge in Primary Channel III.

Tertiary Channel 4 is the most vulnerable zone with a deficit, having a discharge of 0.084 m³/second, primarily due to massive leakage in Primary Channel IV, which reduced its water supply. The low discharge in this channel has the potential to cause drought in the irrigated areas, so short-term solutions, such as pumping or reallocation of water, are needed.

4. CONCLUSION

The Jimat Irrigation Area requires a continuous supply of 0.812 m³/s to meet field demand, with allocation prioritized to the most demanding tertiary reach, yet current conveyance suffers substantial losses (~0.686 m³/s) dominated by infiltration (~99.94%), particularly along Primary Channel V (losing ~59% of its discharge) while evaporation is negligible (~0.06%) due to limited wetted surface and low daily evaporation (≈2.76 mm/day). These deficits stem from a combination of porous alluvial/sandy embankments (e.g., extreme infiltration measured up to ~540.86 mm/h in Primary V), structural defects (cracks, wall failures), and non-technical withdrawals (illegal pumps, bypass gates, channel use for washing), compounded by weak institutional control. To restore reliable delivery and equity, we recommend impermeable linings (concrete/geomembrane) on leaking reaches—notably Primary II, IV, V—paired with crack repair and wall stabilization (with potential savings on the order of the present loss, ~0.686 m³/s), integrated enforcement patrols (farmers–P3A–Public Works–Spatial Planning), IoT flow/level sensors and automated gates for real-time allocation, source optimization by leveraging supplemental inflow from D.I. Geblok (which improved Primary III efficiency to ~101.73% under test conditions) and rainwater storage, and farmer training in efficient irrigation (e.g., alternate wetting and drying) to reduce opportunistic abstractions and enhance end-use efficiency.

5. ACKNOWLEDGMENT

Infrastructure rehabilitation through the installation of impermeable linings (geomembrane/concrete) on critical sections (Primary Channels II, IV, and V) and the immediate repair of cracks in high infiltration segments (>100 mm/hour), especially in Primary Channel IV, is needed. On the institutional side, the formation of an integrated patrol team (farmers-P3A-Public Works Office and Wonosobo Regency Spatial Planning) is essential. In this case, the office should involve irrigation operation and maintenance (OP) personnel to increase the frequency of regular channel inspections to regulate illegal water extraction and illegal washing facility activities.

The implementation of IoT sensors and automatic gates for real-time discharge monitoring is also necessary. Optimizing water sources must include the sustainable use of additional supply from D.I. Geblok, the construction of a rainwater reservoir, and the application of efficient irrigation techniques (alternate wetting and drying). Water allocation management should be based on the actual land area and the growth phase of the crops, with a priority on downstream areas at risk of deficits, supported by regular calibration of discharge measuring equipment. Equally important is stakeholder education through participatory water conservation training and the socialization of sanctions for violators of water allocation rules.

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