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Determinant study for improvement priorities of irrigation assets (a case study of Kedungrejo irrigation network in Pilangkenceng sub-district, Madiun regency – Indonesia)

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Determinant study for improvement priorities of irrigation assets (a case study of Kedungrejo irrigation network in Pilangkenceng sub-district, Madiun regency – Indonesia)

Yosua Panji Nugraha[1], Sri Wahyuni[1], Tri Budi Prayogo[1]

[1]Water Resources Engineering Department, Faculty of Engineering, Universitas Brawijaya, Malang, 65145, Indonesia

E-mail: yuniteknik@ub.ac.id

Abstract. Irrigation plays an important role for increasing agricultural production in order to achieve national food sovereignty. However, in reality, requests of funding for the purpose of irrigation network management from year to year are not always fulfilled according to needs. As such, to resolve this issue, it is necessary to determine improvement priorities for repairs of irrigation assets so that management may be optimally carried out. The aim of this research is to determine and analyse the improvement priorities of irrigation assets in one of the irrigation areas of Madiun Regency. This study utilized the modified Irrigation Network Performance Evaluation Criteria and Weightings for the year 2018. In addition, statistical tests as the Kruskal-Wallis and Mann-Whitney tests were utilized, as the obtained data were in the form of rankings. Google Earth and ArcGIS software were utilized to facilitate the understanding of the conditions and management of all the assets. The required data was the inventory of the irrigation network. The results of the study showed that the Kedungrejo Irrigation Network has 10% of irrigation assets in very good condition, 37% in good condition, 49%, in fair condition, and 4% in poor condition. The highest ranking (ranking 1) was for the spillway, while the lowest ranking (ranking 82) was for a bridge.

Keywords: priorities for improvement, asset performance, ranking, statistical tests.

1. Introduction

Irrigation plays an important role for increasing agricultural production in order to achieve national food sovereignty. Republic of Indonesia Law Number 7 of Year 2004 on Water Resources states that irrigation for national agriculture in the existing irrigation system is the main priority of water resource supplies, above all other needs. What is meant by the irrigation system includes irrigation infrastructure, irrigation water, irrigation management, institution of irrigation management, and human resources. Currently, the development of irrigation infrastructure is included in the National Middle-Term Development Plan (RPJMN) for the years from 2015-2019, which will be realized through the rehabilitation of irrigation networks for an area of 1.5 million hectares and development of new irrigation networks for an area of 1 million hectares.

Funding becomes one of the important factors for realizing the development of irrigation infrastructure. According to Minister of Public Works and National Housing Regulation Number 23/PRT/M/2015 on the Management of Irrigation Assets, in reality, requests of funding for the purpose of irrigation network management from year to year are not always fulfilled according to needs. As such, the resolution of the issue requires determining improvement priorities for repairs of irrigation assets so that management may be carried out in consideration of the available provided budget and other limiting factors.

The primary issues of irrigation channels in the Kedungrejo Irrigation Network are many damaged embankments, sedimentation, and weeds. Several parts of secondary channels are also being utilized by farmers as farmland. Damage also occurs in almost all irrigation structures. Cracks in structures and rusting water gates are the most frequently occurring problems.

Minister of Public Works and National Housing Regulation No. 12 of Year 2015 states that maintenance of irrigation networks is the effort to protect and secure irrigation networks so that they always function well to support their operations and sustain their conservation through activities of management, repairs, prevention, and securing that must be performed in a continuous manner.

2. Study Location and Methods

The Kedungrejo Irrigation Network is located in Wonoayu Village in Pilangkenceng Sub-District, Madiun Regency. This irrigation network is considered a cross-region irrigation network, because its area of service covers the two administrative regions of Madiun Regency and Ngawi Regency.

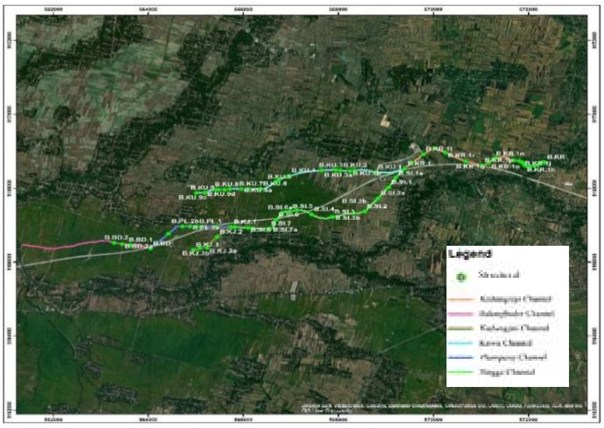

Figure 1. Map of the Study Location

The performed analysis is non-parametric statistical analysis with the Kruskal-Wallis test and the Mann-Whitney test. The aim of the Kruskal-Wallis test is to determine differences in data from research results. If a significant difference is found, then the Mann-Whitney test is carried out.

1. Kruskal-Wallis Test

   The Kruskal-Wallis test is a non-parametric test based on rankings designed to determine whether there is a significant statistical difference between two or more groups of independent variables and dependent variables with a numerical (interval/ratio) data scale and ordinal data scale. The null hypothesis to be tested is population K that has the same mean. The alternative hypothesis is population K that does not have the same mean. The Kruskal-Wallis test is performed with the following equation:

$$H = \frac{12}{N(N+1)} \sum_{K=1}^{K} \frac{R_K^2}{n_K} - 3(N+1) \tag{1}$$

   where H = Kruskal-Wallis, N = number of observations in all groups, K = number of groups, R = number of ranks, and n = number of observations in a group. The end result of the Kruskal-Wallis is that if H > X and K – 1 is of the critical bound of 0.05, for example, then the statistical conclusion of the proposed hypothesis is that there is a difference, which means H1 is accepted and H0 is rejected. If H1 is accepted, testing may continue with the Mann-Whitney test.

2. Mann-Whitney Test

   The Mann-Whitney test is a ranking test for two groups of unequal sizes. The Mann-Whitney test is a continuation of the Kruskal-Wallis test if differences were found through the Kruskal-Wallis test. The following is the Mann-Whitney test for $n \leq 20$.

$$U = n_1 n_2 + \frac{n_1(n_1+1)}{2} - R_1 \quad (2)$$

$$U = n_1 n_2 + \frac{n_2(n_2+1)}{2} - R_1 \quad (3)$$

   where U = Mann-Whitney, n = number of observations in a group, and R = number of ranks. The utilized H0 hypothesis is accepted if $U \geq U\alpha$ and rejected if $U < U\alpha$. Equation 3 is used to find out the value of U using n_1 and Equation 4 is used to find out the value of U using n_2. The resulting values U from n_1 and n_2 are compared, and the smallest U value is compared with the U of the table. If the n_1 and n_2 values are greater than 20, the normal curve approach is used with Equation 4 to find the mean value. Equation 5 is to find the standard deviation and Equation 6 is to find the standard value:

$$E(U) = \frac{n_1 n_2}{2} \quad (4)$$

$$\sigma_U = \sqrt{\frac{n_1 n_2 (n_1+n_2+1)}{12}} \quad (5)$$

$$Z = \frac{U - E(U)}{\sigma_U} \quad (6)$$

   where E (U) = mean, σU = standard deviation, and Z = standard value. The utilized H0 hypothesis is accepted if $-Z_{\frac{\alpha}{2}} \leq Z \leq Z_{\frac{\alpha}{2}}$ and is rejected if $Z > Z_{\frac{\alpha}{2}}$ atau $Z < -Z_{\frac{\alpha}{2}}$.

The following are the stages of conducting the study:

1. Inventorying

   Inventorying functions to identify the condition of physical infrastructure on the field.
2. Condition Evaluation

   The evaluation of physical infrastructure conditions are based on the 2018 criteria and weightings of irrigation performance evaluation by the Ministry of Public Works and National Housing.
3. Determination of handling

   Handling is determined based on the results of physical infrastructure condition evaluation, with handling based on Minister of Public Works and National Housing Regulation No. 12 of Year 2015 (Table 1).
4. Determination of ranking

   Ranking is determined by ordering condition values from the smallest to the largest.
5. Statistical Analysis

   The performed statistical analysis is nonparametric statistical analysis with the Kruskal-Wallis and Mann-Whitney tests.
6. Information System

   The information system consists of the compiled information on physical infrastructure conditions and the map of physical infrastructure conditions.

Table 1. Classification of Physical Conditions of the Irrigation Network and Their Handling

No	Condition	Damage level from initial condition	Handling
1	Good	≤ 10 %	Routine maintenance
2	Minor damage	11 - 20 %	Periodic maintenance for management
3	Moderate damage	21 - 40 %	Maintenance for repairs
4	Major damage	≥ 40 %	Major repairs or replacement

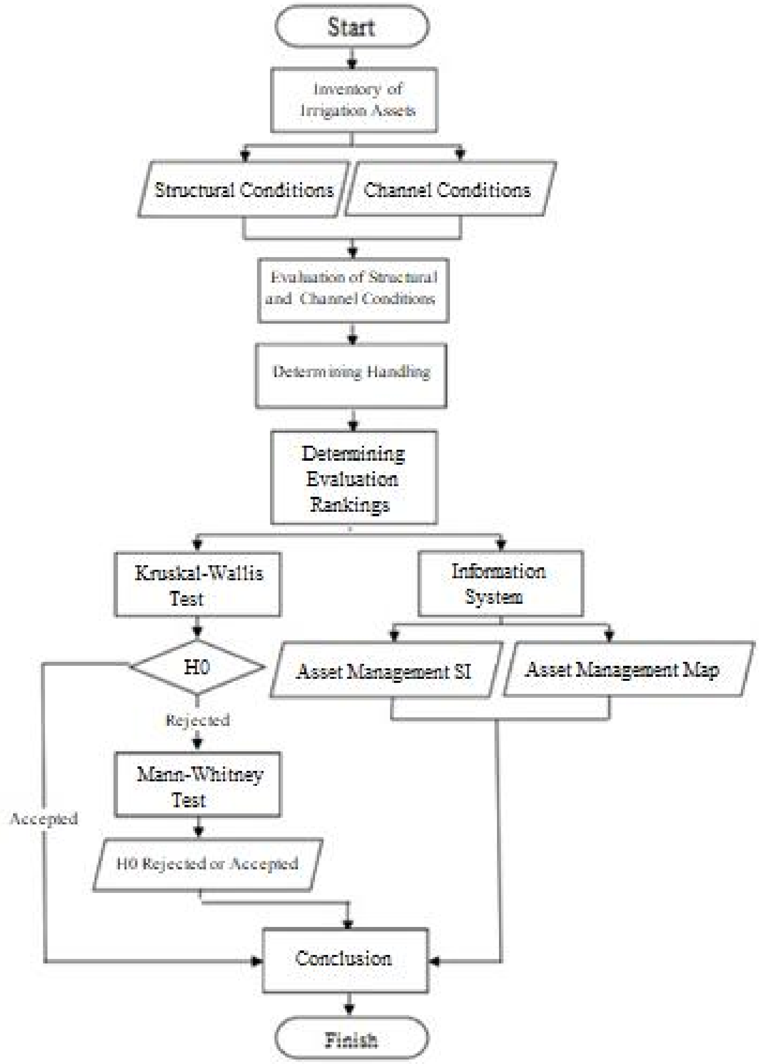

Figure 2. Flowchart

3. Results and Discussion

Data from the results of irrigation asset inventorying is composed of primary data consisting of the conditions of structures and irrigation channels present in the primary and secondary channels of the Kedungrejo Irrigation Area. The total number of assets of physical infrastructure present in the primary and secondary channels is 82 assets (76 structures and 6 channels).

There are four evaluation conditions: 1) Very Good; 2) Good; 3) Fair; and 4) Poor. The following are the results of physical infrastructure evaluation:

Table 2. Results of Condition Evaluation

No.		Name of Channel/Structure	Nomenclature	Condition Score	Condition
1	Kedungrejo PC	Kedungrejo Primary Channel		62.78	Fair
2		Kedungrejo Dam	B.KR	70.67	Fair
3		Washing Ladder	B.KR.1a	60.00	Fair
4		Disposal Entryway	B.KR.1b	77.50	Fair
5		Washing Ladder	B.KR.1c	90.00	Very Good

No.		Name of Channel/Structure	Nomenclature	Condition Score	Condition
6		Groundsill	B.KR.1d	73.33	Fair
7		Bridge	B.KR.1e	80.00	Good
8		Disposal Entryway	B.KR.1f	85.00	Good
9		Washing Ladder	B.KR.1g	80.00	Good
10		Washing Ladder	B.KR.1h	80.00	Good
11		Disposal Entryway	B.KR.1i	65.00	Fair
12		Bridge	B.KR.1j	85.00	Good
13		Disposal Entryway	B.KR.1k	90.00	Very Good
14		Bridge	B.KR.1l	80.00	Good
15		Disposal Entryway	B.KR.1m	55.00	Poor
16		Siphon	B.KR.1n	67.50	Fair
17		Gutter	B.KR.1o	58.75	Poor
18		Siphon	B.KR.1p	68.75	Fair
19		Disposal Entryway	B.KR.1q	87.50	Good
20		Crossing Bridge	B.KR.1r	87.50	Good
21		Culvert	B.KR.1s	70.00	Fair
22		Bridge	B.KR.1t	90.00	Very Good
23		Bridge	B.KR.1u	90.00	Very Good
24		Cascade	B.KR.1v	82.50	Good
25		Disposal Entryway	B.KR.1w	55.00	Poor
26		Gutter	B.KR.1x	75.00	Fair
27		Distributing Structure	B.KR.1	83.33	Good
28	Kuwu SC	Kuwu Secondary Channel		60.00	Fair
29		Absorbing Structure	B.KU.1	78.33	Fair
30		Bridge	B.KU.2a	87.50	Good
31		Animal Bathing Location	B.KU.2b	60.00	Fair
32		Absorbing Structure	B.KU.2	78.33	Fair
33		Bridge	B.KU.3a	90.00	Very Good
34		Absorbing Structure	B.KU.3	80.00	Good
35		Absorbing Structure	B.KU.4	80.00	Good
36		Crossing Bridge	B.KU.5a	85.00	Good
37		Bridge	B.KU.5b	82.50	Good
38		Absorbing Structure	B.KU.5	78.33	Fair
39		Absorbing Structure	B.KU.6	68.33	Fair
40		Absorbing Structure	B.KU.7	73.33	Fair
41		Crossing Bridge	B.KU.8a	85.00	Good
42		Crossing Bridge	B.KU.8b	85.00	Good
43		Absorbing Structure	B.KU.8	68.33	Fair
44		Crossing Bridge	B.KU.9a	82.50	Good
45		Absorbing Structure	B.KU.9	68.33	Fair
46		Singge Secondary Channel		62.78	Fair
47		Bridge	B.SI.1a	90.00	Very Good
48	Singge SC	Absorbing Structure	B.SI.1	75.00	Fair
49		Bridge	B.SI.2a	82.50	Good
50		Washing Ladder	B.SI.2b	80.00	Good
51		Bridge	B.SI.2c	87.50	Good
52		Absorbing Structure	B.SI.2	76.67	Fair
53		Bridge	B.SI.3a	80.00	Good

No.		Name of Channel/Structure	Nomenclature	Condition Score	Condition
54		Bridge	B.SI.3b	87.50	Good
55		Absorbing Structure	B.SI.3	81.67	Good
56		Absorbing Structure	B.SI.4	73.33	Fair
57		Bridge	B.SI.5a	90.00	Very Good
58		Absorbing Structure	B.SI.5	71.67	Fair
59		Bridge	B.SI.6a	85.00	Good
60		Absorbing Structure	B.SI.6	78.33	Fair
61		Bridge	B.SI.7a	77.50	Fair
62		Absorbing Structure	B.SI.7	75.00	Fair
63		Bridge	B.SI.8a	87.50	Good
64		Absorbing Structure	B.SI.8	73.33	Fair
65		Bridge	B.SI.9a	87.50	Good
66		Absorbing-Distributing Structure	B.SI.9	78.33	Fair
67	Kedungjati SC	Kedungjati Secondary Channel		60.56	Fair
68		Culvert	B.KJ.1a	73.75	Fair
69		Absorbing Structure	B.KJ.1	73.33	Fair
70		Absorbing Structure	B.KJ.2	73.33	Fair
71		Culvert	B.KJ.3a	73.75	Fair
72		Absorbing Structure	B.KJ.3	75.00	Fair
73	Plumpung SC	Plumpung Secondary Channel		63.33	Fair
74		Crossing Bridge	B.PL.1a	85.00	Good
75		Culvert	B.PL.1b	75.00	Fair
76		Absorbing Structure	B.PL.1	75.00	Fair
77		Cascade	B.PL.2a	55.00	Poor
78	Balongbader SC	Balongbader Secondary Channel		65.56	Fair
79		Balongbader Dam	B.BD	77.33	Fair
80		Absorbing Structure	B.BD.1	80.00	Good
81		Bridge	B.BD.2a	90.00	Very Good
82		Absorbing Structure	B.BD.2	80.00	Good

Considering the summary of physical infrastructure conditions in the primary and secondary channels of the Kedungrejo Irrigation Network, most have the “fair” condition. This condition will be used to determine the handling that will be performed. The following table details the appropriate handling for the analysed physical infrastructure conditions:

Table 3. Determination of Handling

Handling	Total	Percentage (%)
Routine maintenance	8	9.76
Periodic maintenance for management	30	36.59
Maintenance for repairs	40	48.78
Major repairs or replacement	4	4.88

Based on the research results, the highest ranking (rank 1) was for disposal entryway B.KR.1m, disposal entryway B.KR.1w, and cascade B.PL.2a, each with a percentage of 55.00%, while the lowest ranking (rank 82) was for washing ladder B.KR.1c, disposal entryway B.KR.1k, bridge B.KR.1t, bridge B.KR.1u, bridge B.KU.3a, bridge B.SI.1a, bridge B.SI.5a, and bridge B.BD.2a, each with a percentage of 90.00%.

Table 4. Kruskal-Wallis Test

Channel (K)	R	n
R1 (S.P Kedungrejo)	1102	27
R2 (S.S Kuwu)	766	18
R3 (S.S Singge)	1020	21
R4 (S.S Kedungjati)	147	6
R5 (S.S Plumpung)	142	5
R6 (S.S Balongbader)	228	5
N	82	
α	0.05	
K	6	
df	5	
H	6.639	
$X_{(0.05;5)}$	11.070	

Thus, because H (6.639) ≤ X (0.05;5) (11.070), the statistical conclusion of the proposed hypothesis is that there is no difference, meaning that H0 is accepted and H1 is rejected. Therefore, the Mann-Whitney test does not need to be performed.

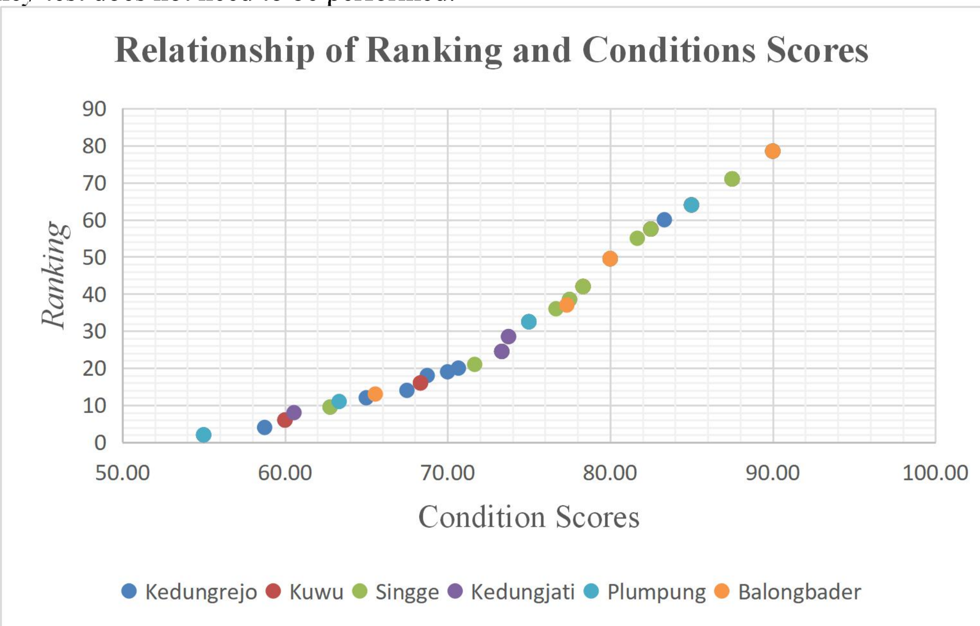

Figure 3. Relationship of Ranking and Condition Scores

The chart in the figure indicates that there are no differences between groups, because the data from each group, symbolized with different colours, are evenly distributed and do not appear dominant in certain rank ranges.

The information system implemented in this study through the software of Google Earth and ArcGIS resulted in the information system of asset management and map of asset management.

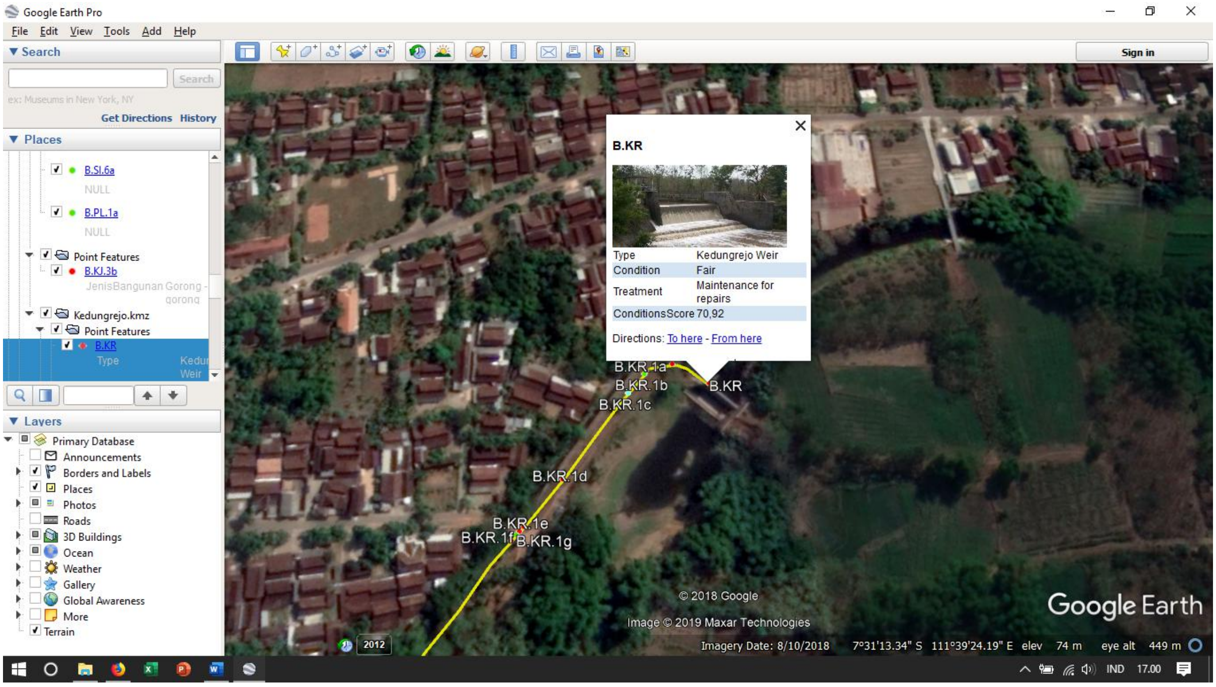

Figure 4. Asset Management Information System

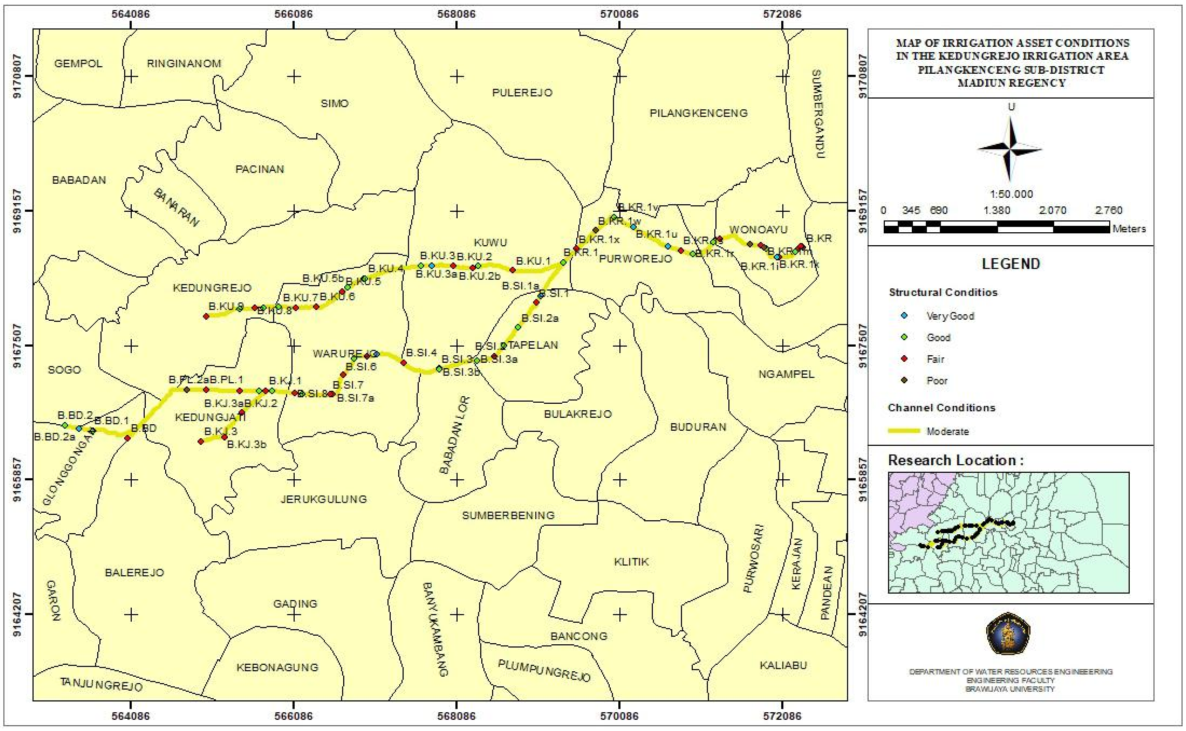

Figure 5. Map of Irrigation Asset Conditions

4. Conclusion

The following are the results of evaluating the performance of physical infrastructure in the Kedungrejo Irrigation Area:

- Those in very good condition amount to 10%

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- Those in good condition amount to 37%
- Those in fair condition amount to 49%
- Those in poor condition amount to 5%

Ranking of irrigation physical infrastructure conditions from the lowest condition score to the highest showed that the highest ranking (rank 1) is for disposal entryway B.KR.1m, disposal entryway B.KR.1w, and cascade B.PL.2a, and the lowest ranking (rank 82) is for washing ladder B.KR.1c, disposal entryway B.KR.1k, bridge B.KR.1t, bridge B.KR.1u, bridge B.KU.3a, bridge B.SI.1a, bridge B.SI.5a, and bridge B.BD.2a.

Results of rank testing using the Kruskal-Wallis test showed an H value of 3.300. The value of H (6.639) $\leq X_{(0.05;5)}$ (11.070) showed that the conclusion of statistical testing of the proposed hypothesis is that there is no difference, which means accepting H0 and rejecting H1. It can then be concluded that by using the evaluation aspects sourced from the Criteria and Weightings for Irrigation Performance Evaluation of the Ministry of Public Works and National Housing of 2018, all channel groups may be considered as the same condition.

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