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Geographic Information System Design for Irrigation System Performance Index Main Network

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ABSTRACT

Irrigation plays an important factor in supporting agricultural land productivity to improve agricultural production. This is achieved by maintaining a sustainable irrigation system through an effective and efficient irrigation system. One method to asses is by using the Irrigation System Performance Index (IKSI). This study designs an information system for IKSI in the main network system. The assessment of IKSI follows PERMEN PU NO.32/2007, with parameters such as physical infrastructure assessment, crop productivity, supporting facilities, personnel organization, documentation, and P3A. The purpose of this system is to determine the operation and maintenance (O&M) strategies and non-physical management strategies. The Main Network SIG IKSI design includes functionalities such as (i) a data folder system, (ii) an imaging system, (iii) GIS, and (iv) an evaluator of physical and non-physical irrigation systems. The results of the program in the Antirogo irrigation area show an IKSI the main network value for physical infrastructure of 85,0% and non-physical strategies (crop productivity, supporting facilities, personnel organization, documentation, and P3A) of 70,0% until 80,0%. The results shows that the physical infrastructure needs to be carried out regularly and non-physical strategies need to be maintained and improved.

1. INTRODUCTION

Irrigation is an important factor in supporting the productivity of agricultural land in order to increase agricultural production which is realized by maintaining the continuity of the irrigation system through effective and efficient irrigation system management activities. One effort to achieve effective and efficient irrigation system management is the assessment of the irrigation system performance index (IKSI). IKSI is an indication that describes irrigation system management. This IKSI assessment was carried out based on the PUPR Ministry Regulation (2015) with parameters for assessing physical infrastructure, planting productivity, supporting facilities, personnel organization, documentation and the Water User Farmer Association (P3A). The output of the physical infrastructure assessment is used for (i) strategies for implementing operations and maintenance (O&M) for physical infrastructure and (ii) fulfilling or improving non-physical strategies (planting productivity, supporting facilities, personnel organization, documentation and P3A).

The IKSI calculation procedure has been carried out in various irrigation areas, including the Barugbug Irrigation Area (Mulyadi *et al*, 2014), the Jragung Irrigation Area (Putri *et al*, 2014), the Uwai Pangoan irrigation area (Fauzi *et al*., 2017), DI Muara Jalai, Kampar Regency (Astri *et al*, 2018), Bekri Irrigation Area Water Gate (Ariyanto, 2019), Tukad Ayung Mambal Irrigation Area (Yekti *et al*, 2020), Cikeusik irrigation area (Ananda *et al*, 2019), Bantimurung irrigation area (Fachrie, 2019), Seberang Gunung Irrigation Area (Yahdita, 2020), D.I Krueng Jreu (Musfira, 2021) and physical infrastructure performance analysis Irrigation Area (Dwiyantama, 2020). Apart from manual, IKSI assessment

is also carried out electronically by E-PAKSI software in the Mojowarno Irrigation Area (Pratama *et al*, 2022), Grogol Irrigation Area (Khabib, 2023). Bungong Tulo Irrigation Area (Zirda *et al*, 2022), Padangkeling Irrigation Area (Purbawa *et al*., 2022). Padang Keling Irrigation Area (Purbawa *et al*., 2022), Dung Uling Irrigation Area (Anisulfuad & Laurentina, 2023) and Sei Belutu Irrigation Area (Tampubolon, 2022). These studies show that the evaluation of physical infrastructure is oriented towards one irrigation system, not based on sub-systems. So it is difficult to interpret the determination of follow-up priorities for the rehabilitation of irrigation areas per sub-system.

In interpreting the condition of physical infrastructure, the E-PAKSI software has (i) limitations in storing images/photos of asset conditions, so that users have difficulty interpreting/assessing the condition of physical infrastructure and (ii) the device interprets irrigation areas in one system, not in sub-systems. Therefore, it is necessary to have an IKSI information system for irrigation networks that is capable of interpreting sub-systems in physical infrastructure, so that (i) it makes it easier to determine follow-up priorities for the rehabilitation of irrigation areas; (ii) increasing large image storage capacity to make it easier to assess the condition of physical infrastructure; and (iii) can carry out sub-system simulations.

The purpose of the study is to design the Geographic Information System (GIS) Irrigation System Performance Index (IKSI) of the main network which is compiled based on the physical infrastructure sub-system, so as to facilitate the determination of follow-up priorities for the rehabilitation of irrigation areas. The IKSI information system is expected to have a large image storage capacity to facilitate the assessment of the condition of physical infrastructure; and can simulate sub-systems.

2.2. RESEARCH METHODS

2.1. Time and Place of Research

The test was carried out in the Antirogo Irrigation Area with coordinates of 113°43.02462' E to 113°44.8038' E and 8°9.69636' N to -8°8.65752' N (Figure 1). The analysis of the IKSI GIS design was carried out at the Environmental Management and Conservation Engineering Laboratory (TPKL) – Department of Agricultural Engineering – Faculty of Agricultural Technology – University of Jember.

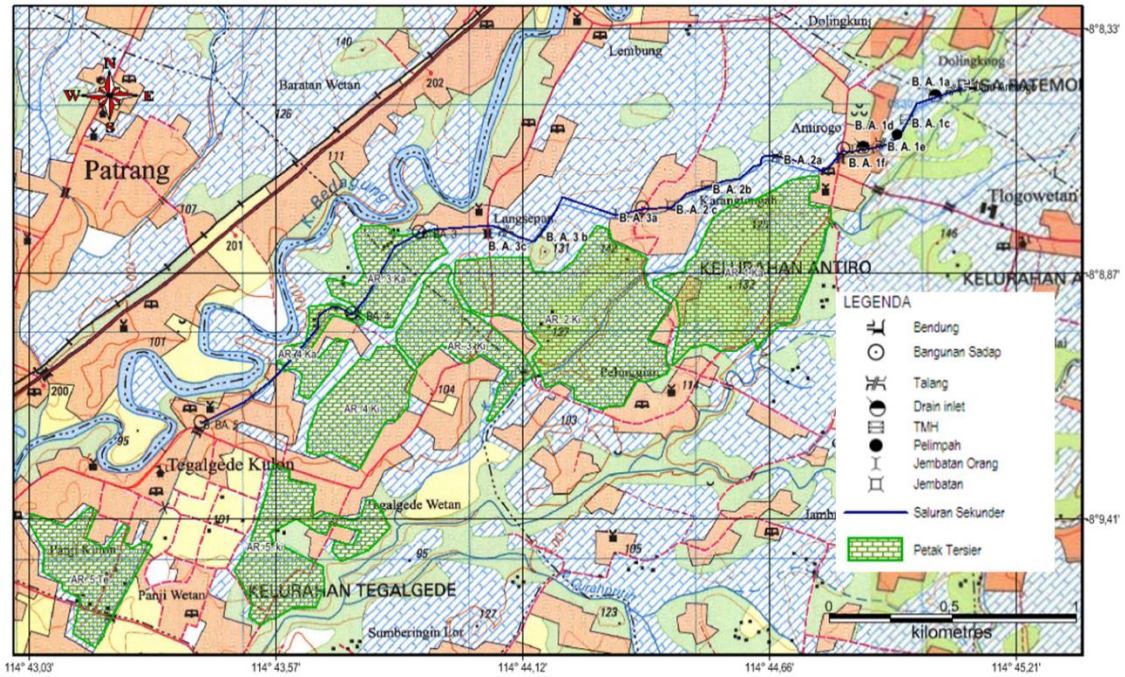


Figure 2. Test location to evaluate Irrigation System Performance Index

2.1. Tools, Materials, and Method

SIG IKSI are designed by combining the facilitation of the Visual Basic Program version 6.0 with the MapInfo Program Version 12.0. The methods used in this study are (i) pre-design; (ii) design and (iii) trial of GIS Irrigation System Performance Index (IKSI) (Figure 2).

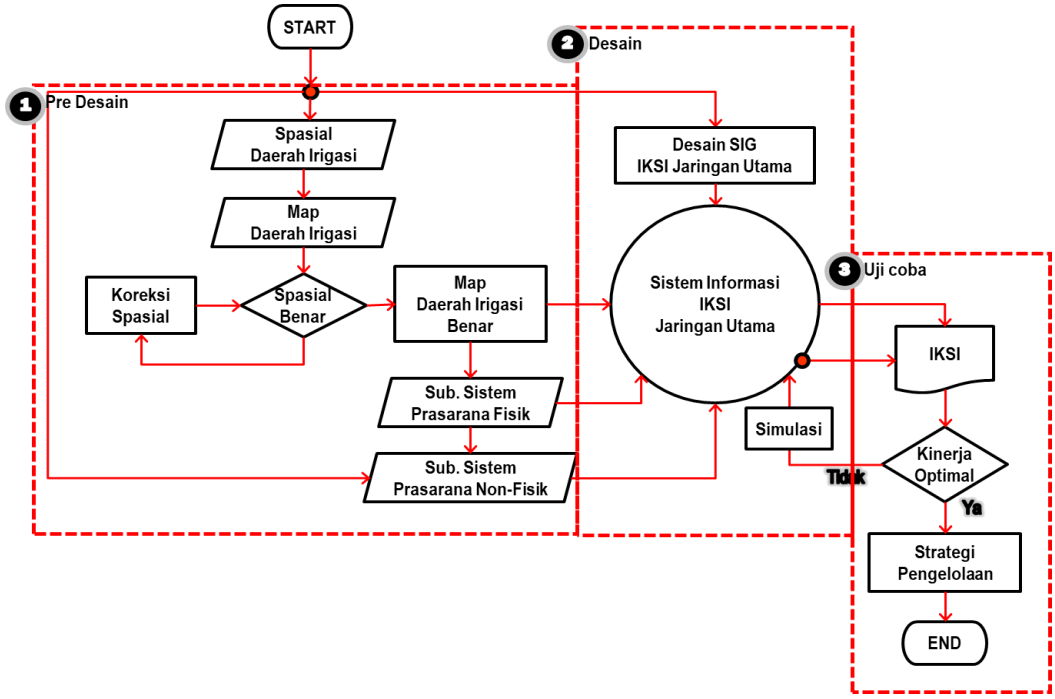


Figure 2. Flow chart of the methodology approach

2.2.1. Pre-Design

Pre-design is used to form a spatial map of irrigation areas and spatial physical infrastructure. The formation of maps and physical infrastructure is carried out by GPS (Global Pointing System) survey with the SW-Maps android application and continued to make maps with MapInfo. Maps interpret the boundaries of the physical and non-physical infrastructure data base subsystems. The physical infrastructure database interprets (i) the main building; (ii) regulatory buildings; (iii) complementary buildings; (iv) channels; (v) drainage system; (vi) inspection roads; and (vii) buildings. Meanwhile, the non-physical infrastructure database interprets the spatial of the work area including (i) P3A and (ii) management institutional OP (UPTD).

2.2.2. Geographic Information System Design

The value of the IKSI Information System Index is formed by physical infrastructure inputs and non-physical infrastructure inputs with the following equations (DBOP, 2019a; 2019b; 2019c):

$$K_i = \sum_{j=1}^{n} (BS_{ij} \times NBS_{ij}) \quad (1)$$

where K_i is the i^{th} Irrigation System Performance Index, i is the Irrigation System Index Number = 0,1,3,...,6, j is the Irrigation Sub-system Index Number = 0,1,3,...,n, and n is the number of irrigation sub-system index to the i, BS is weight factor (Table 1), and NBS is the weight value based on the condition, namely: 95 for very good condition, 85 for good condition, 70 for moderate condition, and 60 for bad condition. Based on Kementerian PUPR (2015) the weight score of the assessment of each IKSI component has a value between 5% to 45%, namely: physical infrastructure (45%), crop productivity (15%), supporting facilities (10%), personnel organization (15%), documentation (5), and Association of Farmer Water Users (P3A) (10%). The total value of IKSI score is 100%.

The output of the OP performance assessment is used for (i) operation and maintenance (O&P) implementation strategies (O&P for regular O&P/heavy repair/rehabilitation) for physical infrastructure and (ii) non-physical strategies (established/adequate/maintained/improved/developed) for crop productivity, supporting facilities, personnel organization, documentation and P3A. According to Djito (2021), the OP strategy includes (i) ordinary O&P for very good physical infrastructure performance (80-100); (ii) O&P minor improvements for good physical infrastructure performance (70 - 80), (iii) heavy O&P for poor physical infrastructure performance (55-70), and (iv) rehabilitation for poor physical infrastructure performance (<50). Meanwhile, the non-physical strategy is maintenances for very good non-physical performance (80-100); maintenances, improvements, and developments for good non-physical performance (70-80); (iii) sufficient performance (55-70), and poor performance (<55).

2.2.3. IKSI Trial

The IKSI trial was carried out for the Antirogo Irrigation Area. The test was carried out to simulate the performance of the irrigation system in order to obtain the performance of the optimal irrigation system

3. RESULTS AND DISCUSSION

3.1. Irrigation Network Tracking

Irrigation network tracing is carried out to obtain data on the condition and functioning of physical infrastructure. The condition of the building/channel, the level of damage to the building/channel that is not in accordance with the design (cracks, leaks, seepage, sedimentation, erosion and others) and the functioning of physical infrastructure (adjustment of the planned capacity, ease of door operation and others). The physical infrastructure of the network observed includes (i) the main building; (ii) regulatory buildings; (iii) complementary buildings; (iv) channels; (v) drainage system; (vi) inspection roads; (vii) OP building facilities and (viii) P3A. Each object is photographed to interpret the condition and functioning of physical infrastructure. Evaluation of the condition and functioning of physical infrastructure based on photos and spatial data is carried out in workshops or offices.

3.2. IKSI Geographic Information System Design

The IKSI Geographic Information System displays and evaluates the potential and spatial conditions of physical and non-physical infrastructure, so that it can be used for follow-up of irrigation areas. The Functional Design of the IKSI Geographic Information System is presented in Figure 3 and structurally presented in Figure 4.

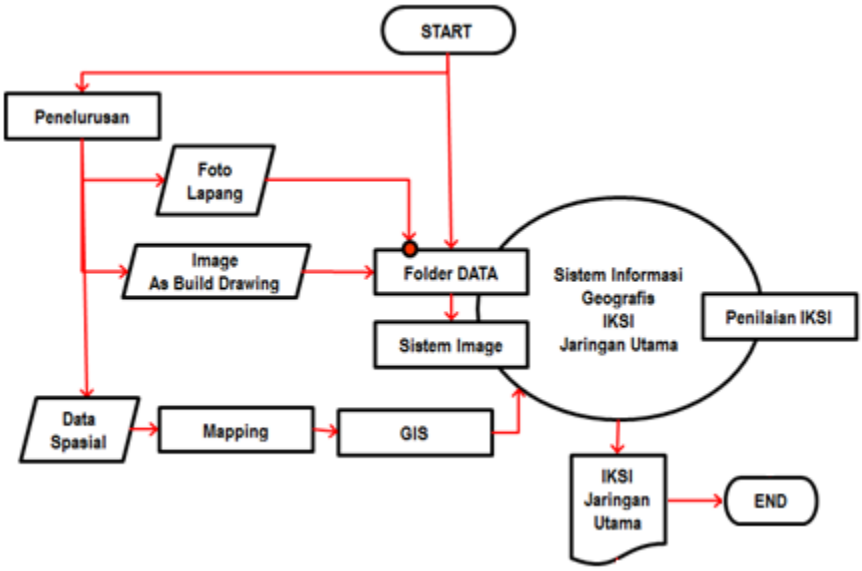
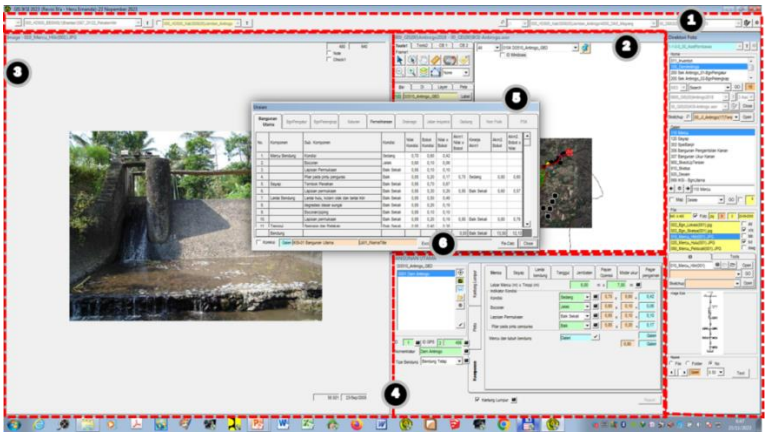
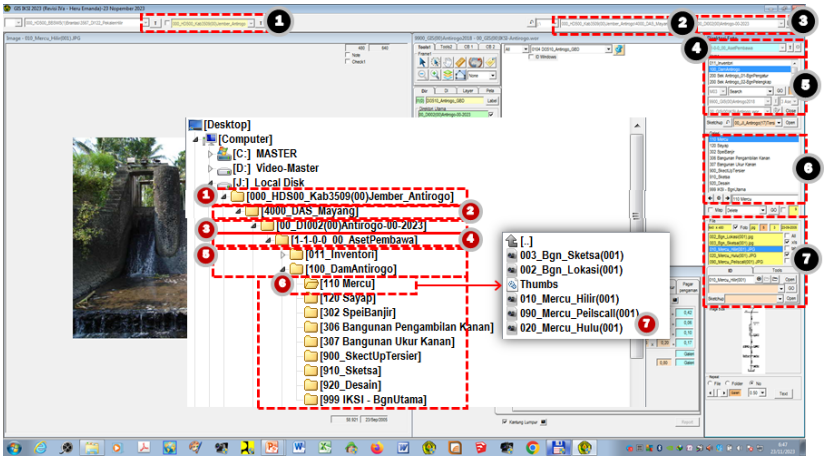


Figure 3. Functional design of IKSI main network GIS



Information::
(1) Folder Data
(2) GIS
(3) Image
(4) Assessment System
(5) Recapitulation
(6) Export Excell

Figure 4. Structural design of GIS IKSI main network



Information :
(1) Main Folder
(2) Sub Folder 1
(3) Sub Folder 2
(4) Sub Folder 3
(5) Sub Folder 4
(6) Sub Folder 5
(7) File System

Figure 5. Folder system of GIS IKSI main network

3.2.1. Data Folder

The Data Image folder functions to store images of the potential and condition of the infrastructure. The Data Image folder consists of nine folders as shown in Figure 5.

3.2.2. Map of Geographic Information System

The spatial data of physical infrastructure is formed by the Geographic Information System Map according to the assessment group by naming the layer as follows: **nnn_GIS(mm)_NameofIrrigationArea_XXXX,** namely:

nnn	: Serial Number of Irrigation Areas
NameofIrrigationArea	: Name of Irrigation Area
_XXXX	: Assessor Group
_GBD	: Main building
_GBS	: Regulatory Building
_GBS	: Complementary building
_GSal	: Channels
_GzDR	: Drainage System
_GzJln	: Inspection Road System
_GzGD	: Building Facilities System
_GzP3A	: Water User Farmers Association (P3A)

Controlling the appearance of a value group was performed with a combo box in Windows GIS.

3.2.3. IKSI Irrigation System Performance Assessment System – Main Network

The irrigation system performance assessment system is an assessment system based on data from field observations and post-asset drawings. The irrigation system performance assessment system consists of nine sub-systems, namely (i) the main building; (ii) regulatory buildings; (iii) complementary buildings; (iv) channels; (v) drainage system; (vi) inspection road system; (vii) maintenance; (viii) building facilities system; (ix) non-physical and (x) Water User Farmers Association (P3A/GP3A/IP3A). Each assessment of building/channel components is designed using ListBox to select assets in the desired sub-system.

A. Main Structure Assessment System - IKSI Main Network

The performance assessment system of the main building irrigation system is used to assess the main building. Condition and functional components include:

(1) Weir body: The assessment of the weir body includes components (i) landmarks; (ii) wings; (iii) the weir floor; (iv) embankments; (v) bridges; (vi) operation board; (vi) the measuring crossbar; and (vii) safety fence.
(2) Weir Gate: The assessment of the dam gate includes (i) the intake door and (iii) the drain door.
(3) Mud bag: Each component of the dam has a weight that is adjusted to the Kementerian PUPR (2015). Structural design of the main building assessment system - IKSI main network is presented in Figure 6.

B. Regulatory Building Assessment System - IKSI Main Network

The performance assessment system of the irrigation system of the regulatory building is used to assess the regulatory building. In general, the regulatory building is in the form of (i) a building for; (ii) the building for tapping or (iii) the building for tapping. The condition and functional components of the building include:

(1) Water Gate: The assessment was carried out on the operational ease of the door of the regulator and tap.
(2) Construction of Regulatory Buildings: Assessment of the construction of the regulatory building includes (i) the condition of the building body and leaks; (ii) building wings; (iii) erosion of the lower floor; (iv) the stability of the embankment and (v) the operation board.
(3) Surveying Building: The assessment of the survey building is carried out on (i) the functional of the survey building; (ii) the condition of the guessboard and (iii) the reading of the discharge.

The structural design of the regulatory building assessment system - IKSI main network is presented in Figure 7.

C. Complementary Structure Assessment System - IKSI Main Network

The performance assessment system of the irrigation system of complementary buildings is used to assess complementary buildings. In general, complementary buildings are in the form of (i) siphons; (ii) culverts; (iii) gutters; (iv) cross drain; (v) bridges; (vi) diving; (vii) side spills; (viii) drain inlet; (ix) washing ladder; and (x) animal baths. Structural design of the complementary structure assessment system - IKSI main network is showed in Figure 8.

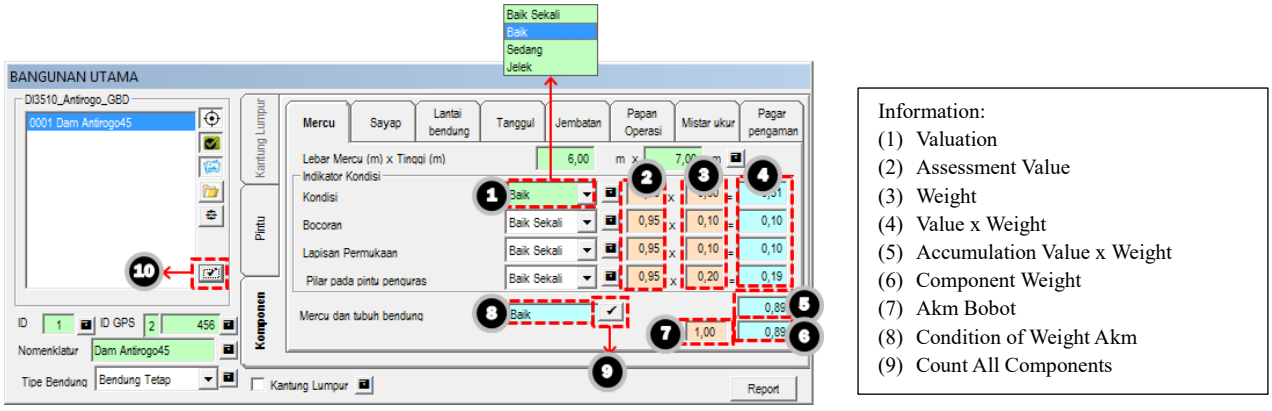


Figure 6. Structural design of main structure assessment – GIS IKSI

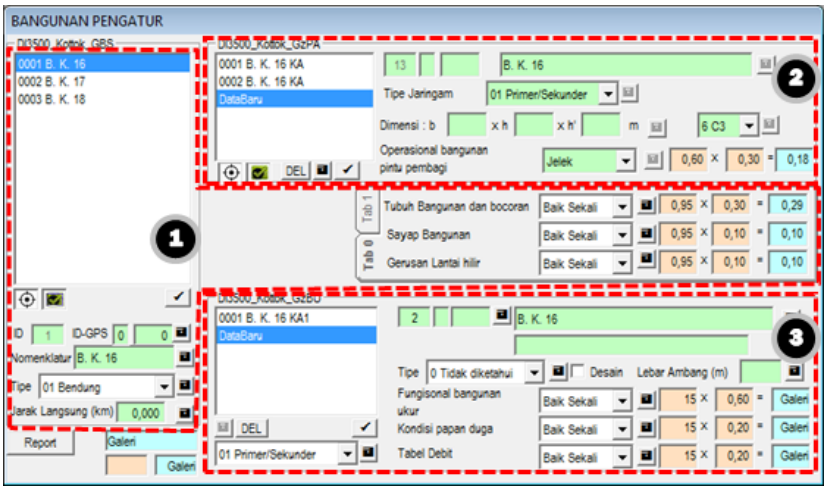


Figure 7. Structural design of regulatory structure assessment – GIS IKSI

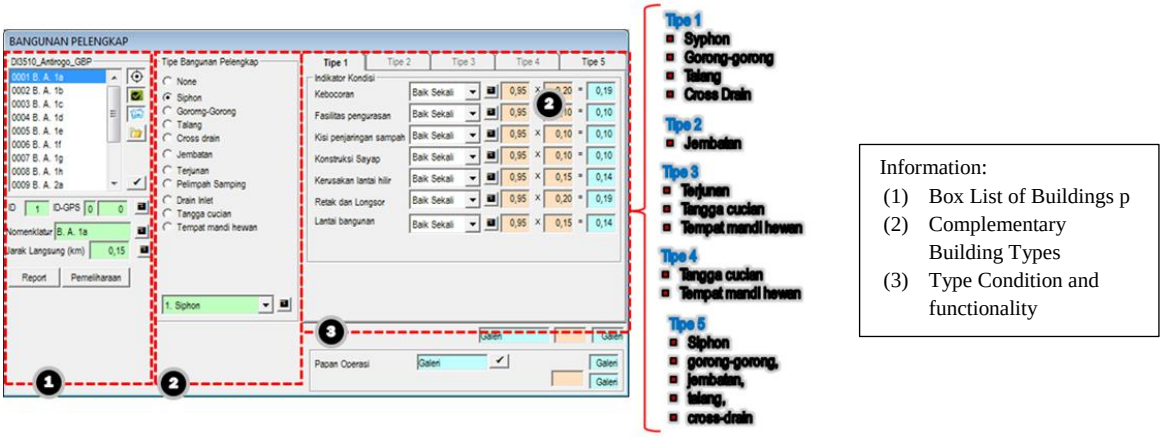


Figure 8. Structural design of complementary structure assessment – GIS IKSI

D. Channel Assessment System - IKSI Main Network

The performance assessment system of the canal irrigation system is used to assess the canal building. The channel is evaluated every 200 m. The identity of the channel is expressed in the form of segments and sections. The structural design of the channel scoring system - IKSI of the main network is presented in Figure 9.

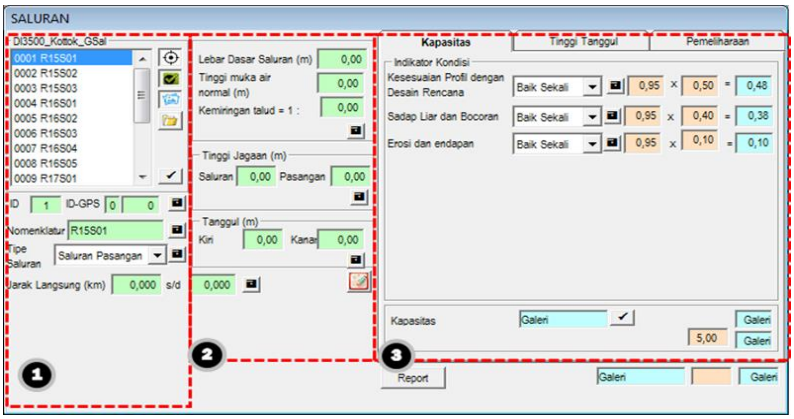
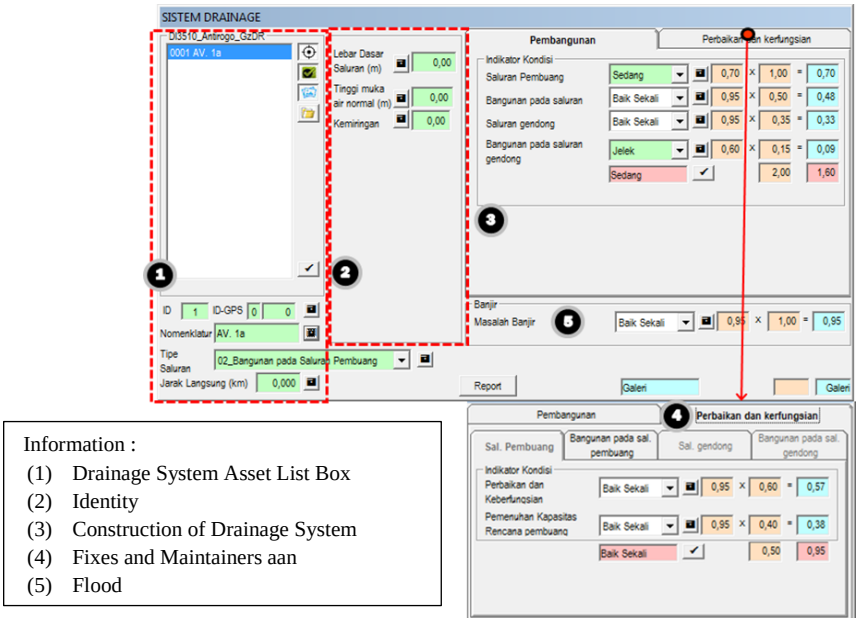


Figure 9. Structural design of channel assessment – GIS IKSI

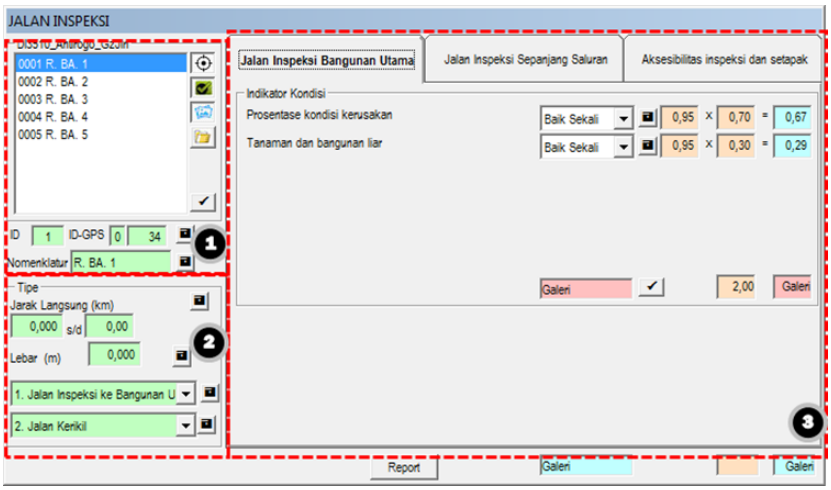
E. Drainage System Assessment System - IKSI Main Network

The drainage system assessment system is used to assess the drainage system. The assessment is carried out on (i) infrastructure development and (2) repair and functionality of sewers, buildings in sewers, sling channels and buildings on sling channels. Structural design of drainage system assessment system - IKSI main network presented in Figure 10



Information :
(1) Drainage System Asset List Box
(2) Identity
(3) Construction of Drainage System
(4) Fixes and Maintainers aan
(5) Flood

Figure 10. Structural design of drainage system assessment – GIS IKSI



Information:
(1) Inspection Road Asset List Box
(2) Identity
(3) Inspection Road Condition and Accessibility Assessor

Figure 11. Structural design of inspection road assessment – GIS IKSI

F. Inspection Road Assessment System – IKSI Main Network

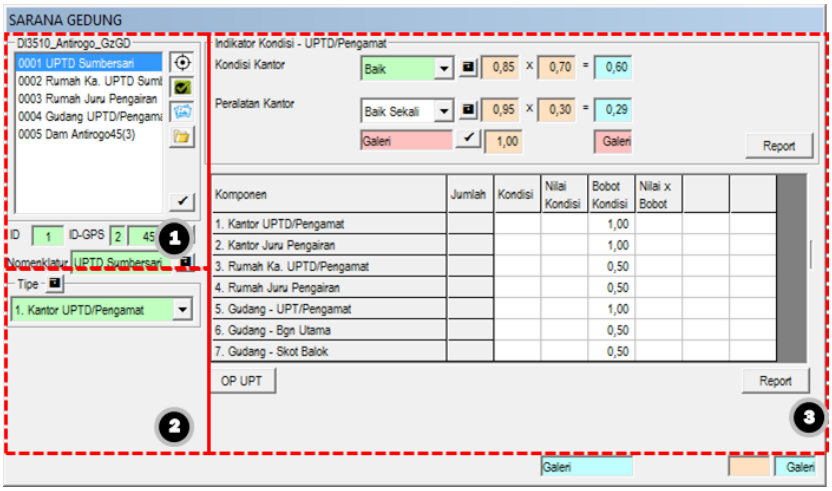
The road is used for the purpose of operation and maintenance of the irrigation network. The inspection road assessment system is used to assess the condition and functionality of the inspection road. Assessment of inspection roads based on damage condition and road accessibility. The weight of the inspection road is differentiated between the inspection of the main building and the inspection along the channel. Structural design of the inspection road assessment system - IKSI main network is presented in Figure 11.

G. Building Facilities Assessment System – IKSI Main Network

Building facilities in the operation and maintenance of irrigation networks are building facilities used for work activities, houses and warehouses. The assessment is carried out on (i) the condition of the space and (ii) the availability of equipment. Structural design of building facilities assessment system - IKSI main network presented in Figure 12.

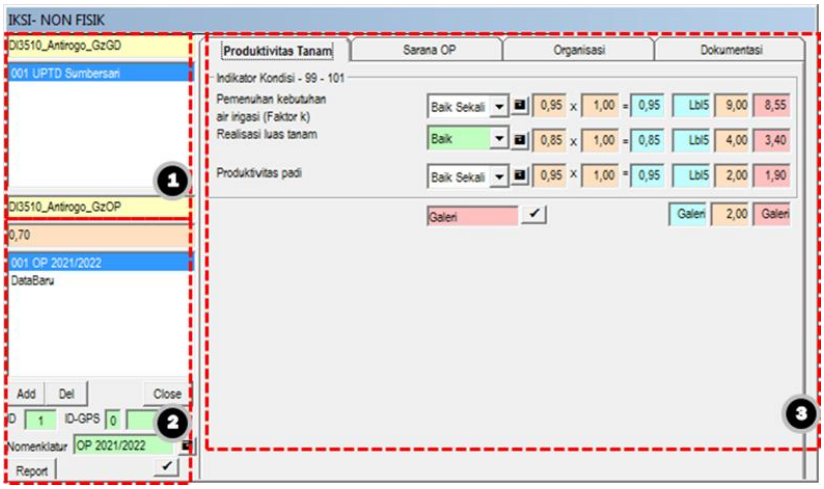
H. Non-Physical Performance Assessment System - IKSI Main Network

The performance assessment system of the channel irrigation system is used to assess non-physical performance. The structure components are presented in Figure 13. The parameters assessed are as follows:
(1) Productivity
(2) OP Facilities: P The assessment of OP facilities includes (i) OP equipment; (ii) transportation; (iii) office equipment; and (iv) communication tools.
(3) Organization: Organizational assessment includes (i) organizational structure and (ii) personnel.
(4) Organization: Organizational assessment includes (i) organizational structure and (ii) personnel..
(5) Documentation: documentation assessment involve (i) log book of Irrigation Area; and (ii) Map and schemes.



Information:
(1) Building Asset List Box
(2) Identity
(3) Building Condition and Repair Assessor

Figure 12. Structural design of building facility assessment – GIS IKSI



Information:
(1) Box List Manager
(2) Box List of OP Management Period
(3) Productivity Assessor, OP Facilities, Organization and Documentation

Figure 13. Structural design of non-physical performance assessment – GIS IKSI

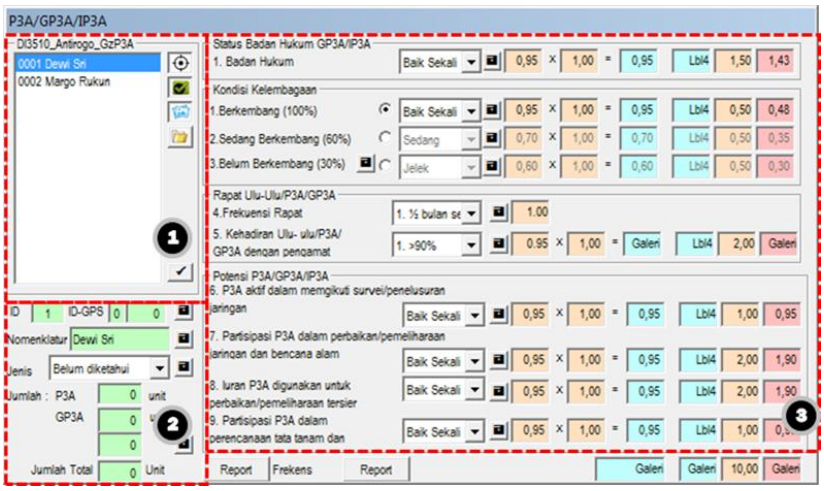


Figure 14. Structural design of Association of Farmer Water Users (P3A/GP3A/IP3A) assessment system – GIS IKSI

I. P3A Performance Assessment System - IKSI Main Network

The Performance Assessment System of the channel irrigation system is used to assess Non-Physical Performance. The parameters assessed are as follows: (1) Legal Entity, (2) Institutional Conditions, (3) Ulu-ulu Meeting, and (4) P3A Potential. The embodied component structure is presented in Figure 14.

J. Report

The report is a recapitulation of the assessment of each assessment system. From various assessment systems, a recap of all assessors was carried out, so that the performance index of the irrigation system – the main network was obtained. The structure of the report program is presented in Figure 15.

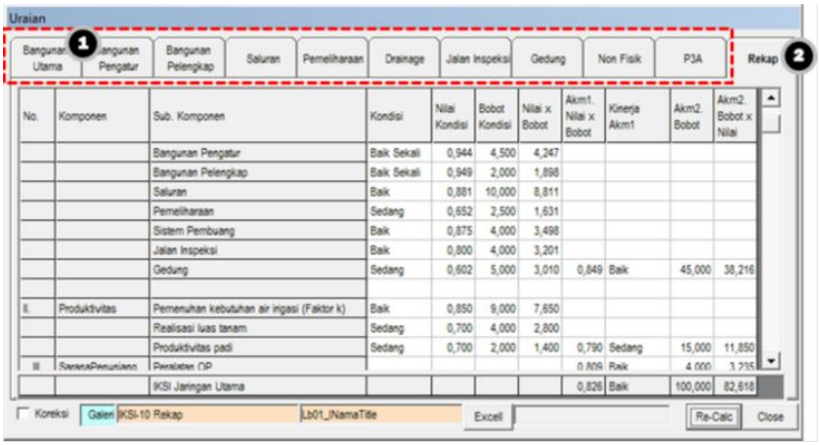


Figure 15. Structural design of report – GIS IKSI

3.3. Trial

The IKSI assessment depends on the condition and functioning of the building/channel, the maintenance carried out, and the ability of the assessor. These components are very different every time. Therefore, the IKSI assessment needs to be carried out every certain period by field officers. Use of Geographic Information Systems used (i) spatial changes (DI Antirogo is located in urban areas and partially changed housing) and (ii) spatial buildings and channels help determine the value of water distribution.

Monitoring of IKSI in each period can show changes in the condition and functioning of assets, as well as spatial changes. The E-PAKSI program from the Ministry of Public Works and Public Housing, Directorate General of Water Resources, Directorate of Operation and Maintenance Development has not been fully implemented in this irrigation area. The IKSI trial for the Antirogo Irrigation Area with field officers is presented in Table 1. The test showed a value of 85.00 for physical infrastructure aspects (very good performance) and non-physical strategies ranging from 70.00% to 80% (good performance). So that physical infrastructure needs to be carried out by ordinary OP and non-physical strategies need to be maintained and improved.

Table 1. IKSI Assessment – DI. Antirogo.

No.	Assets	Assessment Weight	Valuation	Weight xValue	Mark
1.	Aspects of Physical Infrastructure Condition	0.450	0.850	0.383	
2.	Aspects of Planting Productivity	0.150	0.770	0.116	
3.	Aspects of Supporting Facilities	0.100	0.800	0.080	
4.	Aspects of Personnel Organization	0.150	0.700	0.105	
5.	Documentation Aspects	0.050	0.700	0.035	
6.	P3A/GP3A/IP3A condition aspects	0.100	0.700	0.070	
	IKSI Score			0.788	Good

4. CONCLUSIONS

The design of the Main Network IKSI GIS has the functionality of (i) a data folder system; (ii) system image; (iii) GIS; (iv) Physical and non-physical irrigation system assessors form the IKSI value so that it can be used for irrigation area follow-up. The results of the program test in the Antirogo irrigation area show that the value of IKSI – main network – infrastructure is 78.8% with the follow-up of physical infrastructure needs to be carried out ordinary OP and non-physical strategies need to be maintained and improved.

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