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Determination of Weir Type Using Risk Analysis in Extensification Plan for Pedongga Irrigation in West Sulawesi Province

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Abstract**—** *Pedongga Irrigation Area is an irrigated area with an area of 100 ha, which is planned to be expanded considering the potential area of 500 ha. Located downstream and has a gentle elevation, it causes problems in the selection of the main irrigation building. Given the Ministry of Public Works and Housing Number 10/2021 concerning Guidelines for Construction Safety Management Systems, thereafter a risk factor analysis is carried out to determine the type of weir. From the 2 available options--fixed weir and rubber weir, a breakdown of the implementation method was carried out which included 7 items for fixed weir and 8 items for rubber weir. Later on, from these items, sub-items analysis was carried out through a literature study of similar projects that had been completed. The questionnaire method was also used for 1 work item on fixed weir and 2 work items for rubber weir. The risk level assessment for each sub-item uses a probability index and a severity index based on the applicable Ministerial Regulation. In addition to accommodating risk assessments for people, this research also includes risk assessments for equipment, materials, the public, and the environment. The results found that both the fixed weir and rubber weir have low risk of construction. Final score of fixed weir is 3,29 and rubber is 3,25. Therefore, the rubber weir is chosen to be built in DI. Pedongga.*

Keywords**—** *Probability index, risk analysis, severity index.*

I. INTRODUCTION

The existing Pedongga Irrigation Area has an area of 100 Ha which currently using only rainwater for the irrigation. In Pedanda Village, District Pedongga there is a potential area for paddy fields of 500 Ha. An irrigation main structure will be needed for this extensification purpose. The construction of main structure will certainly have impact on rising water level in the upstream of the weir. However, the soil condition at the site makes it impossible to build a barrage, because the lack of soil bearing capacity. Therefore, in this study, there are 2 types of weirs that will be studied, which are fixed weir and rubber weir.

Referring to Government Regulations Number 14/2021 which declares that every User and Provider in Construction must implement Construction Safety Management System or SMKK (similar to CHSE). The SMKK must fulfill the Security, Safety, Health, and Sustainability standards. To meet the standards, a risk factor analysis will be carried out on both weir options, which will later be used as the basis for determining the type of weir in Pedongga Irrigation Area.

II. METHOD

A. Location and Study Period

The study was conducted in Pedanda Village, District Pedongga, Pasangkayu Regency, which located between 1°15'7.47"S and 119°22'35.77"E (Figure 1). The study starts from 1 June 2022 to 31 October 2022.

Figure 1. District Pedongga Map
Source: BPS Kabupaten Pasangkayu, 2020

B. Tools and Materials

Tools which being used in this study is Microsoft Excel 365 for risk analysis and Google Form to collect questionnaire data.

C. Data Collection

Data in this study are divided into primary and secondary data with the following details:

1. Primary Data
   1) Questionnaire
      Results of questionnaire with people who have been in construction of relevant structure.
2. Secondary Data
   1) Fixed Weir and Rubber Weir Design Plan

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For comprehensive description of the design, including site conditions which covers technical planning and environmental conditions.

2) Literature studies that are directly related to study.

D. *Implementation Method*

This study is referring to Ministry of Public Works and Housing of Indonesia Number 10/2021 regarding Construction Safety Management Systems with some adjustments made. The process of completing this study is:

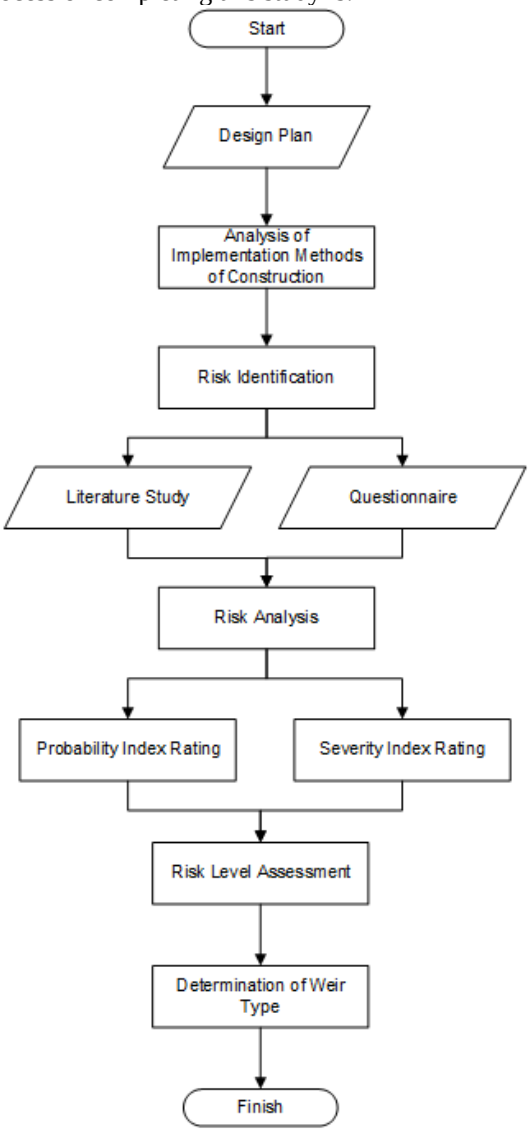

Figure 2. Risk Analysis Process

a) Analysis of Implementation Methods of Construction
Compiling an implementation method to describe the execution of the construction work to obtain elements of the work to then be analyzed for the potential risk.

b) Risk Identification
Done by using literature studies and questionnaires. The identified hazards are obtained from the previous analysis and subsequently questionnaire was made to clarify the identification of hazards that distinguish the two types of weir.

c) Risk Analysis
Includes a risk assessment process for each of the previously identified elements. Determination of the criticality of the incident by using a rating system of Probability Index Rating (PI) and Severity Index Rating (SI).

d) Risk Level Assessment
From the results of PI and SI, an assessment of the level of risk is carried out using the matrix method.

e) Determination of Weir Type
From the results of the risk level assessment that has been obtained, then the selected building is determined to be constructed.

III. Review of Literature

A. *Weir Design*

1. Fixed Weir

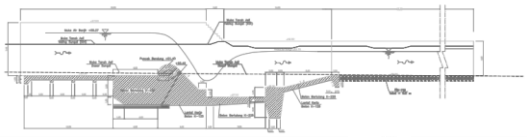

Figure 3. Fixed Weir Design
Source: PT. Aria Jasa Konsultan, 2015

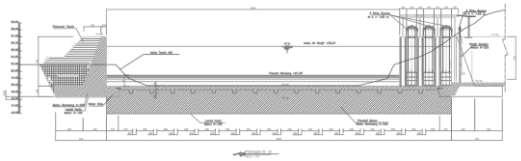

Figure 4. Weir Abutment and Foundation Design
Source: PT. Aria Jasa Konsultan, 2015

2. Rubber Weir

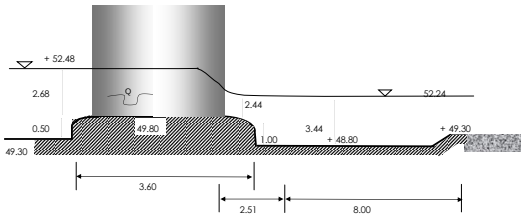

Figure 5. Rubber Weir Design
Source: PT. Aria Jasa Konsultan, 2015

B. *Implementation Methods*

Implementation methods of fixed weir are divided into 7 items, while for the rubber weir there is an additional item of rubber weir installation. The items are:

1. Soil excavation:
   a) Clearing
   b) Hauling
   c) Stripping
   d) Excavation for foundation
2. Dewatering work:
   a) Temporary dyke/kistdam

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b) Pumping water out of the construction area
3. Concrete
   a) K-125 (working floor)
   b) Concrete reinforcement
   c) Formwork
   d) K-225 (concrete casting)
   e) Concrete vibrating
   f) Concrete compacting
4. Stone work
   a) Rip rap
5. Backfill
   a) Backfill
   b) Soil compaction
6. Finishing work
   a) Plaster
   b) Painting
7. Sluicegate
   a) Frame installation
   b) Gate installation
8. Rubber weir installation
   a) Rubber weir hook installation
   b) Pump engine installation on pipe
   c) Rubber weir installation

C. Risk identification

Risk identification process is using literature studies and questionnaire method. Data obtained from literature studies such as:

1. 39 variables in earthwork (Sarmini, 2019)
2. The frequency of falling objects sorted by the average risk score (Putri & Putra, 2020)
3. Potential hazards for waterwork constructions (PT. Hutama Karya, 2022)
4. Potential hazards for rubber weir rehabilitation work (PT. Parama Adhi Pratama, 2021)

Whereas, for the questionnaire method, there are 2 types of questionnaires, which are:

1. Potential hazard for sluicegate work, 11 respondents
2. Potential hazard for rubber weir installment, 2 respondents

D. Risk Analysis

Using Ministry of Public Works and Housing of Indonesia Number 10/2021 as reference, risk assessment is the calculation of the potential hazard based on the possibility of an event that has an impact on losses to construction, human life, public safety, and the environment that can arise from certain sources of danger, occurring in construction work. work.

TABLE I. Probability Index

Probability	Description	Definition
5	Almost certain	• There is a high possibility of accidents while doing work • Possibility of accidents is more than twice a year
4	Very probable	• There is a possibility of accidents while performing work in almost all conditions • Possibility of accidents is once in the last year
3	Probable	• There is a possibility of accidents while performing work in certain conditions • Possibility of accidents is twice in the last 3 years
2	Small chance	• Less chance of accidents when doing work in certain conditions • Possibility of accidents is once in the last 3 years
1	Almost never	• Accidents can only occur while doing work under certain conditions • Possibility of accidents is once in more than the last 3 years

Source: Ministry of Public Housing of Indonesia, 2021

TABLE II. Severity Index

Severity	Safety Consequence Scale			Environment/ Public Facility
	Human	Equipment	Materials	
5	The fatality is more than 1 person dies; or More than 1 person get a permanent disability	More than 1 main equipment are totally damaged, causes work to stop for more than 1 week	The material is damaged and needs to bring in new material which takes more than 1 week and causes work to stop	Causes air/water/soil/sound pollution which results in complaints from the public; or Environmental damage occurred in the National Park related to flora and fauna; or A full damage to the assets of the surrounding community Severe damage to public road access. There is a traffic jam for more than 2 hours
4	The fatality is 1 person dies; or 1 person get a permanent disability	A main equipment is totally damaged, causes work to stop for 1 week	The material is damaged and needs to bring in new material which takes 1 week and causes work to stop	Causes air/water/soil/sound pollution which results in complaints from the public; or Environmental damage related to flora and fauna; or Damage to some of the assets of the surrounding community Severe damage to public road access. There is a traffic jam for 1-2 hours
3	There was an incident that resulted in more than 1 worker with inpatient medical treatment, lost working time	More than 1 equipment are damaged that requires repair and causes work to stop for less than 1 week	The material is damaged and needs to bring in new material which takes 1 week, but without causing the work to stop	Causes air/water/soil/sound pollution that affects the work environment; or Plant-related damage occurs in work environment; or Damage to public road access. There is a traffic jam for 30 minutes-1 hour
2	There was an incident that resulted in 1	An equipment is damaged that requires	The material is damaged and needs to bring in new	Causes air/water/soil/sound pollution that affects part of the work environment; or

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Severity	Safety Consequence Scale			Environment/ Public Facility
	Human	Equipment	Materials	
	worker with inpatient medical treatment, lost working time	repair and causes work to stop for more than 1 day	material which takes less than 1 week, but without causing the work to stop	Several damage to public road access. There is a traffic jam for less than 30 minutes
1	There are incidents that are handled only through first aid, no loss of work time	An equipment is damaged that requires repair and causes work to stop for less than 1 day	Does not cause material damage	Does not cause environmental disturbance

Source: Ministry of Public Housing of Indonesia, 2021

TABLE III. Risk Level Scoring

Probability	Severity				
	1	2	3	4	5
1	1	2	3	4	5
2	2	4	6	8	10
3	3	6	9	12	15
4	4	8	12	16	20
5	5	10	15	20	25

Source: Ministry of Public Housing of Indonesia, 2021

IV. Results and Discussion

A. Risk Level Assessment

Risk identification process is using literature studies and questionnaire method. Data obtained from literature studies such as:

TABLE IV. Risk Level Assessment

No.	Work Item	Risk Identification	Human		Equipment		Materials		Public		Environment	
			PI	SI	PI	SI	PI	SI	PI	SI	PI	SI
1	2	3	4	5	7	8	10	11	13	14	16	17
1	**Soil Excavation**											
a	Clearing	Landslides, people slip and run over by the bulldozer	3	4	0	0	0	0	0	0	0	0
b	Hauling	Collision between dump truck	3	5	3	4	0	0	0	0	0	0
c	Stripping	People hit/run over by bulldozer	3	5	0	0	0	0	0	0	0	0
d	Excavation for Foundation	Brake failure	3	5	3	5	0	0	0	0	0	0
2	**Dewatering**											
a	Temporary dyke/kistdam	People drown	4	5	0	0	0	0	0	0	0	0
b	Pumping water out of the construction area	Pump does not work	3	5	3	5	0	0	0	0	0	0
3	**Concrete Work**											
a	K-125 (working floor)	Broken concrete mixer	0	0	3	5	0	0	0	0	0	0
b	Concrete reinforcement	Broken bar bender and bar cutter machine	0	0	3	5	0	0	0	0	0	0
c	Formwork	People get electrocuted	3	4	0	0	0	0	0	0	0	0
d	K-225 (concrete casting)	People get hit by truck	3	5	0	0	0	0	0	0	0	0
e	Concrete vibrating	People slip and fall from higher elevation	3	5	0	0	0	0	0	0	0	0
f	Concrete compacting	People drown	4	5	0	0	0	0	0	0	0	0
4	**Stone Work**											
a	Rip rap	Accidents due to improper material stock placement	3	3	0	0	0	0	0	0	0	0
5	**Backfill**											
a	Backfill	Brake failure	3	5	0	0	0	0	0	0	0	0
b	Soil compaction	Brake failure	3	5	0	0	0	0	0	0	0	0
6	**Finishing Work**											
a	Plaster	People slip and fall from higher elevation	3	4	0	0	0	0	0	0	0	0
b	Painting	People slip and fall from higher elevation	3	4	0	0	0	0	0	0	0	0
7	**Sluice gate**											
a	Frame installation	Crane sling broke and the frame fell on people	3	5	3	5	0	0	0	0	0	0
b	Gate installation	Crane sling broke and the gate fell on people	3	5	0	0	0	0	0	0	0	0
8	**Rubber Weir Installation**											
a	Rubber weir hook and pipe installation	Crane sling broke and the steel plate fell on people	2	5	2	5	0	0	0	0	0	0
b	Pump engine installation on pipe	Machine or equipment failure	4	4	4	4	0	0	0	0	0	0
c	Rubber weir installation	People slip	4	4	0	0	0	0	0	0	0	0

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B. Vulnerability Factor

From the results of the assessment, then the average is calculated for each work item to determine the score based on vulnerability factor.

TABLE V. The Average Result of the Fixed Weir Risk Level Assessment

Work Item	Risk Factor				
	Human Risk	Equipment Risk	Material Risk	Public Risk	Environmental Risk
Soil Excavation	7.24	2.83	0.00	0.90	0.83
Dewatering	8.86	5.14	2.57	1.43	2.29
Concrete Work	5.16	1.72	0.34	1.04	1.00
Stone Work	6.00	0.00	0.00	0.00	0.00
Backfill	7.12	0.71	0.00	0.71	0.71
Finishing Work	6.14	0.00	0.00	0.00	0.00
Sluice Gate	9.45	2.91	0.36	0.00	0.00

TABLE VI. The Average Result of the Rubber Weir Risk Level Assessment

Work Item	Risk Factor				
	Human Risk	Equipment Risk	Material Risk	Public Risk	Environmental Risk
Soil Excavation	7.14	2.83	0.00	0.90	0.83
Dewatering	8.86	5.14	2.57	1.43	2.29
Concrete Work	5.00	1.72	0.34	1.04	1.00
Stone Work	6.00	0.00	0.00	0.00	0.00
Backfill	7.12	0.71	0.00	0.71	0.71
Finishing Work	4.43	0.00	0.00	0.00	0.00
Sluice Gate	7.50	1.14	0.00	0.00	0.00
Rubber Installation	7.14	2.83	0.00	0.90	0.83

C. Exposure Factor

Each work item has a different period of time in its implementation. Given this, a proportion number is being justified for each work item which will then be used as a reference for calculating the final value of the risk factor for each weir.

TABLE VII. Risk Level of Each Factor for Fixed Weir

Work Item	Time Estimation	Proportion	Risk Factor				
			Human Risk	Equipment Risk	Material Risk	Public Risk	Environmental Risk
Soil Excavation	8 weeks	40%	2.90	1.13	0.00	0.36	0.33
Dewatering	1 weeks	5%	0.44	0.26	0.13	0.07	0.11
Concrete Work	4 weeks	20%	1.03	0.34	0.07	0.21	0.20
Stone Work	1 weeks	5%	0.30	0.00	0.00	0.00	0.00
Backfill	2 weeks	10%	0.71	0.07	0.00	0.07	0.07
Finishing Work	2 weeks	10%	0.61	0.00	0.00	0.00	0.00
Sluice Gate	2 weeks	10%	0.95	0.29	0.04	0.00	0.00
AVERAGE PER FACTOR			**6.94**	**2.09**	**0.23**	**0.71**	**0.72**

TABLE VIII. Risk Level of Each Factor for Rubber Weir

Work Item	Time Estimation	Proportion	Risk Factor				
			Human Risk	Equipment Risk	Material Risk	Public Risk	Environmental Risk
Soil Excavation	8 weeks	40%	3.17	1.26	0.00	0.40	0.37
Dewatering	1 weeks	5%	0.49	0.29	0.14	0.08	0.13
Concrete Work	2 weeks	10%	0.56	0.19	0.04	0.12	0.11
Stone Work	1 weeks	5%	0.33	0.00	0.00	0.00	0.00
Backfill	2 weeks	10%	0.79	0.08	0.00	0.08	0.08
Finishing Work	2 weeks	10%	0.49	0.00	0.00	0.00	0.00
Sluice Gate	2 weeks	10%	0.83	0.13	0.00	0.00	0.00
Rubber Weir	2 weeks	10%	3.17	1.26	0.00	0.40	0.37
AVERAGE PER FACTOR			**6.67**	**1.94**	**0.18**	**0.67**	**0.68**

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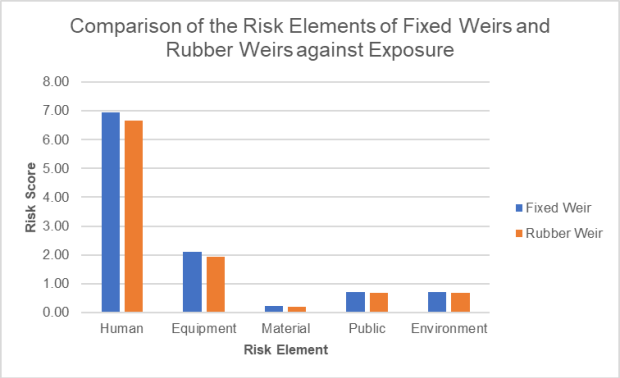

Figure 6. Comparison of Risk Score Against Exposure

D. *Final Score*

Each element of risk has a different proportion. The risk of people certainly has a greater weight than the risk of equipment and materials. Referring to this, a justification is made for each element of risk.

TABLE IX. Risk Score of Fixed Weir

Description	Risk Factor				
	Human Risk	Equipment Risk	Material Risk	Public Risk	Environmental Risk
Average per Factor	6.94	2.09	0.23	0.71	0.72
Proportion	0.40	0.10	0.10	0.20	0.20
Score per Factor	2.78	0.21	0.02	0.14	0.14
Total Score	3.29				
Risk Level	Low Risk				

TABLE X. Risk Score of Rubber Weir

Description	Risk Factor				
	Human Risk	Equipment Risk	Material Risk	Public Risk	Environmental Risk
Average per Factor	6.67	1.94	0.18	0.67	0.68
Proportion	0.40	0.10	0.10	0.20	0.20
Score per Factor	2.67	0.19	0.02	0.13	0.14
Total Score	3.15				
Risk Level	Low Risk				

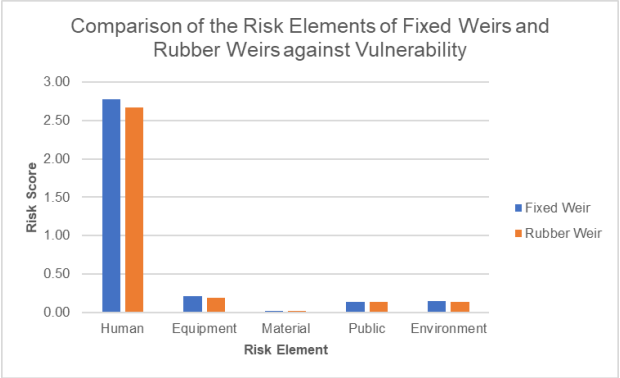

Figure 7. Comparison of Risk Score Against Vulnerability

E. *Determination of Weir Type*

Based on risk level assessment, here is the result of analysis:

TABLE XI. Risk Level Assessment Result

Weir Type	Risk Score
Fixed Weir	3.29
Rubber Weir	3.15

From the result above, the risk score of rubber weir is lower than the fixed weir, therefore the recommended structure in Pedongga Irrigation Area is rubber weir.

V. CONCLUSION

The conclusions are:

1. The elements that need to be considered in the analysis of weir risk factors are the risks of:

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a) Human, in terms od fatality, includes people who died, disabled, hospitalized, and first aid.
b) Equipment, considering how long the delay caused by the related equipment failure.
c) Material, referring on how long it will take to bring in new material.
d) Environment, on its effect on flora and fauna and pollution of air/soil/water/noise.
e) Public facilities, on its influence on surrounding community assets such as roads, power lines, water distribution system, and its effect on traffic flow.

2. The results of rubber weir risk score is 3,15 which is lower than the fixed weir 3,29.
3. From the above results, the weir with the lowest risk level, which is recommended to be built at the study site is the rubber weir.
4. Standards should be set for what elements of risk can potentially exist in a construction, so that there is synergy between one project and another.
5. This study only discussed construction risk factors, thereafter it can also be compared to schedule risks and financial risks that may occur, so that they are more comprehensive.
6. In assessing risk factors, the subjectivity of the Author still dominates, this should be taken into consideration for similar studies.
7. Different project scales must have different risks. Therefore, the results of this study cannot be used as a reference for other locations.

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