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| RESEARCH ARTICLE

Modified Andersen and Modified ICOLD (DOISP-2) Methods of Risk Score for Dams in West Region of Indonesia

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| ABSTRACT
Risk assessment for the dams in West Java Province with a method of Modified Andersen and Modified ICOLD (DOISP-2) have been done; the assessment is part of the activities of Dam Operation Improvement Safety Project-2 (DOISP-2) at Central Project Implementation Unit (CPIU), Ministry of Public Works and Housing. Dams were studied to analyse the risks of the deficiency of the structure due to the load under normal operating conditions, flood conditions, and earthquake conditions. This article summarizes the risk assessment process, assessment results, conclusions and recommendations for both risk index methods. The document also includes an assessment of the risk assessment process and policy recommendations for the operation and maintenance of dams. The results are risk rankings between the two methods give different sequences; this is due to differences in the risk assessment approach of both methods. Modified Andersen focused on structural deficiencies, especially visually, and modification ICOLD Method (DOISP-2) focused on design flaws and risks downstream of the dam. Although both methods have different approaches, both methods can be used in risk analysis of the dam's adjusted purposes of risk index assessment.

| KEYWORDS

Dam, Risk Index, Onsite Inspection, Modified Andersen, DOISP-2 Method (modified ICOLD).

| ARTICLE INFORMATION

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1. Introduction
The construction of a dam, besides having enormous benefits for humans, also holds a very large potential for danger, where if the dam collapses, it can result in a very large disaster in the downstream area. The construction of dams is often followed by the rapid development of communities in the downstream areas, which develop into residential areas, agriculture, industry, commerce and many public facilities; this causes an increase in the level of danger due to dam collapse.

Many dams in Indonesia do not have comprehensive information, such as as-built drawings, behavioural history, and little or no instrumentation records. So, to prioritize maintenance, repair, and evaluation with these conditions, plus limited time and funds, a fast risk analysis method is needed. Among the many methods that can be used for these needs are Andersen modifications and the DOISP-2 method (modified ICOLD).

This paper discusses the analysis of the safety level risk index for 6 dams in West Java Province, including Juanda, Darma, Cipancuh, Malahayu and Setu Patok Dams. Each risk analysis method has a different approach between the Andersen modification and the DOISP-2 method (modification ICOLD). Andersen's modification places less emphasis on the analysis of the risks themselves but more on assessing the visual inspection results, while the DOISP-2 method, apart from assessing based on visual inspection methods, focuses on design flaws and downstream risks. The explanation of the two methods is set forth in this manuscript.

2. Literature Review

The SDA Research and Development Center has carried out studies and evaluations of dam safety by carrying out dam safety inspections, instrument evaluations, the weighting of dam safety levels using the risk index method and analysis of dam stability due to earthquake effects (Najoan & Carlina, 2006, 2007).

In conducting the analysis of the index method risk, use the form for calculating several factors, including:

a. The initial interest level of the dam (*Importance factor* = I_{dam}),
b. Calculation of the relative importance level factor of the dam (*Relative Importance* = *RI*),
c. Weighting with physical parameters in the field and dam safety inspection form,
d. Calculation of the total risk index.

Based on the study/analysis as mention above, in 2012, the SDA Research and Development Centre conducted dam inspections by examining the outer surface of the dam, the body of the dam, instrumentation, pedestals and foundations, reservoirs, landslides and auxiliary buildings. Then, the modified Andersen and modified ICOLD method risk index assessment was carried out as a way of assessing the safety level of the dam. In this method, parameters are needed for analysis, and the results are in the form of weights/values (scores), which are then sorted based on the priority rank (priority rank) of the level of risk. These parameters are based on score tables developed by Andersen G.R. et al. (1999, 2001a & 2001b) and have been modified for Indonesian conditions. Apart from the Andersen method, a simpler risk assessment was also carried out based on the ICOLD modification. This risk assessment is based on the results of dam inspections, design and construction information, monitoring reports, investigation reports and previous inspection reports and discussions with dam O&M staff. Static stability in dams includes slope instability, excessive loads on dams and/or foundations, inadequate filtering and piping through dams and/or foundations, damage to drains or in connection with them, structural damage to geological foundations, and seepage. Overuse leads to reed erosion.

3 Methodology

3.1 Andersen Modification Method

The modified Andersen method is included in the risk index method because it only provides an indication of the level of potential risk due to an embankment dam collapse. The risk is calculated as a deficiency in the actual physical condition of the dam or condition of the dam and weighted according to all levels of importance in the safety of the dam and based on the level of vulnerability and the potential hazard of the dam (Andersen G.R. et al., 2001).

Risk index assessment using the modified Andersen method begins with determining the level of importance of the dam by considering the vulnerability of the dam and potential hazards downstream. After obtaining the importance level of the dam, the next step is to determine the relative importance, which is the result of visually assessing various physical conditions that can cause dam failure using Bayesian procedures, and simplification of criticality analysis based on conditional failure probabilities determined by expert judgment. The results of visual inspection in the field are used to determine the physical condition. This method provides an inspection format to assess physical condition indicators in the field.

The relative importance of physical conditions is combined with the importance of the dam to derive all importance with respect to the entire inventory. The results of the importance determination are then combined with the current physical condition (in simple multiplication) to calculate a risk index for each observed deficiency. For each dam, the risk indices are summed to estimate the overall risk index. Priority can be obtained based on specific physical deficiencies or on the overall risk index.

The equations for calculating the initial interest factor are in the following equation:

$$V = ((I_1+I_2+I_3+I_4)/4) \times ((E_1+E_2)/2) \times ((D_1+D_2)/2)$$
$$I_{dam} = V \times H \quad 1)$$

Descriptions:

V = Total Vulnerability factor,
I_1 = Initial condition factors, the height of the dam,
I_2 = Initial condition factors influence the type of dam,
I_3 = Initial condition factors influence the type of foundation,
I_4 = Initial condition factors, influence reservoir capacity,
E_1 = External factors influence age,
E_2 = External factors influence seismicity,
D_1 = Abundance adequacy factor,

D_2 = Slope stability adequacy factor,
I_{dam} = Initial importance level factor (key determinant),
H = Disaster potential factor

The relative importance factor of the dam is obtained from equation 2 below:

$$RI_j = P[M_i|F] \times P[C_j | M_i] \times I_{dam} \qquad 2)$$

Description:

RI_j = Factor relative importance of physical condition to j,

$P[M_i|F]$ = Conditional probabilities of the failure mode to i,

$P[C_j | M_i]$ = Conditional probabilities on the physical condition to j.

Parameter $P[M_i|F]$ dan $P[C_j | M_i]$ is a very difficult parameter to obtain. This is due to the limited data on dam failures in Indonesia, so a thorough analysis cannot be carried out. In this regard, in assessing the safety of dams in Indonesia, USCOLD 1998 research experience was used.

A dam safety inspection needs to be carried out to determine the actual conditions on the ground. A total of 9 physical conditions in the field must be identified by giving weight according to the checklist, namely:

1. Obstruction in the spillway (CF_1),
2. Reduction of guard height (CF_2),
3. Obstruction in the outlet (CF_3),
4. Erosion of the spillway (CF_4),
5. Protective material on the surface of the dam (CF_5),
6. Reed erosion on the body of the dam (CF_6),
7. Reed erosion on dam foundation (CF_7),
8. Dam body stability (CF_8),
9. Dam body and foundation stability (CF_9).

Total risk index (IR_{tot}), being a factor that describes dam risk, is obtained by combining the weighted field condition (CFi) value with the relative importance factor using equation 3 below:

$$IR_j = RI_j \times (10 - CF_j) / 10$$
$$IR_{tot} = \sum IR_j \qquad 3)$$

Description:
CF_j, field condition weights to j.

Dam Data Collection							
Intrinsic Initial Factor (I)		External Factor (E)		Design Characteristic (D)		Disaster Factor (H)	
associated with the dam	Weight	associated with the dam	Weight	associated with the dam	Weight	associated with the dam	Weight
Height of Dam	I1	Age	E1	Spillway adequacy	D1	Risk Class	H
Dam Type	I2	Seismicity	E2	Mass movement factor of safety	D2		

Foundation Type	13		
Storage Capacity	14		

Key Determinants of Dam Inventory Data

$I_{dam} = V \times H$

$V = ((I1+I2+I3+I4)/4) \times ((E1+E2)/2) \times ((D1+D2)/2)$

Relative Determinants for Physical Conditions

$RIj = P[\, Mi\ I\ F\,] \times P[\, Cj\ \ I\ Mi] \times I_{dam}$

RIj	Relative importance index
P[Mi I F]	Failure Probability
P[Cj I Mi]	the probability of the physical conditions that are the factors causing the failure.
I_{dam}	Main determining factor index

Failure Mode (1)	P [C, M]	Failure Description	P[MIF]
Overoping (1)	0,49	Loss of or inadequacy in spillway capacity (1)	0,3
		Loss of crest elevation (2)	0,1
		Loss of function of outlet works (3)	0,6
Surface Erosion (2)	0,09	Erosion in spillway (4)	0,7
		Protective Material on the surface of the Dam (5)	0,3
Piping (3)	0,32	Piping in embankment (6)	0,7
		Piping in foundation (7)	0,3
Mass movement (4)	0,1	Slide in embankment (8)	0,7
		Slide in foundation and embankment (9)	0,3

Inspection for Key Determinants Index Pre-Rehabilitation Condition (CF)	
Inspection	Weight
Obstruction on spillway	CF_1
Loss of crest elevation	CF_2
Loss of function of outlet works	CF_3
Erosion in spillway	CF_4
Protective Material on the surface of the Dam	CF_5
Piping in embankment	CF_6
Piping in foundation	CF_7
Slide in embankment	CF_8
Slide in foundation and embankment	CF_9

Inspection for Key Determinant Index of Conditions After Rehabilitation (CF)	
Inspection	Weight
Obstruction on spillway	CF_1
Loss of crest elevation	CF_2
Loss of function of outlet works	CF_3
Erosion in spillway	CF_4
Protective Material on the surface of the Dam	CF_5
Piping in embankment	CF_6
Piping in foundation	CF_7
Slide in embankment	CF_8
Slide in foundation and embankment	CF_9

Calculation of the main determinant factor index of Total Conditions Before Rehabilitation

$IR\ T = IRi(10-Cfi)/10$

Calculation of the main determinant factor index of Total Conditions After Rehabilitation

$IR\ T = IRi(10-Cfi)/10$

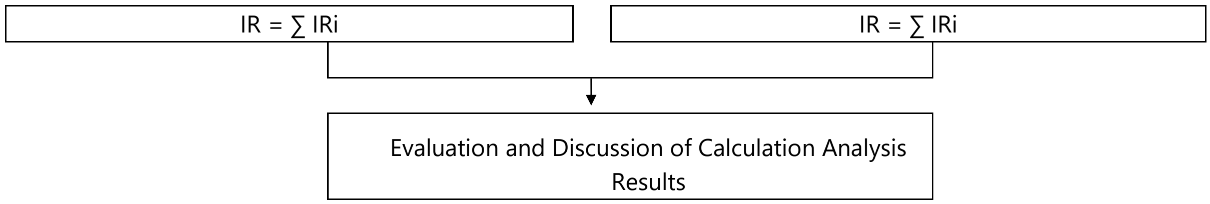

Figure 1. Flowchart of Calculation of Risk Index (Modified Andersen Method)

Determination of priority level of risk Andersen modification method is determined based on the order of the total risk index (IR_{tot}) the biggest.

3.2 Modified ICOLD Method (DOISP-2)

The risk index assessment of the modified ICOLD method (DOISP-2) is similar to the modified Andersen method. At the initial stage, the importance of the dam is calculated first. The parameters used to determine the level of importance of the dam in the DOISP-2 modification method are slightly different from the Andersen modification method, where in the modified ICOLD method (DOISP-2), the dam engineering data needed is only reservoir capacity and dam height, but in the modified ICOLD method (DOISP-2) added parameters for evacuation needs, potential damage downstream, and business risks due to dam collapse.

Once the importance level of the dam is known, the next step is to assess additional factors on the dam related to dam operation and maintenance activities, such as the availability of construction and maintenance data and the availability of instrumentation and inspection processes. The sum of the dam importance factors and additional factors is then added to the factors related to structural deficiencies that can cause dam failure.

The DOISP-2 Risk Score method is part of the results of DOISP Phase 2, including the development of a new, simple tool for Priority Risk-Based Dam Safety for use by dam owners in Indonesia. The development goals of the "Risk Tool" are outlined below:

a. Basically, a decision making tool to identify those dams in a large inventory that need the most attention and then allocate resources accordingly.
b. Provides a better understanding of the main risk contributors in each dam
c. A systematic and reasoned framework for prioritizing and executing resources among dam safety measures
d. Provide a quantifiable measure of risk to assess the urgency of action
e. Means to communicate the dam safety risk situation effectively to decision makers and politicians to influence funding priorities
f. Provide a consistent methodology across the country for regulators to evaluate dam safety.
g. Consistent with standards-based regulatory programs in each province.
h. To achieve this goal, consideration must be given to the diversity of State institutions, policies, regulations and available resources. The dam risk categorization process and the Risk Tool should:
    - Simple, fast and easy to implement
    - Applicable to any type or number of dams
    - Acknowledge that available resources are limited
    - Be flexible to accommodate large differences between owners and known information about each dam
    - Avoid unnecessary subjectivity and bias
    - Be transparent, defensible and reproducible

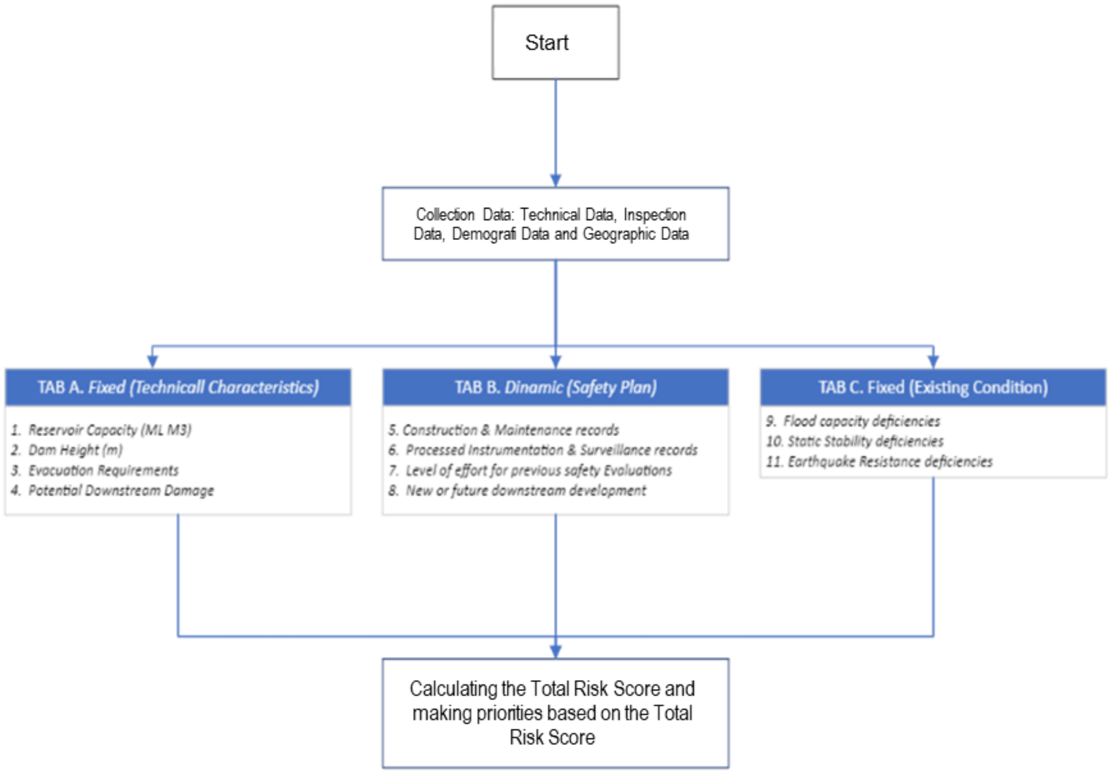

Figure 2 Flowchart of Risk Index Calculation (Modified ICOLD) DOISP-2 Method

Table 1 Risk Index, for Modified ICOLD Method (DOISP-2)

Risk Indexes Range, Risk Class and Summation for DOISP-2 Method

S.N.	*Risk Class* / *Risk Index*	*Extreme*	*High*	*Moderate*	*Low*	
1	*Reservoir Capacity (ML m3)*	***(6)***	***(4)***	***(2)***	***0***	*Tab A. Fixed (Technical Characteristics)*
2	*Dam Height (m)*	***(6)***	***4***	***(2)***	***0***	
3	*Evacuation Requirements*	***(12)***	***(8)***	***4***	***0***	
4	*Potential Downstream Damage*	***(18)***	***12***	***(6)***	***0***	
5	*Construction & Maintenance records*	***(3)***	***(2)***	***(1)***	***0***	*Tab B. Dynamic (Safety Plan)*
6	*Processed Instrumentation & Surveillance records*	***(3)***	***(2)***	***(1)***	***0***	
7	*Level of effort for previous safety Evaluations*	***(3)***	***(2)***	***(1)***	***0***	
8	*New or future downstream development*	***(3)***	***(2)***	***(1)***	***0***	
9	*Flood capacity deficiencies*	***(6)***	***(4)***	***(2)***	***0***	*Tab C. Fixed (Existing Conditions)*
10	*Static stability deficiencies*	***18***	***(12)***	***(6)***	***0***	
11	*Earthquake resistance deficiencies*	***(12)***	***(8)***	***(4)***	***0***	
Total Score						

Risk Range & Class	*76 to 90 (Extreme)*	*46 to 75 (High)*	*16 to 45 (Moderate)*	*0 to 15 (Low)*

Risk Score Summation

Tab A	*Technical Characteristics*	*0 to 42*
Tab B	*Safety Plan*	*0 to 12*
Tab C	*Existing Conditions*	*0 to 36*
	Total	

The following definitions are included here for easy reference when conducting risk assessments:

a) Abutment Outflanking - During flooding, flow over the boundary of the reservoir crosses the boundary of the dam structure, possibly bypassing the abutments.
b) As Low as Reasonably Practical (ALARP) - The risk has been reduced to as low as possible. This test for reasonableness reflects society's aversion to incidents that have the potential to cause loss of life but recognizes that there is a diminishing advantage. ALARP is defined as the point at which additional risk reduction is not possible without a disproportionate investment in the gains made.
c) Concrete Core Wall - Early 20th century dam building design when the concrete wall served as the core with an earthen embankment shell around it
d) Dam Element - a subject dam feature that has the potential to fail for one of the reasons indicated by the element failure mode (i.e., earth dam, unlined spillway, drain works, etc.).
e) Dam Risk Profile - a collection of Elements and an individual dam LLP worksheet. The Dam Risk Profile is an Excel workbook.
f) Failure Mode - a method (i.e., piping for earthen dams, earthquake for concrete dams, etc.) in which the Dam Elements can be damaged, resulting in an uncontrolled release of the reservoir.
g) Failure Probability (F) - User rated value representing the probability that a particular failure mode will cause a failure of the Dam Element. The F value is illustrated as 1 in 100, 1 x 10-2 or 0.01, for example.
h) Life Loss Potential (LLP) - the number of lives potentially lost due to Dam Element failure. The LLP value is equal to the estimated population at risk multiplied by the dependent distance from the dam. Sometimes referred to as "Potential Loss of Life".
i) Maximum Design Earthquake (MDE) - An extreme design earthquake where the dam can cause damage but not a catastrophic release from the reservoir. The return period can range from 1 in 5,000 to 1 in 100,000 or can be taken as a deterministic maximum credible earthquake (MCE).
j) Operating Basis Earthquake (OBE) - An unusual design earthquake is expected over the life of the structure with a return period of approximately 1 in 500 years that does not disrupt reservoir operations.
k) Population at Risk (PAR) - estimate of the number of people in the inundation zone from dam failure. The values are based on the assumptions of people inside residences, cars, factories, camping areas, etc. Which is in the puddle zone where they will get their feet wet.
l) Risk Portfolio - a collection of User created Dam Risk Profiles. Risk Portfolio is a Microsoft Excel Workbook that manages the Dam Risk Profile workbook.
m) Risk Tools - A combination of Excel spreadsheets (riskportfolio.xls and template.xls) which together form a dam risk priority program.
n) Threshold Failure Flood (TFF) - Flood where there is sufficient dam runoff to cause dam failure due to reverse erosion, landslide, or collapse.
o) Workbook - A workbook is an Excel file that contains one or more worksheets, user forms, and macro code. The Risk Portfolio application is an Excel workbook, as is each Dam Risk Profile.
p) Worksheet - A worksheet is a single page in a workbook that contains data arranged in rows and columns.

Deficiency assessment related to the problem of static stability in the dam is checking design data regarding the availability of filters, foundation geology, and conduits in anticipating cane erosion problems and embankment design in anticipating slope stability problems. In addition to checking design data, field inspections are also carried out to assess seepage conditions, cracks, embankment material conditions, and movement symptoms. Deficiency assessment related to flood capacity is done by checking spillway capacity, inspection of spillway structural damage and electro-mechanical damage related to spillway adequacy.

Deficiency assessment of earthquake resistance is by checking design data to determine whether the design meets the regulations for new seismic loads, high availability of guards, whether there is a potential for liquefaction in the foundation layer or embankment, and checking the slope of the embankment slope and the edge of the reservoir.

After all the factors above are added up, the next step is to classify based on the sum of these values. For dams that have a total value between 0–15, included in the "Low" category, 16–45 are included in the "Moderate" category, 46–75 are included in the "High" category, and more than 75 are included in the "Extreme" category.

4. Experimental Results

Field inspection of 6 dams in the West Region in 2021 found several physical deficiencies indicating problems with reed erosion, slope stability, deformation and erosion. Field photos shown in this paper are only a small part of the photos taken at each dam. In this paper, photos indicating physical deficiencies are grouped for similar problems, as follows:

1) Piping

Of the 6 dams studied (Merancang, Jatiluhur, Gintung, Cipancuh, Malahayu and Setu Patok), there were 2 dams that visually showed signs of piping, namely the Cipancuh Dam and Malahayu Dam. During the inspection at the Cipancuh Dam, along 30 m, on the right side of the slope/toe of the dam, seepage was found with a cloudy color. Installation of concrete pile cap is complete, 40 cm thick, 2.4 m wide, and 63.20 m total length. Although the embankment in the area is stable, the problem of seepage through the body and foundation of the dam has not been completely resolved. Meanwhile, at the Malahayu Dam, seepage occurred on the slopes of the V-Notch channel, concrete conduit and the connection of the Stoplog Gate Valve and Needle Valve.

As previously explained, if the reed erosion is too large, it will be difficult to control it, especially in this case, the uncontrolled seepage is close to the operating building structure; damage to the operating building structure will be difficult to avoid if the reed erosion has already enlarged.

2) Mass movement stability

Mass movement problems during field inspections were encountered at the Gintung Dam, Cipancuh Dam, and Malahayu Dam. At the Gintung Dam, mass movement problems are found on the upstream and downstream slopes (**Figure 3**). This is due to the poor arrangement of the Riprap rocks, so the Riprap rocks found on the upstream and downstream slopes easily shift. Field inspection of the Cipancuh Dam in February 2009 found landslides and collapses along 30 m upstream and 50 m downstream, subsidence (**Figure 4**), and on the downstream slopes, there were deflections (**Figure 5**). During field inspections at the Malahayu Dam, the problems encountered were landslides on the cliff of the left pedestal hill (**Figure 6**), and on the upstream slope, there was a hole because the Riprap rock was taken by fishermen and used as a boat rest (**Figure 7**).

Figure 3 The upstream and downstream slopes of the Gintung Dam have decreased

Figure 4 shows the condition of the top of the Cipancuh dam, which experienced an avalanche.

Figure 5 The downstream slope of the Cipancuh Dam, which is experiencing deflection

Figure 6 Landslide on the cliff of the left pedestal of the Malahayu Dam

Figure 7 The Upper Slope has a hole because the rip-rap rock was taken by fishermen (Malahayu Dam).

If the avalanche material is not immediately cleaned up, it is feared that when large runoff discharges, the water flow in the chute passes over the top of the chute channel wall and erodes the cliff behind the wall, thereby increasing the problem of slope stability on the chute behind the chute channel wall. Handling the problem of slope stability, in this case, can use shotcretes.

1) Deformation

The deformation at the top of the dam was most visible at the Cipancuh Dam, where on January 10, 2010, the top of the dam cracked and sank 50 cm deep, 30 m long, while on January 29 2010 (Figure 2) the decline continued quickly, the crest and slope fell/subsided, and the downstream slope has collapsed. Symptoms of deformation in the form of cracks at the top can also be seen in the Merang Dam, but the symptoms of deformation in the dam are not so significant that they affect the safety of the dam; the cracks are generally very small, and their position is where the body of the embankment meets the abutment or spillway wall.

2) Erosion

Indications of a deficiency due to erosion were found in the Malahayu Dam and Merancang Dam. Most of the erosion symptoms were seen in the overflow channel, only in the erosion channel dam on the downstream slope. It was indicated that the cause was the embankment material which was in poor condition and was not protected by thick grass, so it was easily eroded by rainwater.

3) Assessment of Risk Index

Summary of the results of the dam safety evaluation using the two risk index methods, as can be seen in **Table 1**, T**able 2** and **Table 3**.

Table 1 Condition of field inspection results

No	Dams	Issues
1	Merancang	The absence of instrumentation equipment resulted in the consultant not being able to make observations, and instrument data was also not available, so a seepage study had not been carried out, but from the results of the discussion in the Final Report, it was suggested that the consultant install temporary instrumentation equipment to be able to observe the seepage that occurs.
2	Jatiluhur	The asphalt section at the top of the dam has hairline cracks.
3	Gintung	There is a hole on the downstream slope of the dam, and on the upstream slope, there is a rip-rap which is overgrown with grass and uneven; the physical condition of the instrument is not well maintained, there are cracks in the spillway wall, the V-Notch and Toe Drain are not maintained, the placement of the V-Notch is not suitable for measure seepage.
4	Cipancuh	The safety of the dam from the hydraulics aspect is not safe; there are cracks in the intake concrete, Cipancuh intake, Kiarakurung intake, spillway and foundation.
5	Malahayu	There was a leak on the slope of the V-Notch canal caused by piles of garbage in the canal, there was an avalanche on the cliff of the pedestal hill, and there was a hole on the upstream slope due to rip-rap rocks that were not neatly arranged and taken by local residents.
6	Setu Patok	There is a need for pavement at the top of the dam, regular grass cleaning to prevent avalanches, leveling of the downstream slopes of the dam, especially in areas that are inflated and regular observations.

Table 2 Summary of dam safety evaluation modified ICOLD method

No	Dams	*Score* ICOLD	ICOLD Priority Order
1	Merancang	50.00	6.00
2	Jatiluhur	54.50	3.00
3	Gintung	55.50	2.00
4	Cipancuh	75.50	1.00
5	Malahayu	50.00	5.00
6	Setu Patok	53.50	4.00

Table 3 Summary of modified Andersen Dam safety evaluation

No	Dams	*Score* Andersen IR_{tot}	Priority
1	Merancang	161.64	4
2	Jatiluhur	107.21	6
3	Gintung	133.47	5

4	Cipancuh	326.22	3
5	Malahayu	358.06	2
6	Setu Patok	534.44	1

Based on the priority order of risk index assessment, the modified ICOLD method can be arranged as follows:

1. Cipancuh Dam
2. Gintung Dam
3. Jatiluhur Dam
4. Setu Patok Dam
5. Malahayu Dam
6. Merancang Dam

Meanwhile, based on the risk index assessment of the modified Andersen method, the order of priority is as follows:

1. Setu Patok Dam
2. Malahayu Dam
3. Cipancuh Dam
4. Merancang Dam
5. Gintung Dam
6. Jatiluhur Dam

There are several differences in the results shown from the two risk index methods; this occurs because:

1) Andersen's assessment is highly dependent on the physical condition of the dam as a result of visual inspection in the field. Detailed assessment of design information, construction processes and geological conditions does not have a major influence on the assessment.
2) Apart from being influenced by the results of field inspections, the ICOLD assessment is also heavily influenced by the availability of complete information regarding the design, construction process, and geological conditions, as well as increased safety risks downstream of the dam.
3) The result of Andersen's assessment of the physical condition of the building is the sum of the deficiencies that occur in the field and by, including the probability factor for each event that occurs.
4) The results of the ICOLD assessment of physical conditions are based on the most critical events for each loading condition.

The most visible difference is the assessment of the Cipancuh Dam and Setu Patok Dam. This is because the ICOLD Modification (DOISP-2) assessment focuses more on the increased risk downstream of the dam (dam importance level) in the event of a structural failure. As is known from the technical data of the dam, the Cipancuh Dam has a height of h = 9.5 m while it has a reservoir of v = $8x10^6$ m3 and has a population of more than 100,000 downstream. The Cipancuh dam embankment elevation is +31.50 m, while based on the calculation of the $Q1000^{th}$ guard height, the dam embankment elevation is at El. 31.960 m, so it is necessary to add a guard as high as 50 cm to an elevation of 32.00 msl. Thus, although visually, the physical damage that occurs in the field is not too serious, nevertheless, the risk due to structural failure downstream of the dam has the greatest impact.

Setu Patok Dam, based on the Andersen method of assessing the risk of structural damage due to seepage, is one of the factors that greatly affect the safety level of the dam. On the other hand, the Modified ICOLD Method (DOISP-2) has a slightly different assessment because the impact caused by damage to the dam is not too large. This is because the height of the Setu Patok Dam is h = 16.2 m, with a storage volume of v = $11x10^6m^3$ and a population of 9,000 downstream.

5. Conclusion

By using Andersen's modified risk index, it is known that 1 dam is included in the "Unsatisfactory" category, namely the Setu Patok Dam, 4 (four) dams are included in the "Enough" category, namely the Cipancuh Dam, and Malahayu Dam, and 3 (three) dams are included in the "Satisfactory" category, namely the Merancang Dam, the Gintung Dam, and the Jatiluhur Dam. By using the Modified ICOLD risk index (DOISP-2), it is known that the 3 dams studied are classified as high risk. Several dams, such as the Malahayu Dam and Merancang Dam, are almost impossible to reduce the risk class to Moderate given the high level of importance of the dams, so even though there is rehabilitation and an increase in OP, it is very difficult to reduce the risk class to Moderate. The results of the modified Andersen and Modified ICOLD (DOISP-2) risk index methods provide a different order, even though the two risk index methods are still relevant for use in assessing the dam risk index.

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