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IMPROVING MODIFIED ICOLD METHOD WITH LOSS OF LIFE INDEX FOR DAM SAFETY RISK ASSESSMENT

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Abstract — This research paper explains the results of the prediction analysis of the number of lives lost in the event of a catastrophic dam collapse in Indonesia as a further consideration in assessing the level of risk of dam safety. The proposed procedure is to make a new prediction index of the number of lives lost (LoL) as the development of a risk index of evacuation requirements from Risk Affected Populations (PENRIS), on the Modified ICOLD Method which is always used in Indonesia. This study, resulting in a regression equation as a correlation between PENRIS and LoL, takes its source from various catastrophic dam collapse events that have occurred in the world including Indonesia. Furthermore the regression equation is integrated with the standard determination of the level of risk of dam safety used in Indonesia and the world, for conditions with and without a disaster early warning system based on the Graham formula (2010). Further analysis of the Emergency Action Plan (EAP or RTD) of 16 dams in Indonesia as a sample, gives an indication that the implementation of an early warning system will reduce the amount of LoL by almost 100% if implemented according to design. This research, with its focus on developing a prediction index for the number of LoL, proves that in Indonesia, where there are still many dams even though they already have RTDs, and have not conducted a disaster-based space arrangement based on predicted LoL numbers, the reduction in the value of dam security risks can only be optimal in the range of 50 % of the total dam studied.

***Keywords* :** Dam, Failure, Loss of Life, Improving, Index and ICOLD

1.0 INTRODUCTION

Indonesia is a country prone to earthquake disasters because geographically, it is located in a series of pacific volcanic mountain ranges, where the potential for tectonic plates to change, namely the Pacific Plate, the Eurasian Plate and the Australian Indian Plate, is always there. On the one hand, as a developing country, the need for public activity space makes people ignore disaster risk by living in disaster risk areas, namely in most of the downstream around 257 dams in Indonesia, most of which are old dams. On the other hand, the existence of a government program that will build 65 dams starting in 2014 - 2019 in order to support water security, will further emphasize that in addition to providing more benefits it also automatically saves more potential disasters. The International Committee on Large Dams (ICOLD), requires that each dam must have an Emergency Action Plan (EAP), which in Indonesia is also a condition for dam operation. The EAP studies that have been made, refer to the Guidelines for the Determination of Dam Hazard Classification in Indonesia in 1998, only to Population at Risk (PAR or PENRIS). The fact that occurs, in the event of a catastrophic dam failure is almost always there LoL with an amount that was never estimated before. Prediction of the number of LoL in a measured amount will give more suggestions to relevant stakeholders to be able to increase disaster preparedness in many forms, including increasing the frequency of disaster response socialization activities, preparing disaster-based spatial planning, etc. all of which aim at efforts to reduce the risk of fatalities such as in the event of the collapse of the Situ Gintung dam in 2009, it did not happen again.

2.0 METHODOLOGY

The research methodology begins with the development of the framework of the 3 pillars of the conception of dam safety in Indonesia, it is proposed to add 1 more pillar, namely the concept of handling the risk of loss of life as shown in Figure 1 as follows:

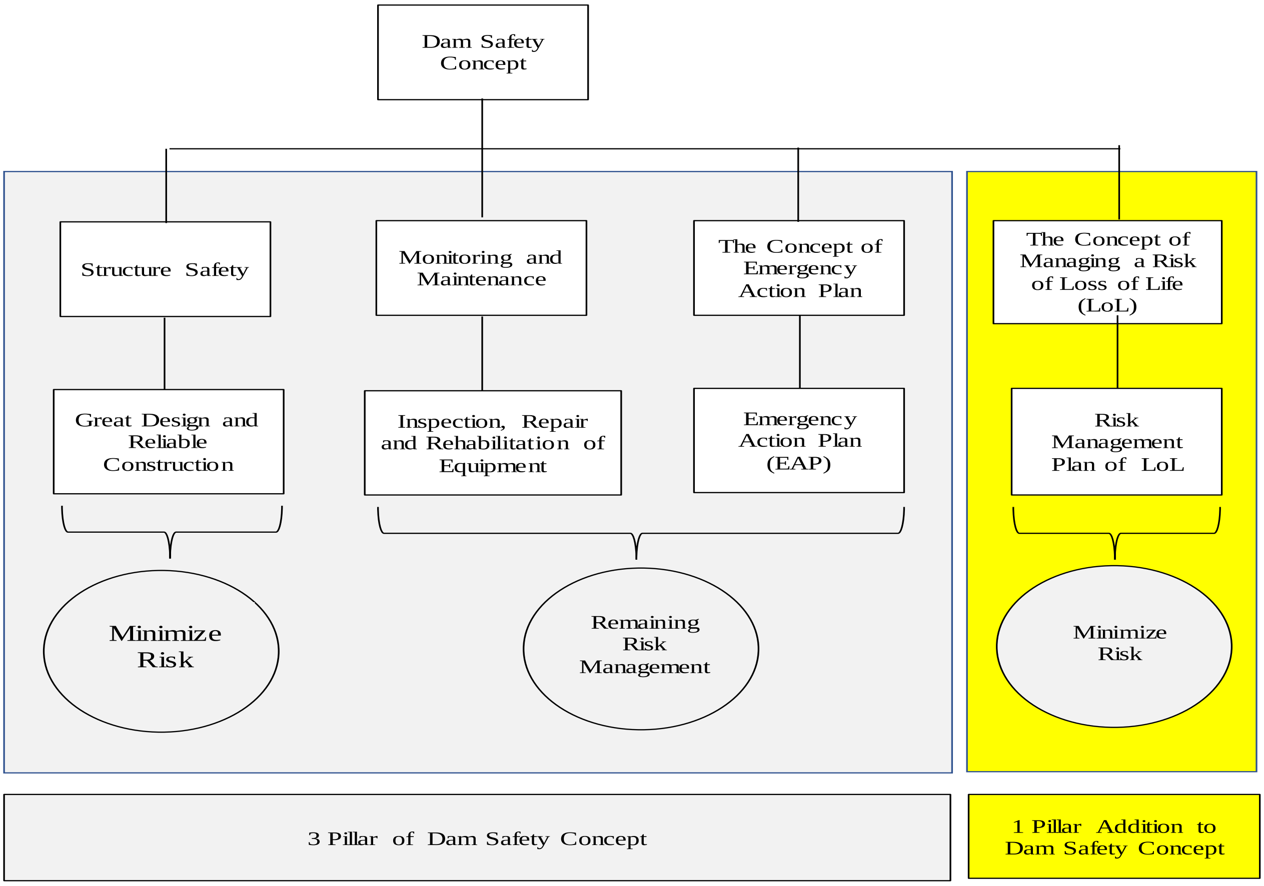

Figure 1. Development of the 3 Dams in Safety Pillar Concept

The concept of adding a fourth pillar to the concept of dam safety, shown in Figure 2 as follows:

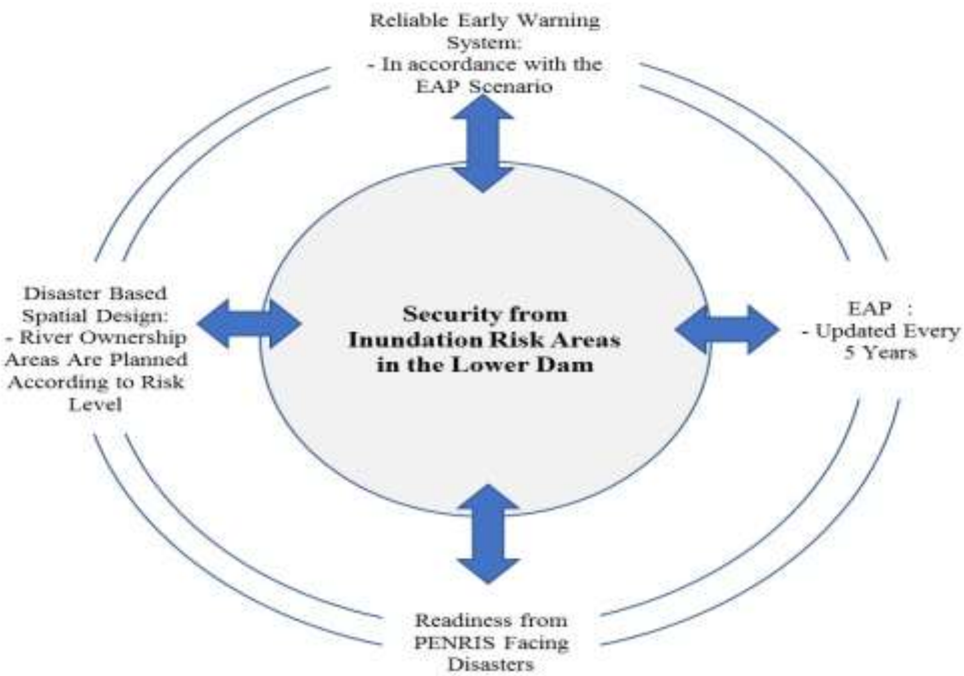

Figure 2. Development of the 4th Pillar of Dam Safety Concept

The fourth pillar begins with a study of EAP products that are updated every 5 years, becoming a reference for the initial steps of applying the concept. PENRIS readiness in the face of disasters depends on the design of the accuracy and reliability of the early warning system by synchronizing the determination of risk levels based on ICOLD [11], prediction of the number of LoL from the regression equation of the event history of the event of a dam collapse in the world and the PENRIS response index from Graham (2010) for various level of understanding of disaster. Next is a long-term effort to prepare a disaster-based spatial plan that will reduce the risk of loss of PENRIS life to the maximum extent possible where each dam has a different level of risk, expressed as LoL index risk..

2.1 MODELING PREDICTION OF LOSS OF LIFE

The risk of loss of life on PENRIS depends on the readiness of PENRIS to face the catastrophic collapse of the dam that can occur at any time [3]. Approach to the prediction of loss of life is carried out by making a regression equation for 38 dam events in the world [14], namely, Vega de Terra Dam in Spain, in 1959 until the last Situ Gintung Dam in Indonesia, in 2009 and applied as a LoL prediction of 16 dams in Indonesia that The EAP has been made, divided into conditions the number of PENRIS that can be seen in Figures 3 and 4 as follows:

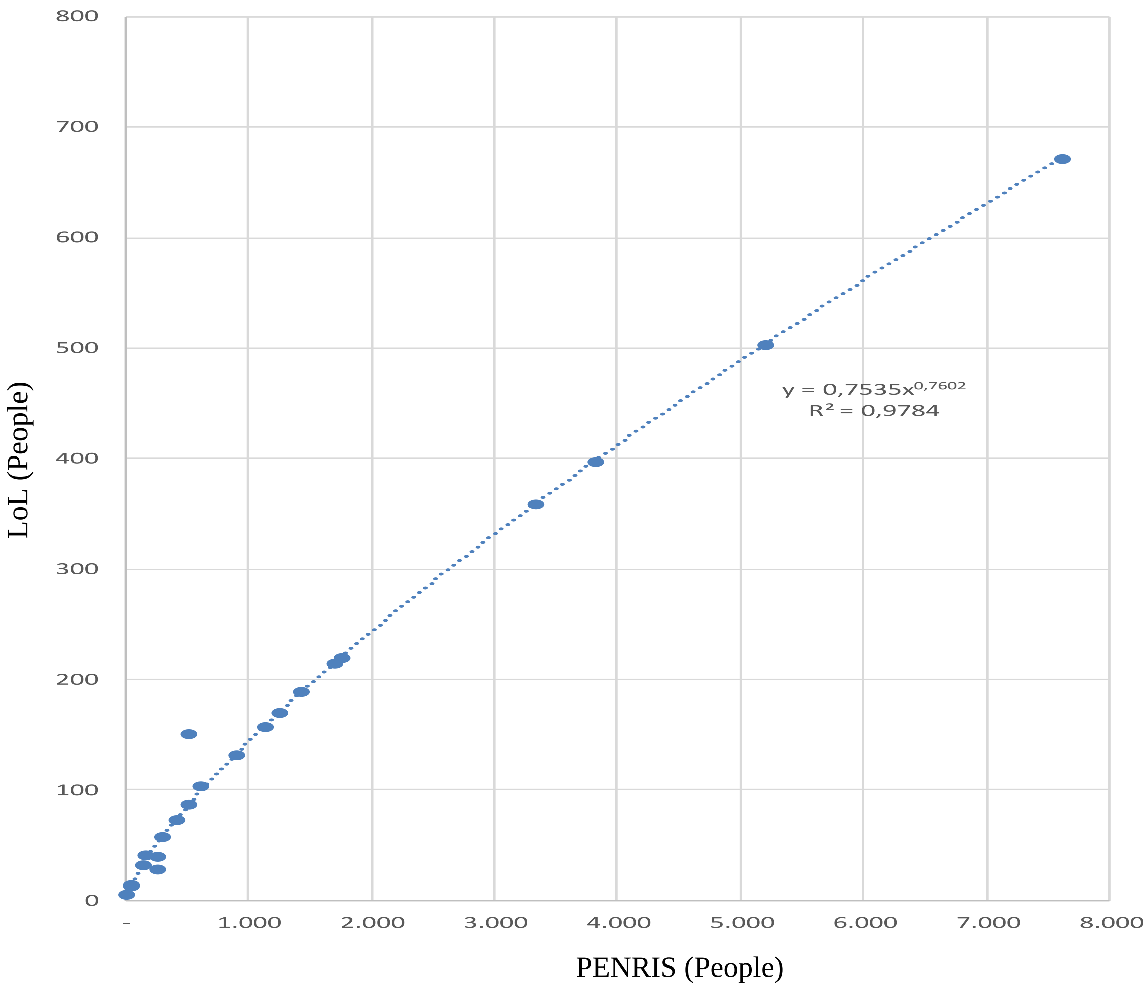

Figure 3 Regression Equation of LoL vs PENRIS (PENRIS < 10.000 people)

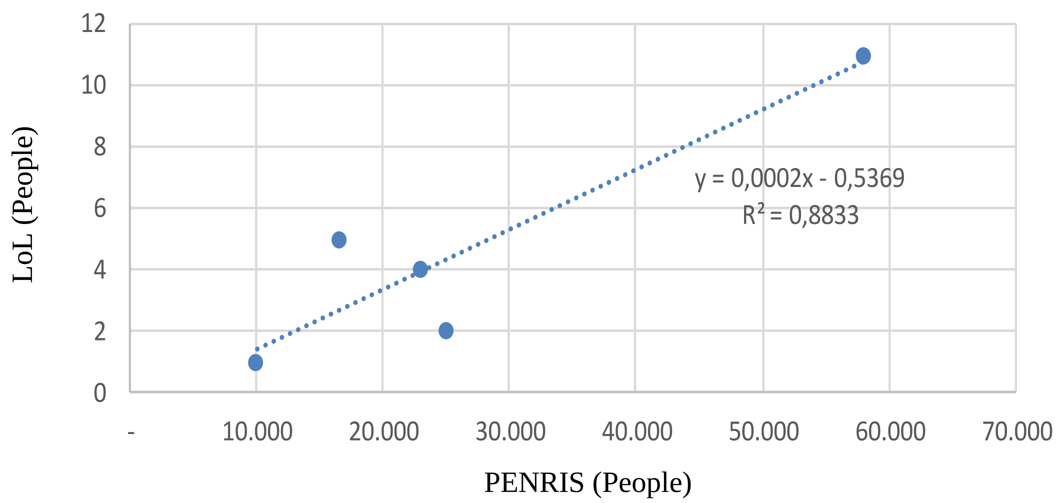

Figure 4. Regression Equation of LoL vs PENRIS (PENRIS >10.000 people)

Prediction of the number of LoL, with PENRIS > 10,000 people is far less than PENRIS <10,000 people. Under these conditions, it can be assumed that the regression equation, hereinafter referred to as LoL 2019 Equation as follows:

- PENRIS without Early Warning System : LoL = 0,7535 (PENRIS) ^{0,76}
- PENRIS with Early Warning System : LoL = 0,0002 (PENRIS)

While PENRIS's response to disaster, measured through an index from Graham (2010), can be seen in Table 1 as follows:

Table 1. PENRIS Vulnerability Levels to Flood Category

Flood Category	**Warning Time (Minutes)**	**Level Respons of Flood**	**Level Severity PENRIS become LoL**	
			Recommended	**Suggestion Interval**
	No Warning	Not Applied	0,75	0,30 – 1,00
	15 -60	Not Clear	The amount of PENRIS in the reservoir area is directly determined without using the vulnerability value	
High	> 60	Estimate		
		Clear		
Moderate	No Warning	Not Applied	0,15	0,03 – 0,35
	15 -60	Not Clear	0,04	0,01 – 0,08
	> 60	Estimate	0,02	0,0005 – 0,04
		Clear	0,03	0,005 – 0,06
Low	No Warning	Not Applied	0,01	0,002 – 0,02
	15 -60	Not Clear	0,007	0,0 – 0,015
		Right	0,002	0,0 – 0,004
	> 60	Estimate	0,0003	0,0 – 0,0006
		Clear	0,0002	0,0 – 0,0004

Source : Lee, Graham [13,16]

LoL 2019 equation is tested against the suggestion interval from Graham [8] where the results will indicate whether for conditions in Indonesia, the recommended interval is appropriate or needs to change because the downstream conditions of dams in Indonesia are not the same as in the location where the Graham formula was made in Europe and the United States.

2.2 DETERMINING HAZARD CLASSIFICATION

Determination of the index refers to the classification of potential disasters from ICOLD [11], where the amount of flowrate, with a parameter $H^2(V)^{1/2}$ indicating water damage consists of 2 factors, namely inundation height (H) and magnitude of flow velocity (V), can be seen in Table 2 as follows:

Table 2. Potential of Hazard Classification

Component $H^2 (V)^{1/2}$	**Potential of Hazard Classification**		
	Low - (I) $H^2 (V)^{1/2} < 20$	**Moderate - (II) $20 < H^2 (V)^{1/2} < 100$**	**High - (III) $H^2 (V)^{1/2} \geq 100$**
Life Safety Risk (PENRIS become LoL)	≈ 0	< 10	$\geq$ 10
Risk of Economy	Low	Moderate	High or Extreme
Risk of Socio-Economic Disruption	Low	High	Extreme

Source : ICOLD [11]

For field correction, the inundation map used from the EAP design was developed into a hazard inundation risk map using the Semi-Quantitative Method and Raster Method [2,5], which are not discussed more detail in this paper.

2.3 IMPROVING RISK INDEX

Determination of Risk Index is based on short-term program follow-up (early warning system), and long-term (disaster-based spatial planning), which has been carried out on dams in Indonesia, where the implementation will determine the level of anticipation of the risk of the amount of LoL in the event of a disaster .

The development of LoL prediction index prediction is directly related to the index that will be developed on the risk rating parameters of the Modified ICOLD Method, which is the evacuation requirements with the highest point value 12 for PENRIS > 250,000 people, into the extreme category.

If efforts to reduce the LoL factor can be accommodated in a measurable form and in the downstream there is a disaster-based spatial design, along with an early warning system, then the recommended extreme risk level can be reduced by 12 digits, into a low or moderate category. Reference recommendations for reducing the risk of loss of life index can be seen in Table 3 as follows:

Table 3. Recommendations for Reducing LoL Risk Value in the Modified ICOLD Method

No	Benchmark Reference	Risk Reduction	Number of Parameter PENRIS			
			> 250.000 (Extreme)	10.000 -250.000 (High)	1 – 10.000 (Moderate)	0 (Low)
1	Long and Short Term Efforts Implemented	100 %	12	8	4	0
2	Short Term Efforts Implemented	50 %	6	4	2	0
3	Long and Short Term Efforts Not Implemented	0%	0	0	0	0

3.0 RESULT AND DISCUSSION

Figures 3 and 4 represent the relationship between PENRIS and LoL which produces a regression equation for estimating the number of LoL in dams in Indonesia that still stands intact because no disaster has occurred. In the process, there will never be an exact value for the number of LoL, but it can be predicted at intervals based on research from the history of the dam collapse events that have occurred. The closest village to the dam will receive a higher risk than villages that are further away. The higher of PENRIS response to early warning, the lower the LoL risk so that the dam safety risk value can be lowered. This can be discussed as an effort to reduce the safety risk value of a dam

3.1 PENRIS RESPONSE, HAZARD CLASSIFICATION AND EARLY WARNING SYSTEM

Because the data of dams that have collapsed in Indonesia in the official publications [12]. are only a few, namely 2 events namely Sempor Dam (1965) and Situ Gintung Dam (2011), if it will be applied to dams in Indonesia that already have EAPs [15], calculations based on Table 3.1 are used. for conditions approaching, that is, without an early warning and with an early warning where the level of PENRIS understanding of early warning is described as follows:

1. Risk Level : ICOLD (2018) dan Balai Keamanan Bendungan (1998)
2. Prediction of LoL : LoL Equation 2019 and Interval Respons PENRIS using Graham (2010) formula
3. Level of Understanding of Floods : Not Apply (Without Early Warning System) and > 60 minutes – Clearly (Early Warning System)

An overview of predicted LoL with and without early warning can be seen in Tables 4 and 5 below:

Table 4. Calculation of LoL Prediction (Without Early Warning System)

Condition : PENRIS are Not Ready for Disasters
Level of Understanding of Floods : Not Apply

No	Name of Dam	Total PENRIS (People)	Nearest Village: Variation Distance Village to Dam (km)	Nearest Village: Name of Village	Nearest Village: PENRIS (People)	Karakteristik Banjir: Variation Warning Time (Hour)	Karakteristik Banjir: Warning Time (Hour)	Karakteristik Banjir: Highest Number V (m/s)	Karakteristik Banjir: Highest Number H (m)	Karakteristik Banjir: Highest Number Q (m3/s)	Low Tide (Hour)	$DV = H^2 * V^{0.5}$	ICOLD (2018): Risk Interval	ICOLD (2018): Risk Level	Indonesia: House	Indonesia: Child	Indonesia: Mature	Determine Risk Level: Remaining Villages (ICOLD, 2018)	Determine Risk Level: Remaining Villages (Indonesia)	LoL Equation for Remaining Villages (Jiwa)	PENRIS of Remaining Village (People)	Predict of LoL Remaining Villages (People)	Graham (2010): Interval Respons PENRIS of Remaining Villages Min	Graham (2010): Interval Respons PENRIS of Remaining Villages Max	Graham (2010): Interval Respons PENRIS of Nearest Village Min	Graham (2010): Interval Respons PENRIS of Nearest Village Max	Graham (2010): Status of LoL Data Remaining Villages	Graham (2010): Status of LoL Data Nearest Villages	Developing for Indonesia: Equation of LoL Nearest Villages (Min)	Developing for Indonesia: Correction Interval for Nearest Villages (Min)
1	Wadaslintang	447.804	3,00 - 17,60	Rahayu dan > 50 Desa	121.449	0,43 - 0,83	< 1,00	12,60	5,00	7.487,09	8,50	89	20 < DV < 100	Moderate	High	High	High	Moderate	Tinggi	5.511	326.355	11.681	9.791	114.224	36.435	121.449	IN	OUT	5.511	IN
2	Penjalin	38.314	0,10 - 1,14	Keseran dan Kr. Nangka	7.611	0,50 - 0,75	< 1,00	2,21	4,37	2.815,00	144,00	28	20 < DV < 100	Moderate	High	High	High	Moderate	Tinggi	671	30.703	1.938	921	10.746	2.283	7.611	IN	OUT	671	IN
3	Cengklik	9.118	0,10 - 1,70	Ngesrep - Ngargorejo	469	0,50 - 0,85	< 1,00	0,90	6,50	798,00	13,90	40	20 < DV < 100	Moderate	High	High	High	Moderate	Tinggi	81	8.649	740	259	3.027	141	469	IN	OUT	81	IN
4	Simo	420	0,50 - 4,20	Suru dan 7 Desa	420	0,1 - 0,70	< 1,00	0,80	7,80	135,98	30,00	54	20 < DV < 100	Moderate	High	High	High	Moderate	Tinggi	74	-	-	-	-	126	420	IN	OUT	74	IN
5	Sanggeh	3.805	0,15 - 5,00	Tambirejo dan 4 Desa	3.768	0,50 - 1,00	< 1,00	2,79	2,95	374,23	64,80	15	DV ≤ 20	Low	High	High	High	Low	Tinggi	393	37	12	1	13	1.130	3.768	IN	OUT	393	IN
6	Gondang	67.845	0,15 - 5,52	Gondang Lor	22.202	0,15 - 0,99	< 1,00	1,36	3,00	4.768,00	72,00	10	DV ≤ 20	Low	High	High	High	Low	Tinggi	1.515	45.643	2.619	1.369	15.975	6.661	22.202	IN	OUT	1.515	IN
7	Krisak	16.204	0,50 - 4,20	Singodutan	5.205	0,07 - 0,99	< 1,00	2,08	2,63	2.089,00	9,00	10	DV ≤ 20	Low	High	High	High	Low	Tinggi	503	10.999	888	330	3.850	1.562	5.205	IN	OUT	503	IN
8	Cipancuh	142.061	0,25 - 2,25	Situraja dan Gantar	1.758	0,15	< 1,00	1,68	2,08	3.600,00	72,00	5,6	DV ≤ 20	Low	Moderate	High	High	Low	Tinggi	220	140.303	6.150	4.209	49.106	527	1.758	IN	OUT	220	IN
9	Greneng	21.807	1,20 - 5,20	Tunjungan + 2 Desa	357	0,25 - 0,93	< 1,00	3,10	4,00	1.070,70	14,20	28	DV ≤ 20	Low	High	High	High	Low	Tinggi	66	21.450	1.476	644	7.508	107	357	IN	OUT	66	IN
10	Tempuran	14.297	0,6 - 1,92	Tempuran dan 4 Desa	3.083	0,3 - 0,95	< 1,00	1,10	2,90	893,30	10,00	9	DV ≤ 20	Low	High	High	High	Low	Tinggi	338	11.214	901	336	3.925	925	3.083	IN	OUT	338	IN
11	Way Jepara	13.882	3,83	Sumberrejo	1.622	3,5	> 1,00	2,18	1,68	895,00	24,00	4	DV ≤ 20	Low	High	High	High	Low	Rendah	0	12.260	2	-	5	-	1	IN	IN	0	IN
12	Batujai - Pengga	104.065	0,5 - 3,60	Batujai dan Penunjak	9.828	0,37 - 0,80	< 1,00	2,25	2,25	3.610,00	17,67	8	DV ≤ 20	Low	High	High	High	Low	Tinggi	815	94.237	4.545	2.827	32.983	2.948	9.828	IN	OUT	815	IN
13	Gembong	42.490	0,07	Pohgading	1.124	0,25	< 1,00	4,25	5,96	8.377,60	67,33	73	20 < DV < 100	Moderate	High	High	High	Moderate	Tinggi	157	41.366	2.431	1.241	14.478	337	1.124	IN	OUT	157	IN
14	Klego	1.300	0,50	Bade Klego	138	0,25	< 1,00	1,25	4,50	2.435,63	12,00	23	20 < DV < 100	Moderate	High	High	High	Moderate	Tinggi	32	1.162	161	35	407	41	138	IN	OUT	32	IN
15	Gunung Rowo	94.057	0,54	Siti Luhur	893	0,25	< 1,00	1,80	3,50	604,95	16,00	16	DV ≤ 20	Low	High	High	High	Low	Tinggi	132	93.164	4.505	2.795	32.607	268	893	IN	OUT	132	IN
16	Banyukuwung	20.754	0,77	Sukorejo	236	0,5	< 1,00	1,80	3,50	1.862,29	16,00	16	DV ≤ 20	Low	High	High	High	Low	Tinggi	48	20.518	1.427	616	7.181	71	236	IN	OUT	48	IN

Tabel 5. Calculation of LoL Prediction (With Early Warning System)

Condition : PENRIS are Ready for Disaster
Level of Understanding of Floods : > 60 minutes (Clearly)

No	Name of Dam	Total PENRIS (People)	Nearest Village: Variation Distance Village to Dam (km)	Nearest Village: Name of Village	Nearest Village: PENRIS (People)	Karakteristik Banjir: Variation Warning Time (Hour)	Karakteristik Banjir: Warning Time (Hour)	Karakteristik Banjir: Highest Number V (m/s)	Karakteristik Banjir: Highest Number H (m)	Karakteristik Banjir: Highest Number Q (m3/s)	Low Tide (Hour)	ICOLD (2018): $DV = H^2 * V^{0.5}$	ICOLD (2018): Risk Interval	ICOLD (2018): Risk Level	Indonesia: House	Indonesia: Child	Indonesia: Mature	Determine Risk Level: Remaining Villages (ICOLD, 2018)	Determine Risk Level: Remaining Villages (Indonesia)	LoL Equation for Remaining Villages (Jiwa)	PENRIS of Remaining Village (People)	Predict of LoL Remaining Villages (People)	Graham (2010): Interval Respons PENRIS of Remaining Villages Min	Graham (2010): Interval Respons PENRIS of Remaining Villages Max	Graham (2010): Interval Respons PENRIS of Nearest Village Min	Graham (2010): Interval Respons PENRIS of Nearest Village Max	Graham (2010): Status of LoL Data Remaining Villages	Graham (2010): Status of LoL Data Nearest Villages
1	Wadaslintang	447.804	3,00 - 17,60	Rahayu dan > 50 Desa	121.449	0,43 - 0,83	< 1,00	12,60	5,00	7.487,09	8,50	89	20 < DV < 100	Moderate	High	High	High	Low		24	326.355	65	0	131	0	131	IN	IN
2	Penjalin	38.314	0,10 - 1,14	Keseran dan Kr. Nangka	7.611	0,50 - 0,75	< 1,00	2,21	4,37	2.815,00	144,00	28	20 < DV < 100	Moderate	High	High	High	Low		2	30.703	6	0	12	0	12	IN	IN
3	Cengklik	9.118	0,10 - 1,70	Ngesrep - Ngargorejo	469	0,50 - 0,85	< 1,00	0,90	6,50	798,00	13,90	40	20 < DV < 100	Moderate	High	High	High	Low		0	8.649	2	0	3	0	3	IN	IN
4	Simo	420	0,50 - 4,20	Suru dan 7 Desa	420	0,1 - 0,70	< 1,00	0,80	7,80	135,98	30,00	54	20 < DV < 100	Moderate	High	High	High	Low		0	-	-	0	-	0	-	IN	IN
5	Sanggeh	3.805	0,15 - 5,00	Tambirejo dan 4 Desa	3.768	0,50 - 1,00	< 1,00	2,79	2,95	374,23	64,80	15	DV ≤ 20	Low	High	High	High	Low		1	37	0	0	0	0	0	IN	IN
6	Gondang	67.845	0,15 - 5,52	Gondang Lor	22.202	0,15 - 0,99	< 1,00	1,36	3,00	4.768,00	72,00	10	DV ≤ 20	Low	High	High	High	Low		4	45.643	9	0	18	0	18	IN	IN
7	Krisak	16.204	0,50 - 4,20	Singodutan	5.205	0,07 - 0,99	< 1,00	2,08	2,63	2.089,00	9,00	10	DV ≤ 20	Low	High	High	High	Low		1	10.999	2	0	4	0	4	IN	IN
8	Cipancuh	142.061	0,25 - 2,25	Situraja dan Gantar	1.758	0,15	< 1,00	1,68	0,84	3.600,00	72,00	6	DV ≤ 20	Low	Moderate	High	High	Low		0	140.303	28	0	56	0	56	IN	IN
9	Greneng	21.807	1,20 - 5,20	Tunjungan + 2 Desa	357	0,25 - 0,93	< 1,00	3,10	4,00	1.070,70	14,20	28	DV ≤ 20	Low	High	High	High	Low		0	21.450	4	0	9	0	9	IN	IN
10	Tempuran	14.297	0,6 - 1,92	Tempuran dan 4 Desa	3.083	0,3 - 0,95	< 1,00	1,10	2,90	893,30	10,00	9	DV ≤ 20	Low	High	High	High	Low		1	11.214	2	0	4	0	4	IN	IN
11	Way Jepara	13.882	3,83	Sumberrejo	1.622	3,5	> 1,00	2,18	1,68	895,00	24,00	4	DV ≤ 20	Low	High	High	High	Low		0	12.260	2	0	5	0	5	IN	IN
12	Batujai - Pengga	104.065	0,5 - 3,60	Batujai dan Penunjak	9.828	0,37 - 0,80	< 1,00	2,25	2,25	3.610,00	17,67	8	DV ≤ 20	Low	High	High	High	Low		2	94.237	19	0	38	0	38	IN	IN
13	Gembong	42.490	0,07	Pohgading	1.124	0,25	< 1,00	4,25	5,96	8.377,60	67,33	73	20 < DV < 100	Moderate	High	High	High	Low		0	41.366	8	0	17	0	17	IN	IN
14	Klego	1.300	0,5	Bade Klego	138	0,25	< 1,00	1,25	4,50	2.435,63	12,00	23	20 < DV < 100	Moderate	High	High	High	Low		0	1.162	0	0	0	0	0	IN	IN
15	Gunung Rowo	94.057	0,54	Siti Luhur	893	0,25	< 1,00	1,80	3,50	604,95	16,00	16	DV ≤ 20	Low	High	High	High	Low		0	93.164	19	0	37	0	37	IN	IN
16	Banyukuwung	20.754	0,77	Sukorejo	236	0,5	< 1,00	1,80	3,50	1.862,29	16,00	16	DV ≤ 20	Low	High	High	High	Low		0	20.518	4	0	8	0	8	IN	IN

For the condition of dam collapse without early warning systems on 16 (sixteen) dams in Indonesia, which shows a minimum interval of not constant one value as in Graham [8], but as a function of the equation ie LoL Equation 2019 Formula 1. This condition also reflects the characteristics of PENRIS which varies at each dam location in Indonesia. As for the condition of dam collapse with early warning, the minimum interval is a function of the LoL Equation 2019 Formula 2 can be seen in Table 6 as follows:

Table 6. Prediction LoL for16 Dams in Indonesia (Without Early Warning Systems)

No	Name of Dams	Location	Risk Level	PENRIS (People)		Prediction of LoL (People)	
				Remaining Village	Nearest Village	Remaining Village	Nearest Village
1	Wadaslintang	Central Java	Moderate	326.355	121.449	11.681	5.511
	Penjalin	Central Java	Moderate	30.703	7.611	1.938	671
3	Cengklik	Central Java	Moderate	8.649	469	740	81
4	Simo	Central Java	Moderate	0	420	0	74
5	Sanggeh	Central Java	Low	37	3.768	12	393
6	Gondang	Central Java	Moderate	45.643	22.202	2.619	1.515
7	Krisak	Central Java	Moderate	10.999	5.205	888	503
8	Cipancuh	West Java	Moderate	140.303	1.758	6.150	220
9	Greneng	Central Java	Moderate	21.450	357	1.476	66
10	Tempuran	Central Java	Moderate	11.214	3.083	901	338
11	Way Jepara	Lampung	Moderate	12.360	1.622	2	0
12	Batujai – Pengga	NTB	Moderate	94.237	9.828	4.545	815
13	Gembong	Central Java	Moderate	41.366	1.124	2.431	157
14	Klego	Central Java	Moderate	1.162	138	161	32
15	Gunung Rowo	Central Java	Low	93.164	893	4.505	132
16	Banyukuwung	Central Java	Low	20.518	236	1.427	48

As for the condition of dam collapse with early warning, the minimum interval is a function of the LoL 2019 Equation Formula 2 can be seen in Table 7 as follows :

Table 7. LoL Prediction of 16 Dams in Indonesia (with early warning system)

No	Name of Dams	Location	Risk Level	PENRIS (Soul)		Prediction of LoL (Soul)	
				Remaining Village	Nearest Village	Remaining Village	Nearest Village
1	Wadaslintang	Central Java	Moderate	326.355	121.449	65	24
2	Penjalin	Central Java	Moderate	30.703	7.611	6	2
3	Cengklik	Central Java	Moderate	8.649	469	2	0
4	Simo	Central Java	Moderate	0	420	0	0
5	Sanggeh	Central Java	Moderate	37	3.768	0	1
6	Gondang	Central Java	Moderate	45.643	22.202	9	4
7	Krisak	Central Java	Moderate	10.999	5.205	2	1
8	Cipancuh	Central Java	Moderate	140.303	1.758	28	0
9	Greneng	Central Java	Moderate	21.450	357	4	0
10	Tempuran	Central Java	Moderate	11.214	3.083	2	1
11	Way Jepara	Lampung	Moderate	12.360	1.622	2	0
12	Batujai – Pengga	NTB	Moderate	94.237	9.828	19	2
13	Gembong	Central Java	Moderate	41.366	1.124	8	0
14	Klego	Central Java	Moderate	1.162	138	0	0
15	Gunung Rowo	Central Java	Low	93.164	893	19	0
16	Banyukuwung	Central Java	Low	20.518	236	4	0

3.2 CALIBRATION PREDICTION OF LoL

The event of a collapsed dam that can be used in Indonesia, as calibration is Situ Gintung Dam, because the other dam collapse events are incomplete or support the data, described as follows :

- Sempor Dam (1965), there were no PAR data when the dam incident collapsed
- Situ Gintung Dam, when it collapsed, officially recorded 103 fatalities from the total number of PAR recorded at 600 people, and included a high risk dam. Referring to Table 2.19, the dam collapse disaster is categorized without early warning, so that the LoL is 0.75 * 600 = around 450 people with a prediction range of 0.3 * PAR = 180 < LoL <1.00 * PAR = 600 people. The number of official LoLs recorded by Graham (2010) estimates differ greatly.
- The wide difference in the number of LoLs gives an indication that in conditions without early warning, most PENRIS or PAR can save themselves and casualties are the result of not being able to save themselves because they are not ready and the position of PENRIS being LoL is those who live near the location of the dam collapse. Therefore PENRIS with the condition of the closest village to the dam is the dominant victim. If calculated back, then PAR or PENRIS, for the nearest

village, if the number of LoL = 103 people, if using the Graham equation (2010) is 103 / 0.75 = 137 people or around 30-35 families (logical reasons due to downstream Situ Gintung is a dense settlement to the area of the structure of the dam).

- If using the 2019 LoL Equation, the LoL amount is 103 = 0.7535 * $(PAR)^{0.76}$; PAR = 646 inhabitants. Difference of 46 inhabitants. It can be interpreted that there are non-PAR victims who are victims of casualties indicated as non-permanent residents for example tourists.
- Based on the results of these calculations it is clear that the Graham Method (2010) used as the ICOLD standard and LoL Equation 2019, in addition to being able to predict the number of LoL in Indonesia, can also be used to re-predict the number of PAR in the closest location to a dam during a dam collapse disaster.
- With the results of the study of the Situ Gintung Dam collapse event, the Graham Method (2010) can be used as a reference for dams that are still standing well, to be able to provide a temporary reference to LoL with a measurable amount that will occur if a disaster occurs.
- With this condition, the factual regression equation with the condition that a good correlation coefficient can be a solution to estimate the number of LoL or vice versa, namely estimating the number of PAR that existed during the Dam collapse disaster.
- In addition to the Situ Gintung Dam, there is the Sempor Dam. If we would predict the number of PENRIS or PAR at that time, in 1965, with a total LoL of 127 people, we could use 2 alternative formulas, namely:
    a. Graham (2010): PAR = LoL / 0.75 = 127 / 0.75 = 164 people or around 40 - 50 households.
    b. LoL Equation 2019: 127 = 0.7535 * $(PAR)^{0.76}$; PAR = 851 people or around 212 families.
- If there is a difference, it can be assumed that the amount can increase due to loss of life after a disaster or body is not found.

3.3 CASE STUDY SANGGEH DAM

As a control, based on the disaster risk map, it can be seen that the suitability of the number of houses and PENRIS data on the latest conditions can be seen on the disaster risk map in Figure 5 as follows :

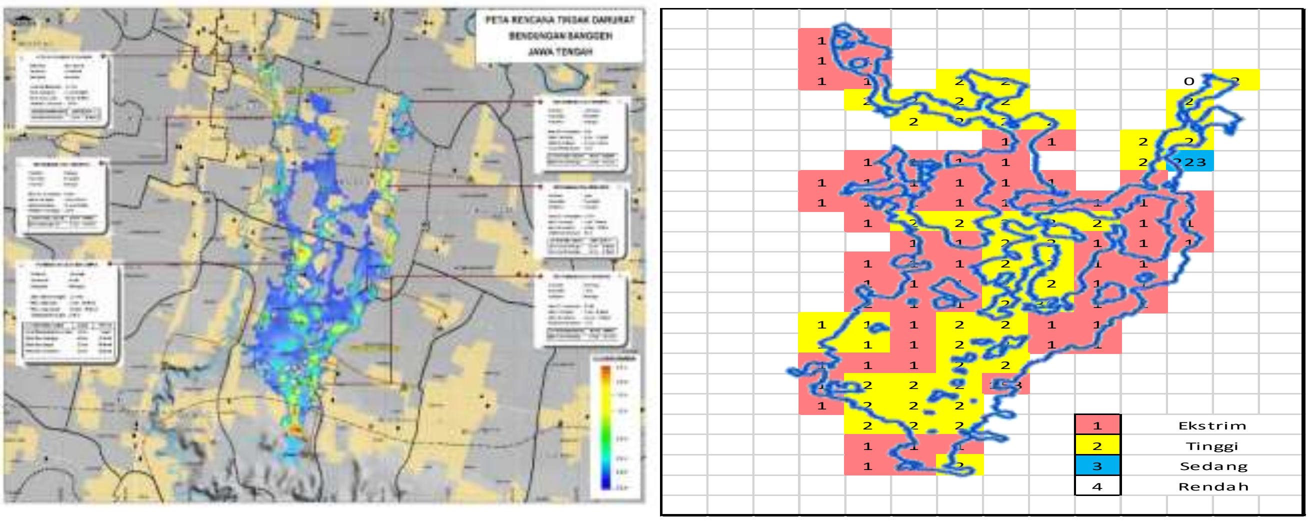

Figure 5. Risk Map of Sanggeh Dam

For example: Sanggeh Dam [14,17], there are 499 houses in extreme risk locations with PENRIS 2,245 people or 1 house occupied by 4 to 5 people. Based on Equation 2019 Formulas 1 and 2, the predicted number of PENRIS to lose lives in the nearest village namely Tambirejo and 4 other villages with WT <1 hour, is 393 people and 12 people in the remaining villages (dam disaster suddenly collapsed). If early warning has been functioning properly, the risk of loss of life will be reduced to 0 (zero) lives or there are no fatalities in the nearest village and a maximum of 1 (one) people in the remaining village.

3.4 IMPROVING LoL INDEX IN MODIFIED ICOLD METHOD

Dam Risk Assessment based on the Modified ICOLD Method in 2015 of around 37 dams in Indonesia [16], has resulted in a decrease in the value of risk in some dams, but there are also dams that are still at high risk status after DOISP work has ended. Some dams taken as examples, to recommend a decrease in the value of dams are dams that have been made EAP at the same time have also been assessed the risks in the DOISP project made in Table 8 as follows:

Table 8. Risk Reduction Recommendations

No.	Name of Dams	PAR/PENRIS (People)		Risk Assessment 2015		Prediction LoL (Soul)		Efforts to reduce the value of risk			Risk Assessment in 2019	
		Remaining Villages	Nearest Villages	Level of Risk	Risk and Evacuation Reguirement	Remaining Village	Nearest Village	Long and Short Term Programs Implemented	Short Terms Implemented	No Implemented	Recommendation of Reduction Value	Final Risk Value
1	Cengklik	8.649	469	59 (High)	12	740	81	0	Done		6	53 (High)
2	Simo	0	420	46 (High)	4	0	74	0	Done		2	44 (High)
3	Sanggeh	3.768	37	53 (High)	4	12	393	0	Done		2	51 (High)
4	Way Jepara	12.260	1.622	52 (High)	8	3.761	2	8	Done		4	44 (Moderate)
5	Batujai	100.248	3.817	47 (High)	8	1.002	397	0	Done		3	43 (Moderate)
6	Pengga			39 (Moderate)	8			0	Done		4	35 (Moderate)
7	Klego	1162	138	40 (Moderate)	4	174	32	0	Done		2	38 (Done)

From the 7 (seven) dams studied, all of them experienced a decrease in risk value. There are 3 dams namely Simo, Way Jepara and Batujai where the initial security risk status is 46 (High) for Simo, 52

(High) for Way Jepara and 47 (High) for Batujai, to 44 (Medium) for Simo and Way Jepara and 43 (Medium) for Batujai. However, only Way Jepara Dam has implemented the Long Term Program, where the nearest village, namely Sumberejo Village, is at a distance of 3.83 km with WT: 3.5 hours > 1 hour. For the remaining 6 (six), other dams for long-term program interventions such as the Way Jepara Dam, will have a significant effect on reducing the value of dam security risk. Recommendations on predicting the number of LoLs, for each relevant stakeholder in each dam, are very useful for anticipating preparing measurable needs to accommodate PENRIS so that they do not become LoL.

4.0 CONCLUSION

Based on the discussion in this chapter, it can be concluded that:

a. The discussion about the predicted number of loss of life, has provided an illustration that PENRIS with the factor of awareness of life safety in the event of a disaster is the most important thing to minimize the risk of loss of life, one example is by realizing where the location resides downstream of the dam, is there an extreme risk area , high or low.
b. Based on the time of arrival of the flood, PENRIS can learn to respond to the time of early warning for evacuation if given enough time to make preparations. According to Graham [8], 1 hour is a normal time for PENRIS to receive evacuation information properly. Therefore, the PENRIS location which is within the reach of the time of arrival of the flood for a maximum of 1 hour is at high risk, where the area should not become a settlement. If it has already become a residential area, then PENRIS must always be vigilant and coordinate with stakeholders so that in case of a disaster the status does not increase to loss of life.
c. The closest village that was first hit by flooding due to the dam collapse disaster has certainly had to move if it does not want to always be at risk of loss of life. In the case of the Sanggeh Dam, the closest village at high risk is at a distance of 0.15 - 5.00 km. The 0.15 km location is an extreme risk area, while the remaining villages thereafter are in a high risk status.
d. Based on calculations, the existence of an early warning system on dams will reduce the status of high risk to low so that the risk of loss of life can be reduced by almost 100%.

5.0 RECOMMENDATION

From the overall discussion and analysis of our study, we can come to the following recommendations:

1. In every natural disaster event, especially dam collapse disaster, there are always casualties or LoL from residents who live downstream of the dam. Casualties can be avoided or reduced to a minimum if disaster is anticipated beforehand when the dam is still standing properly.
2. Anticipation of the LoL is not enough just from the number of PENRIS it self, but also needs to accommodate a group of PENRIS that have the potential to lose lives. Prediction of the measured amount is needed in order to facilitate the reference of relevant stakeholders to anticipate handling.
3. Prediction of the number of loss of life is very dependent on the number of PENRIS, PENRIS distance to the dam, the characteristics of flooding when the dam collapses which includes the arrival time, speed and depth of the flood flow.
4. The application of the Raster Method and Life Loss Risk Index in the case of the estimated collapse of the Sanggeh Dam, Purwodadi, shows that the estimated results of the number of PENRIS are more accurate than the global approach that is commonly applied in the preparation of EAP in Indonesia today.

5. Based on data on the occurrence of dam damages in the United States, Spain and Situ Gintung (2009) combined with 16 (sixteen) Indonesian EAP data, the amount of loss of life (LoL) can be estimated as follows:
    - Formula 1: LoL = 0.7535 (PENRIS) $^{0.76}$; R^2 = 0.9784 (Nearest Village or High Risk Status)
    - Formula 2: LoL = 0,0002 (PENRIS) ; R^2 = 0.8833 (Remaining Village or Low Risk Status)
6. The estimated number of LoL in conclusion no.5 (five), above gives the same results as the Graham Equation (2010) for the remaining villages, but for the nearest village the results are smaller than the Graham Equation (2010). Considering that the Graham formula (2010) is generated based on data on the occurrence of dams that have collapsed, while in Indonesia for the sake of risk prediction of dams that still stand well, then for the nearest village, the predictions are not the same as Graham (2010), for the minimum limit of the interval suggestion. So for the condition of Indonesia the LoL prediction for the minimum limit of suggestion interval can be replaced by the 2019 LoL Press where the value will be different from one dam to another dam, because in reality, the condition of each dam in Indonesia differs and the PENRIS activity is downstream of the dam.
7. PENRIS responses to disasters are described for 2 (two) conditions, which are sudden conditions (without early warning), and ready conditions (with early warning), using the formula from Graham (2010), to test whether for Indonesia, LoL prediction LoL according to the formula. The results for 16 (sixteen) dams, are as follows:
    - Sudden Dam Collapse Conditions
        - Nearest Village: LoL predicted value is outside the recommended PENRIS response interval. The minimum interval value for Indonesian conditions refers to LoL Equation 2019 Formula 1 so that it can be used as a predictive reference.
        - Remaining Village: LoL Value 16 EAP dam, using Formula 1, all of which enter the recommended response interval (Can be a reference).
    - Conditions with Early Warning > 60 minutes (Clearly)

      With the implementation of an early warning system, the level of dam security risk is considered to have gone from High to Low, so that the Nearest and Remaining Villages, LoL Values using Formula 2 are included in Graham's recommended interval (2010).
8. From the 7 (seven) dams that have been carried out by EAP and its Risk Assessment, concludes that the long-term handling of the 4 (four) dams, namely the implementation of disaster-based spatial planning, makes a reduction in the maximum risk value only to a reduction rate of 50% so an early warning system is absolutely necessary to minimize loss of life to PENRIS. For the other 3 (three) dams, only 1 (one) dam, Way Jepara, has implemented the nearest village with WT = 3.5 hours > 1 hour so that the risk of PENRIS becoming LoL when the dam suddenly collapses is small because there is still plenty of time for evacuation.

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