

Introduction to Landslide Dam

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What is landslide dam ?

In addition to steep terrain, torrential river, loose soil material, and fragile geologic conditions, typhoon and extreme rainfall events cause frequent land collapse, landslide, and debris flow events. These events may result in landslide dams.

Landslide mass moves to the river channel and block the flow, the mass can be called the landslide dam.

The water is stored behind the dam and forms a lake, the lake can be called the landslide-dammed lake.



Causes of landslide dam

Earthquakes and rainfall often occur in Taiwan, if earthquakes and rainfall induced avalanches, landslides or debris flows, the material blocked river will form landslide dams.

Exemple

In 1999, the Chi-Chi Earthquake caused 13 dams in Taiwan.

In 2008, The Wenchuan Earthquake caused 256 dams in China.

In 2009, Typhoon Morakot stroke southern Taiwan and caused 17 dams.

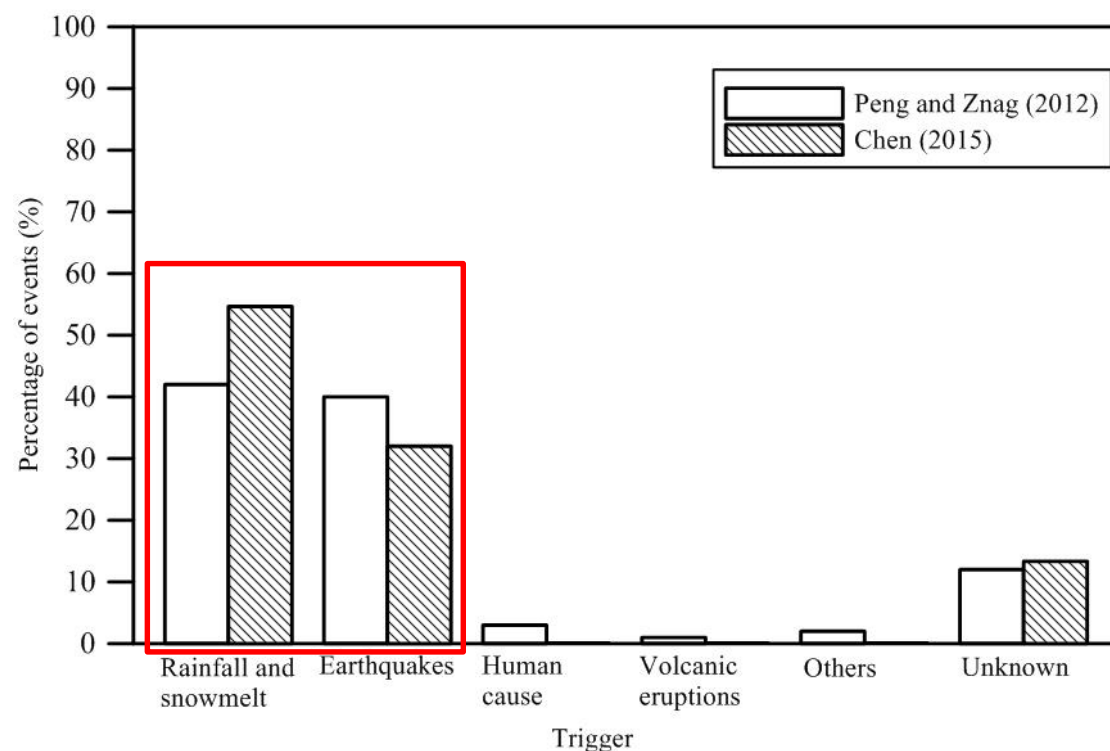
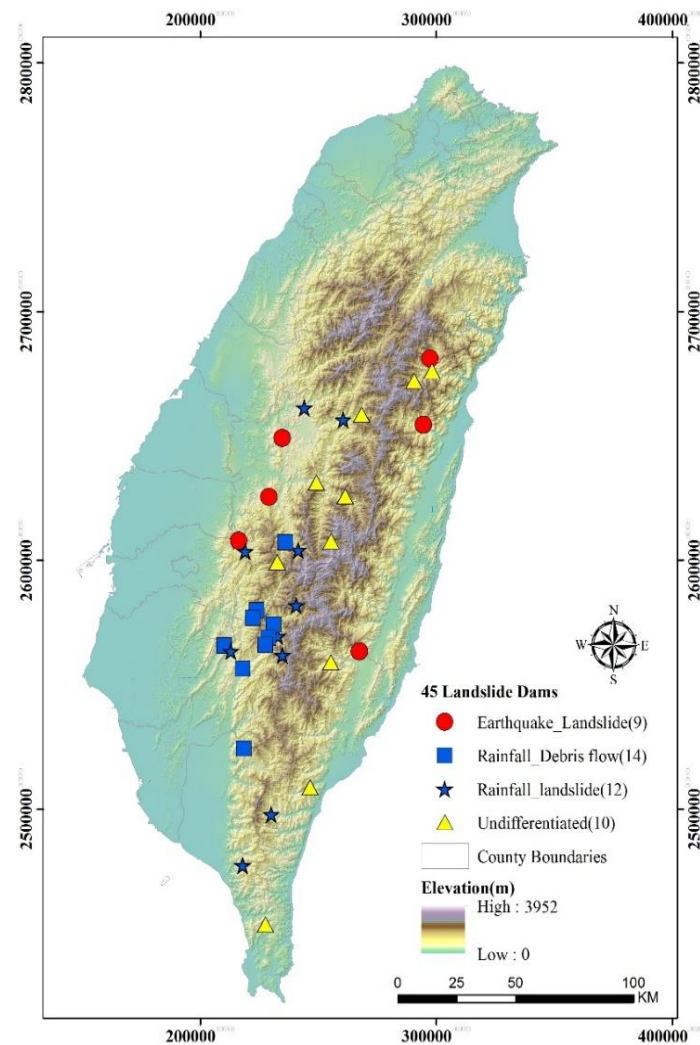


Figure illustrates the coordinate data distribution of 45 landslide dams in Taiwan.

The triggering causes of landslide dam via earthquake or typhoon event are similar to many cases throughout the world.



●=Earthquake Landslide

■=Rainfall Debris

★= Rainfall Landslide

▲=Undifferentiated

The hazards of landslide dam

Multiple landslide dams may form within a mountainous area and pose an additional potential danger to the region.

When a landslide dam suddenly fails, the material of the dam and the river flow rapidly transport to downstream. The momentum of the flow can cause serious damages.

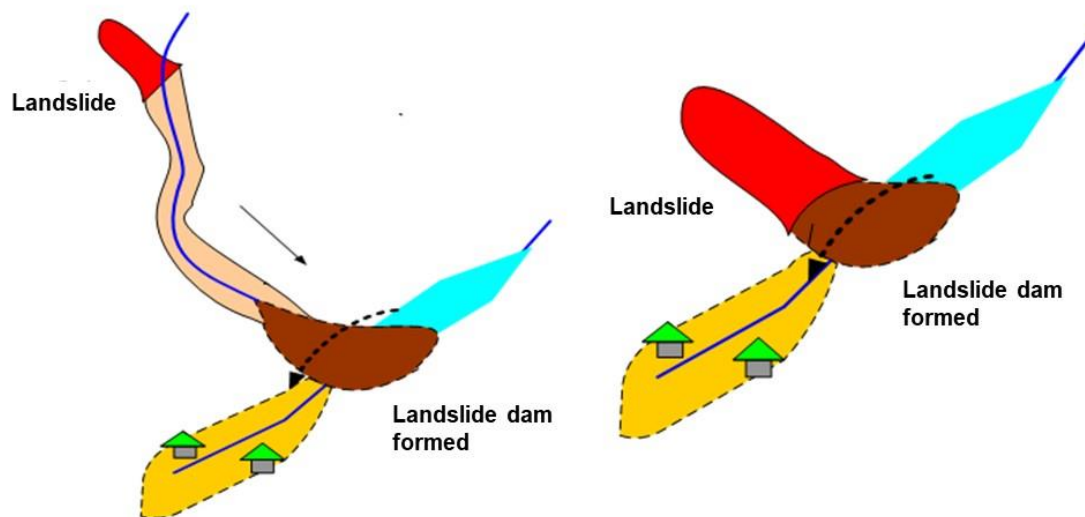
The formation of landslide dams occurs over a short time, and often causes large disasters that are sudden and may have a high impact over a large area, thus seriously threatening lives and properties both upstream and downstream.

Therefore, we must understand the mechanism of its formation, and further improve the countermeasures of disaster prevention and mitigation.

Formation mechanism of landslide dam

The formation mechanisms of landslide dam are mainly divided into two parts:

1. Landslide masses are transformed into a debris flow to form a natural dam.
2. Landslide masses directly to be a natural dam.



https://246.swcb.gov.tw/Landslide/Landslide_Introduction

River was not blocked by a debris flow



River blocking induced by a debris flow



Photos provided by DPRC, NCKU

River was not blocked by a landslide



River blocking induced by landslide



Photos provided by DPRC, NCKU

The formation of landslide dams is controlled by geomorphological and hydrological conditions.

In mountain valleys with steep slopes and narrow rivers, the momentum of landslide debris will frequently be sufficient to reach the valley floor. If the landslide debris deposited in the river cannot be eroded immediately by the stream or river flow, the flow will become obstructed, leading to the formation of a landslide dam.

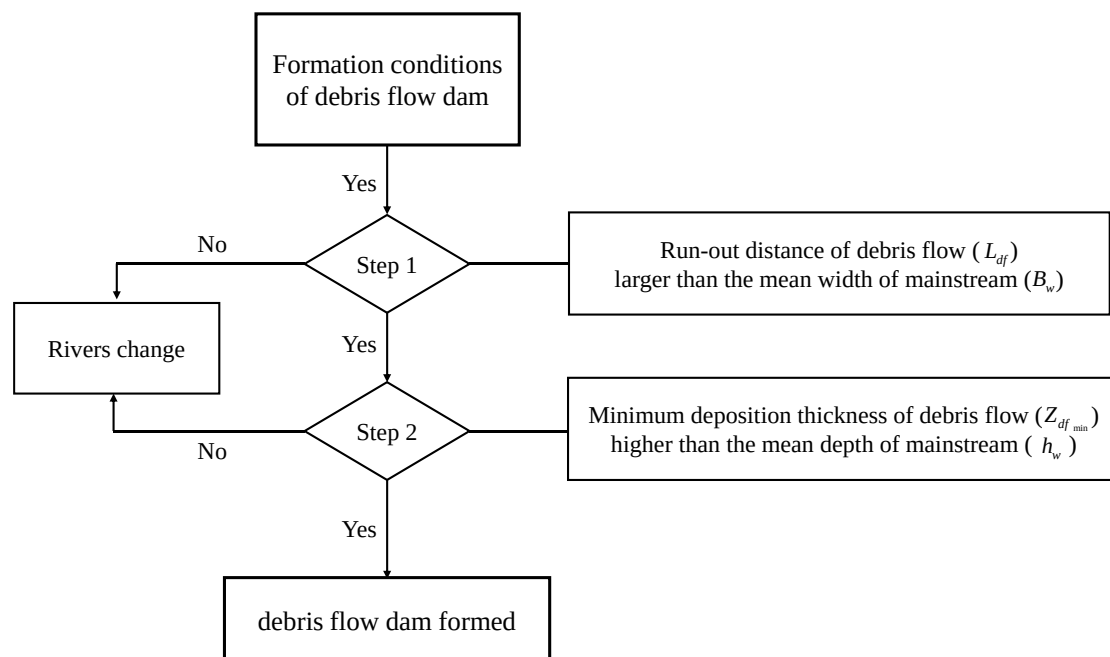
There are three conditions for the formation of a landslide dam:

1. the runout of the landslide debris needs to traverse the width of the stream or river.
2. the thickness of the landslide debris in the stream or river must be greater than the water depth.
3. the depositional capacity of the landslide must be higher than the erosive capacity of the river.



For formation of landslide dam by debris flow, The fig. shows method for evaluating the formation of a debris flow dam, based on the two characteristics of river blocking.

The potential for the formation of a debris flow dam relies on whether the run-out distance is larger than the river width and whether the deposited thickness by the debris flow is larger than the in situ water depth.

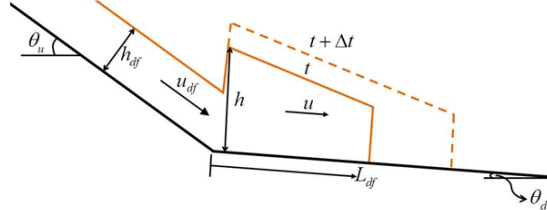


Run out distance of debris flow

This is relevant calculation methods for Run out distance of debris flow.

$$L_{df} > B_w$$

$$L_{df} = \frac{U^2}{G}$$



$$U = u_{df} \cos(\theta_u - \theta_d) \left\{ 1 + \frac{[(\sigma - \rho) C_{df} K_a + \rho] \cos \theta_u}{2[(\sigma - \rho) C_{df} + \rho]} \frac{g h_{df}}{u_{df}^2} \right\} \quad \text{Takahashi (1977)}$$

$$G = \frac{(\sigma - \rho) g C_{df} \cos \theta_d \tan \phi_k}{(\sigma - \rho) C_{df} + \rho} - g \sin \theta_d \quad \text{Takahashi (1977)}$$

$$C_{df\infty} \equiv C_{df} = \frac{\rho \tan \theta_u}{(\sigma - \rho)(\tan \phi_{df} - \tan \theta_u)} \quad \text{Takahashi (1977)}$$

$$u_{df} = \frac{2}{5d_{50}} \left\{ \frac{g \sin \theta_u}{a \sin \phi_k} \left[C_{df} + \left(1 - C_{df} \right) \frac{\rho}{\sigma} \right] \right\}^{\frac{1}{2}} \left[\left(\frac{C_*}{C_{df}} \right)^{\frac{1}{3}} - 1 \right] h_{df}^{\frac{3}{2}} \quad \text{Takahashi (1974)}$$

$$Q_{df} = \frac{1}{360} \frac{C_*}{C_* - C_{df}} C I A_{df} \quad \text{Tsai (2006)}$$

$$Q_{df} = B_u q_{df} = B_u h_{df} u_{df} \quad \text{Tsai (2006)}$$

Thickness of debris flow and water depth

This is relevant calculation methods for Thickness of debris flow and water depth.

$$Z_{df_{min}} > h_w$$

$$Z_{df_{max}} = L_{df} \tan(\theta_{df} - \theta_d)$$

$$Z_{df_{min}} = (L_{df} - B_w) \times \tan(\theta_{df} - \theta_d)$$

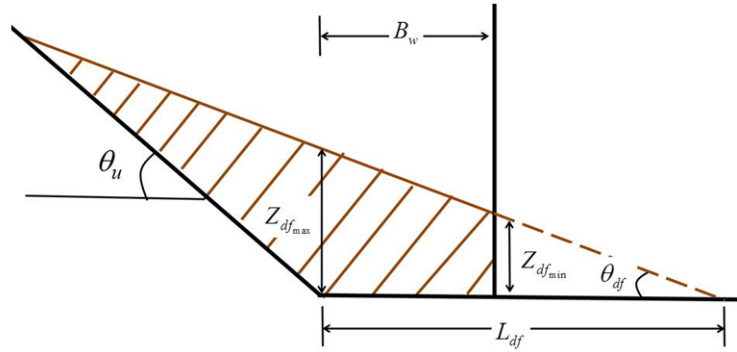
Tsai et al. (2006)

$$\tan \theta_{df} = \frac{C_* (\sigma - \rho) \tan \phi_{df}}{C_* (\sigma - \rho) + \rho \left[1 + 4.5 \times 10^{-4} C_{df}^{-6} \left(\frac{q_{df}^2}{g d_{50}^3} \right)^{\frac{1}{3}} \right]}$$

Tsai et al. (2006)

$$Q_w = \frac{A_w}{A_{w1}} Q_{w1}$$

$$Q_w = \frac{1}{n} \frac{(B_w h_w)^{\frac{5}{3}}}{(B_w + 2h_w)^{\frac{2}{3}}} \theta_w^{\frac{1}{2}}$$



Scenarios of debris flow deposition

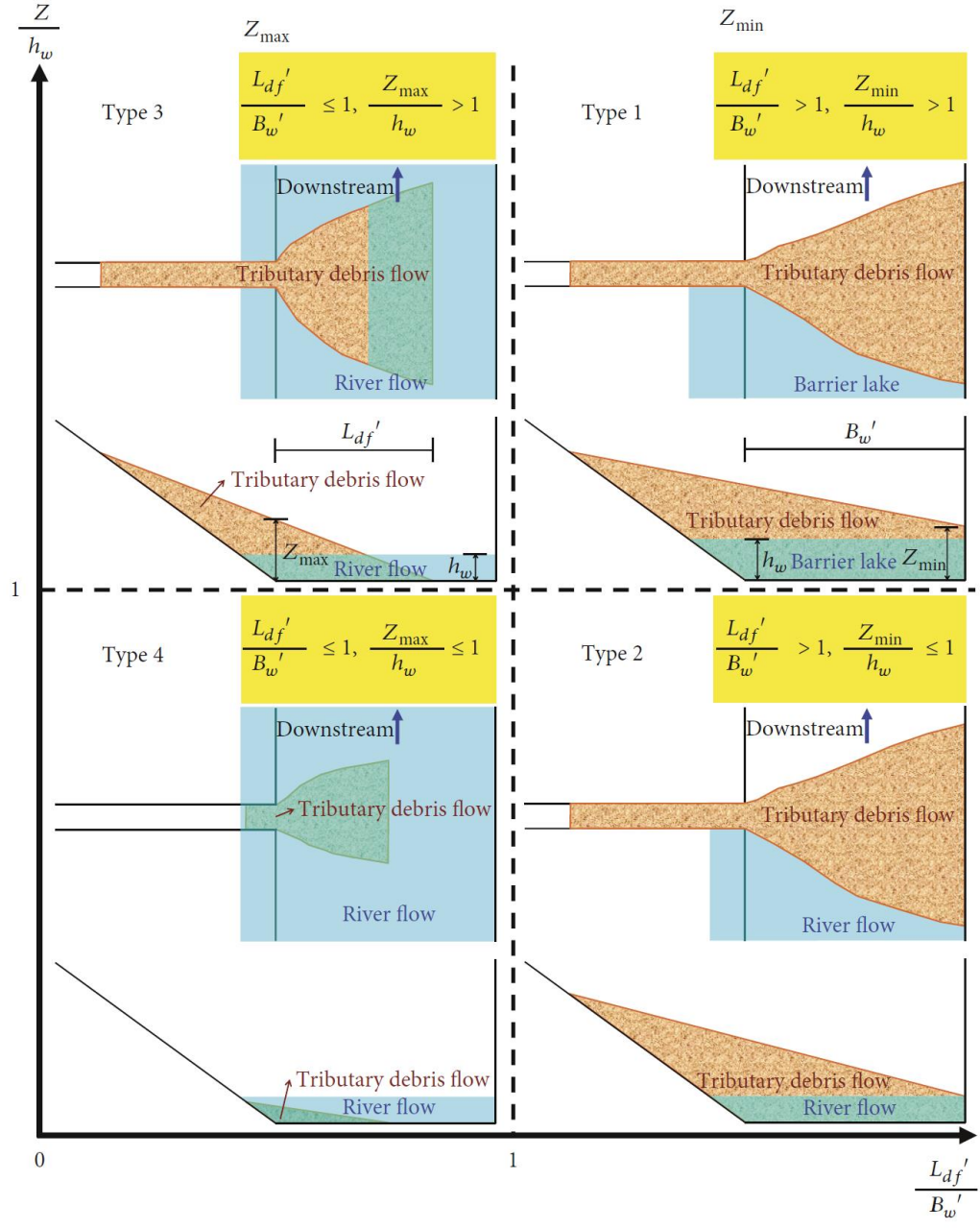
The depositional outcome of a tributary debris flow entering into a main stream can be classified into one of the four scenarios

(type 1) the tributary debris flow enters into the main stream and forms a landslide dam

(type 2) the tributary debris flow enters into the main stream but overflow occurs across the main stream at the junction, thus preventing blockage of the main stream

(type 3) the tributary debris flow enters into the main stream, does not reach the far bank, and sediment remains partially above the water table of the main stream

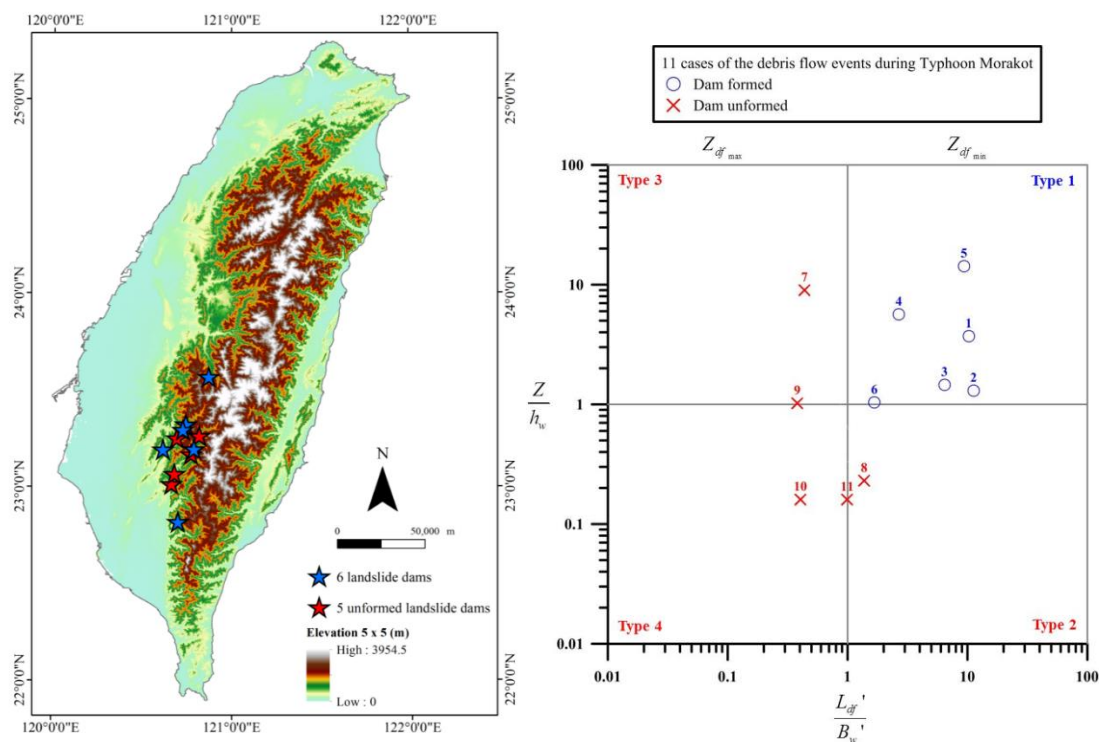
(type 4) the tributary debris flow enters into the main stream, does not reach the far bank, and sediment is fully submerged in the main stream. Only the first type can be defined as a landslide dam created by a tributary debris flow.



Case study of debris flow dam in Taiwan

The methods for assessing landslide dam formation were applied to 11 tributary debris flow events during Typhoon Morakot.

Based on the landslide dam formation conditions, the dimensionless assessment method can be used to discriminate the formation of a landslide dam from other depositional scenarios at the confluence of a tributary and its main stream.

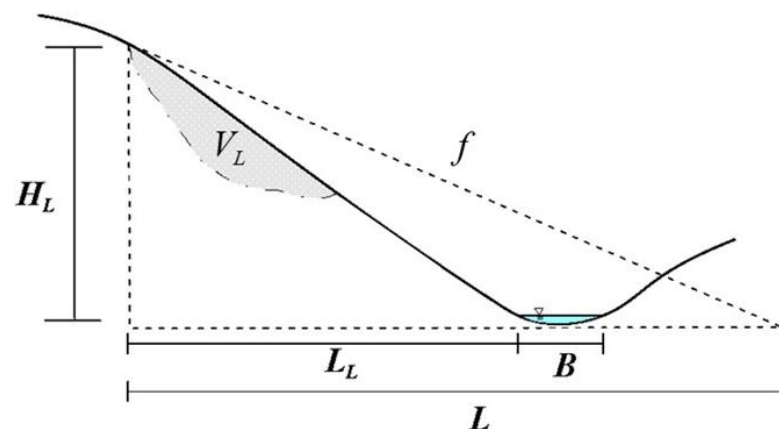


Formation of dam by landslide

Next is Formation of dam by landslide. We also consider the two characteristics of river blocking.

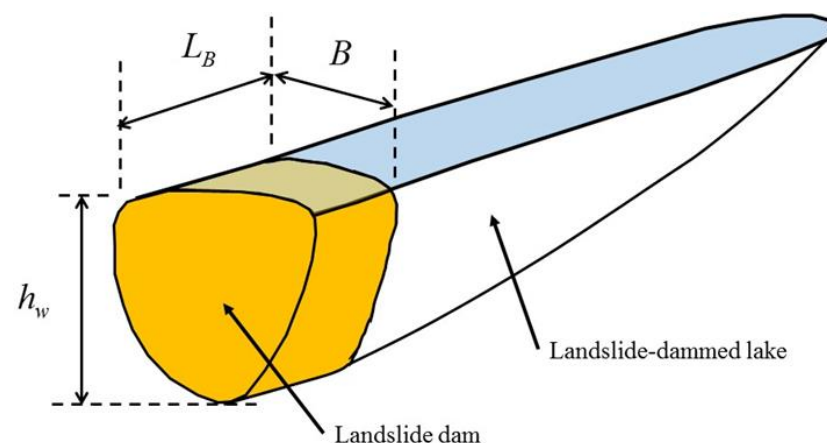
1. the runout of the landslide debris needs to traverse the width of the stream or river.
2. the thickness of the landslide debris in the stream or river must be greater than the water depth. Here, we further think of it as deposition volume of landslide.

1. Run out distance of landslide



Heim (1932)

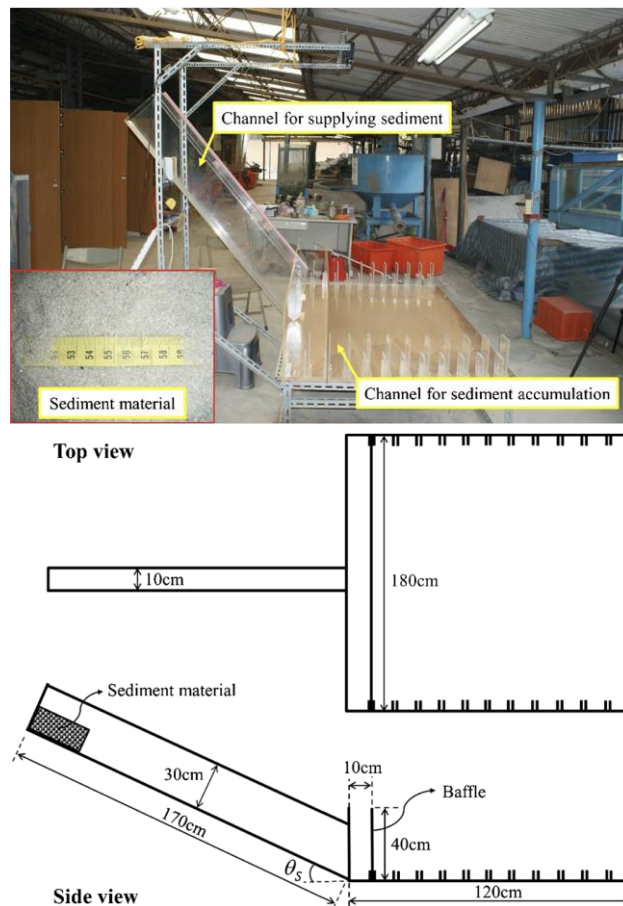
2. Thickness of landslide and water depth



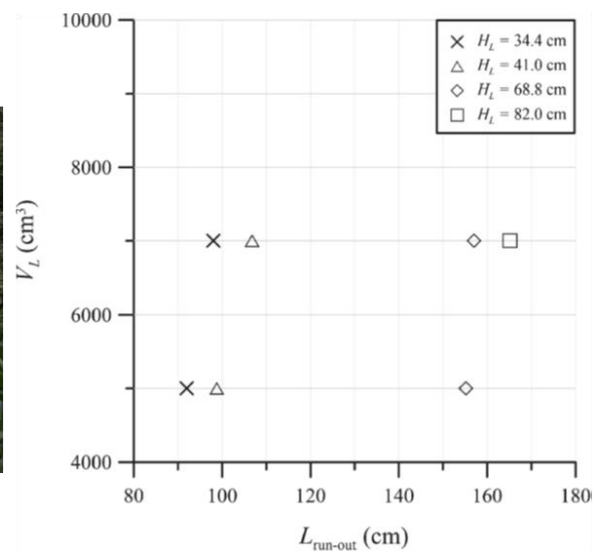
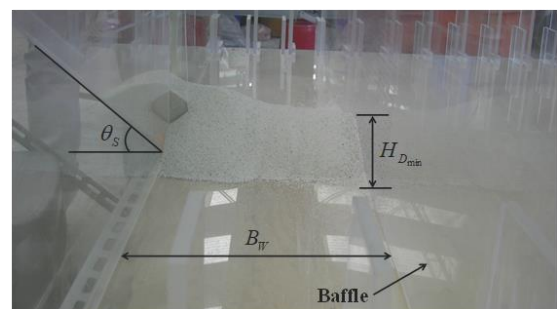
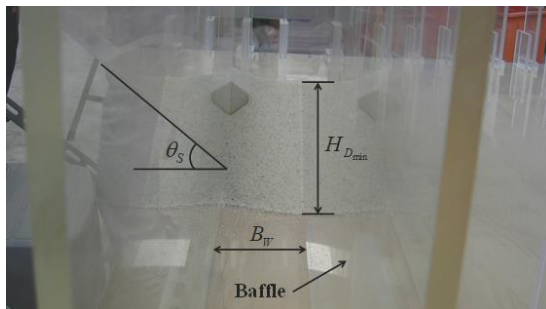
Tabata et al. (2002)

laboratory experiments of landslide dam

we investigated the effects of the volume of the landslide, the slope angle, the maximum height of the landslide, the width of the river channel, and other parameters on the minimum height of the landslide dam through laboratory experiments. The relationship between Run-out distance, the width of the river channel, and the minimum height of the landslide dam was determined, and a dimensionless method for evaluating the minimum height was established.



Since the potential energy at the initial position of the landslide mass is converted into kinetic energy as it slides downward, a higher initial position of the landslide mass results in a higher kinetic energy which leads to a greater distance over which the landslide mass moves.



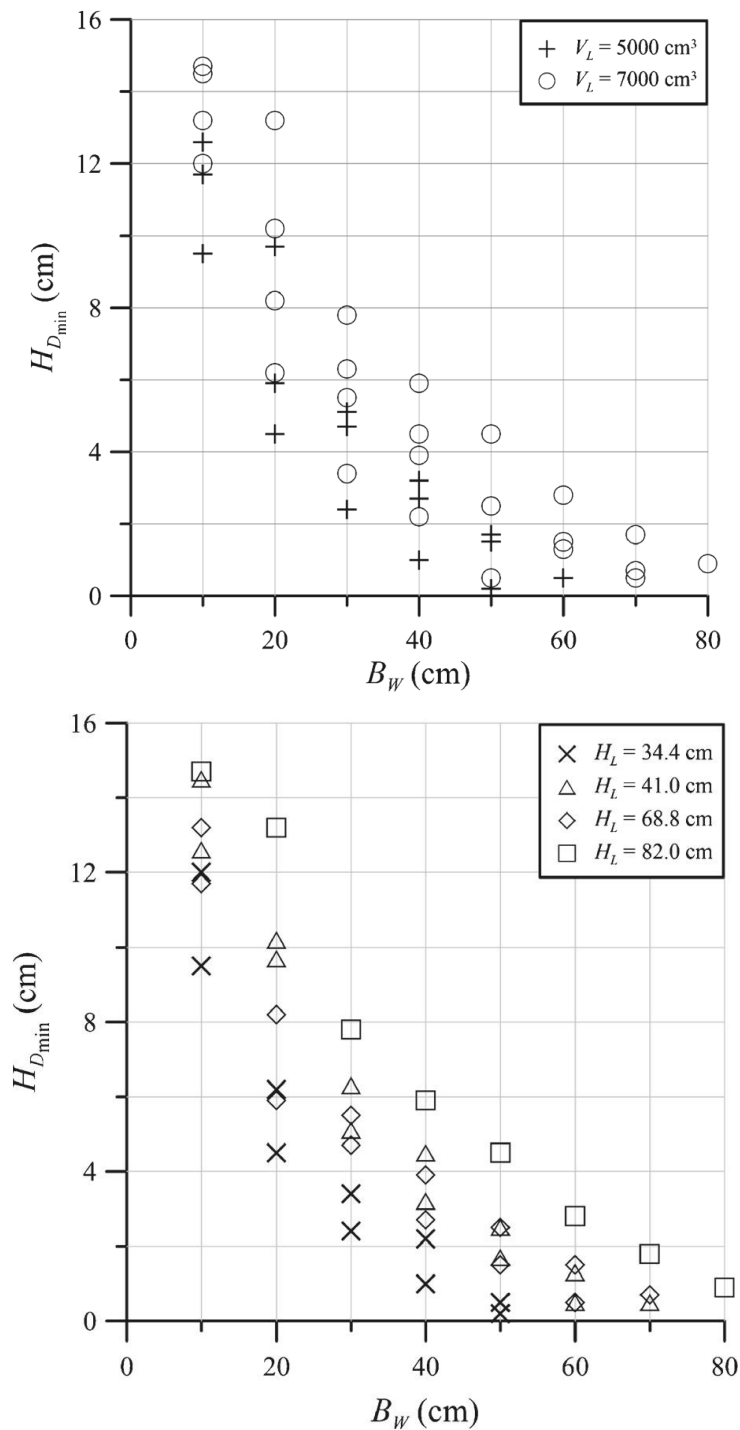
According to the results of these experiments, the height of the landslide dam shows a decreasing trend with an increase in the river width for different the landslide volume.

For the same the river width but with varying the landslide volume, it was found that when the landslide volume is larger, the height of the landslide dam is higher, which is in line with the trend of the landslide volume and the height of the landslide dam being positively correlated.

With an increase in the landslide volume and the maximum height of the landslide, the runout distance of the landslide also increases; thus the distance over which the landslide mass moves that can block the river channel, presents an increasing trend. With larger the maximum height of the landslide, as the landslide volume increases, the speed of the landslide mass increases.

For a narrow the river channel, the distance that the landslide mass can move is limited, resulting in the landslide volume fully blocking the river channel and increasing the height of the landslide dam. In contrast, when the potential energy decreases,

the speed of the landslide mass decreases, and even for a narrow the river channel, the landslide volume fails to fully block the river channel, and the height of the landslide dam is low.



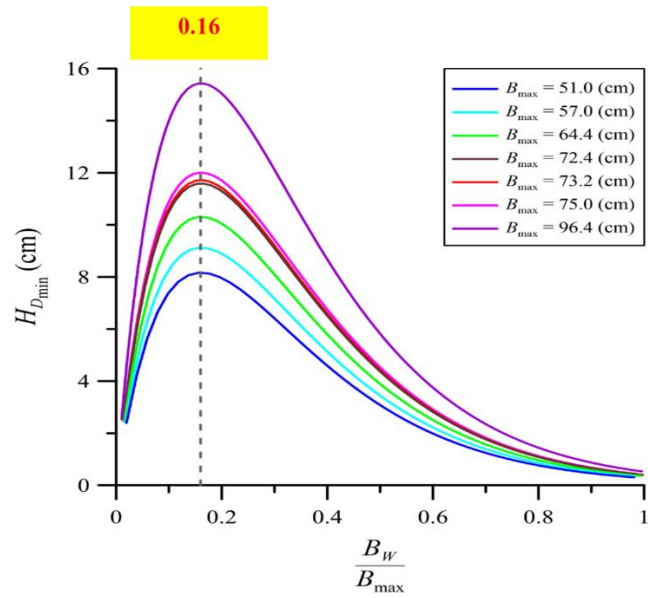
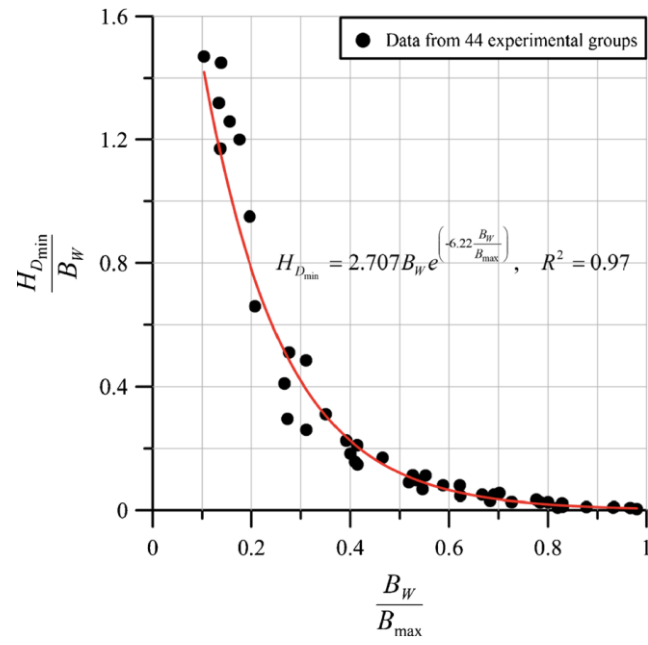
Dimensionless analysis

Whether the landslide mass can cross and block the river channel depends on the values of the river width and the horizontal run-out distance of the landslide. Additionally, the height of the landslide dam decreases with an increase in the river width. Hence, when the horizontal run-out distance of the landslide is less than the river width, the landslide mass does not reach the opposite bank of the river channel, and the landslide volume does not completely block the river channel or form a landslide dam.

We define two dimensionless parameters in this study, the height of the landslide dam over the river width, and the river width over the horizontal run-out distance of the landslide.

A dimensionless analysis of the results of laboratory experiments yields the relationship between dimensionless parameters

$\frac{H_{D_{\min}}}{B_W}$ and $\frac{B_W}{B_{\max}}$, when $\frac{B_W}{B_{\max}} > 1$, the minimum height is 0.

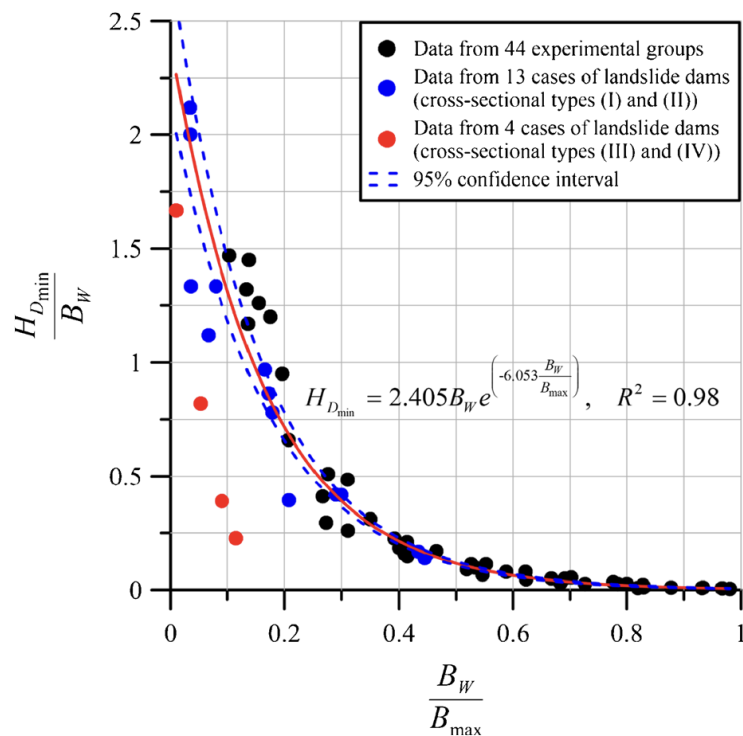


Case study of landslide dam in Taiwan

This study collected 17 landslide dam cases with relatively complete sets of parameters to verify the method of determining the height of the landslide dam. Whether the landslide dams are caused by earthquakes or rainfall, the height of the landslide dam is affected by the run-out distance of the landslide and the river width.



Photos provided by DPRC, NCKU



The geometry parameters of landslide dam

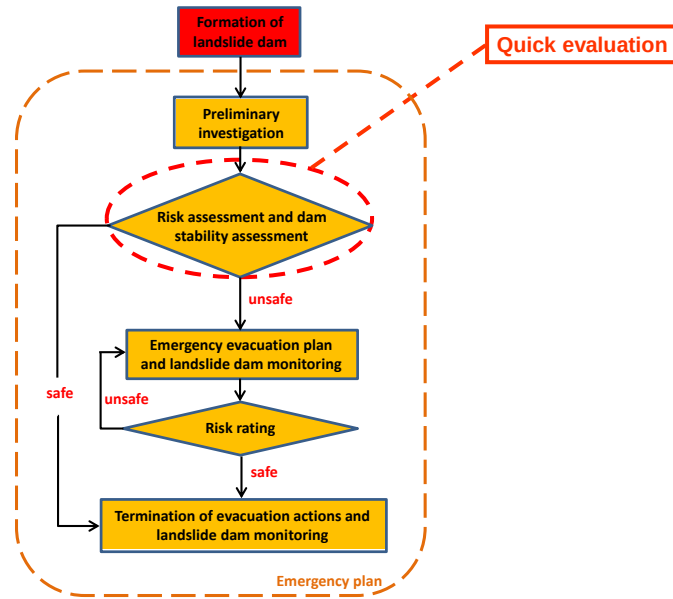
We need an emergency plan when a landslide dam forms. Risk assessment and dam stability assessment are important in an emergency plan.

Several methods based on morphometric and watershed characteristics for the preliminary assessment and risk evaluation of the dam stability, including dam height and volume, impounded water volume, watershed area, and relief.

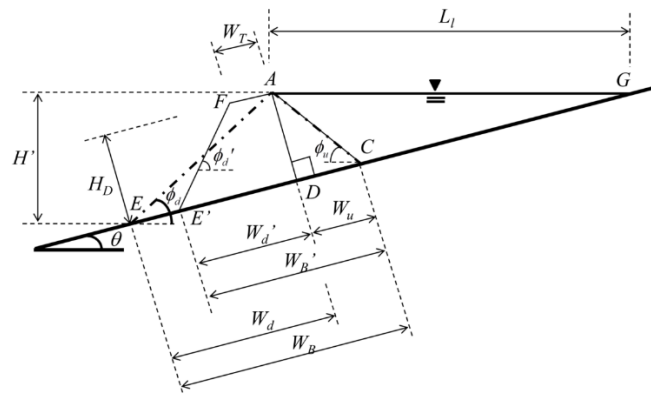
All of these methods need the geometry parameters of the dam.

However, field investigation needs three days or more to obtain these parameters, while the dam may fail during the investigation, especially when the dam is in a less accessible location.

So, this study develops a rapid assessment method for the geometry of landslide dams induced by rainfall or earthquake events based on statistical analysis and real measurement data in Taiwan.



This is relevant geometry parameters of landslide dam.

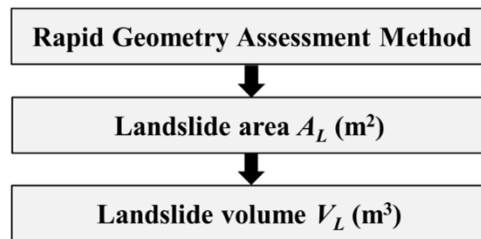


geometry parameters	Definitions
H_D	Height of landslide dam, from river bed to overflow point, $\overline{AD}$
H'	Characteristic height of dam, from toe of the dam to overflow point
W_d	The width of the triangular dam in downstream direction, $\overline{ED}$
W_d'	The width of the trapezoidal dam in downstream direction, $\overline{E'D}$
W_u	The width of the triangular and trapezoidal dam in upstream direction, $\overline{DC}$
W_B	The width of the triangular dam bottom, $\overline{EC}$
W_B'	The width of the trapezoidal dam bottom, $\overline{E'C}$
W_T	The width of the trapezoidal dam top, $\overline{FA}$
L_l	Maximum length of landslide-dammed lake, $\overline{AG}$
θ	River bed slope
ϕ_u	The angle of the triangular and trapezoidal dam in upstream direction
ϕ_d	The angle of the triangular dam in downstream direction
ϕ_d'	The angle of the trapezoidal dam in downstream direction
$\triangle ACE$	The area of the triangular dam
$\square ACE'F$	The area of the trapezoidal dam

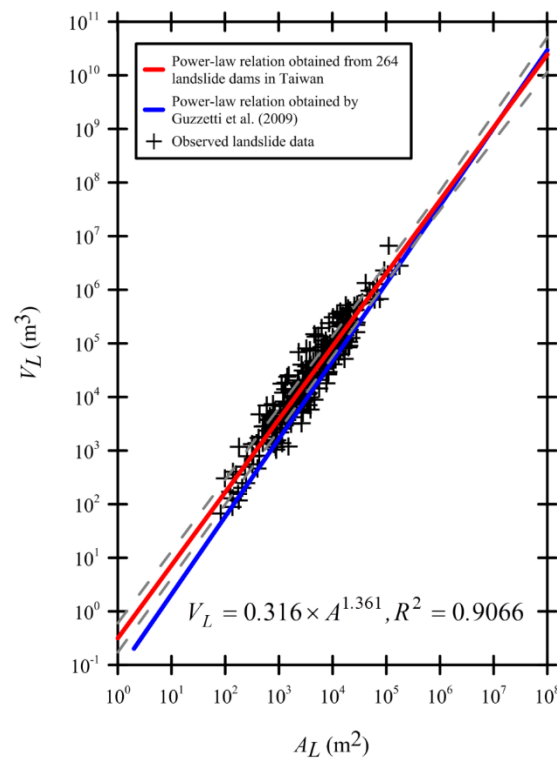
The establishment process of geometry assessment model

This study proposes a rapid geometry assessment model to analyze the geometry of a landslide dam, including rainfall-induced and earthquake-induced dams in the early stages when the data are limited.

Frist is calculate landslide volume from landslide area.

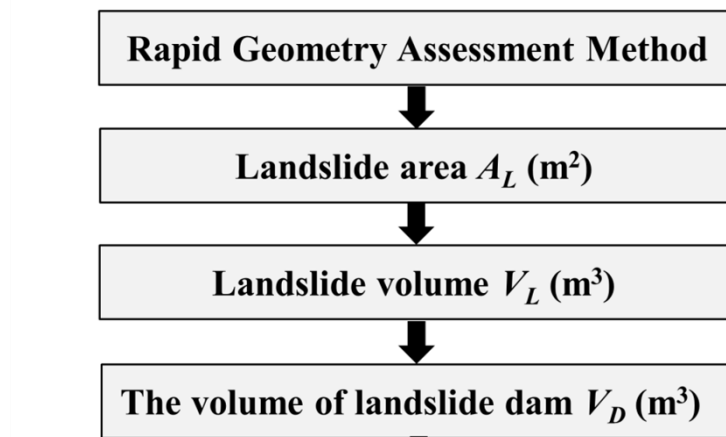


$$V_L = 0.316A_L^{1.361}, R^2 = 0.9066$$



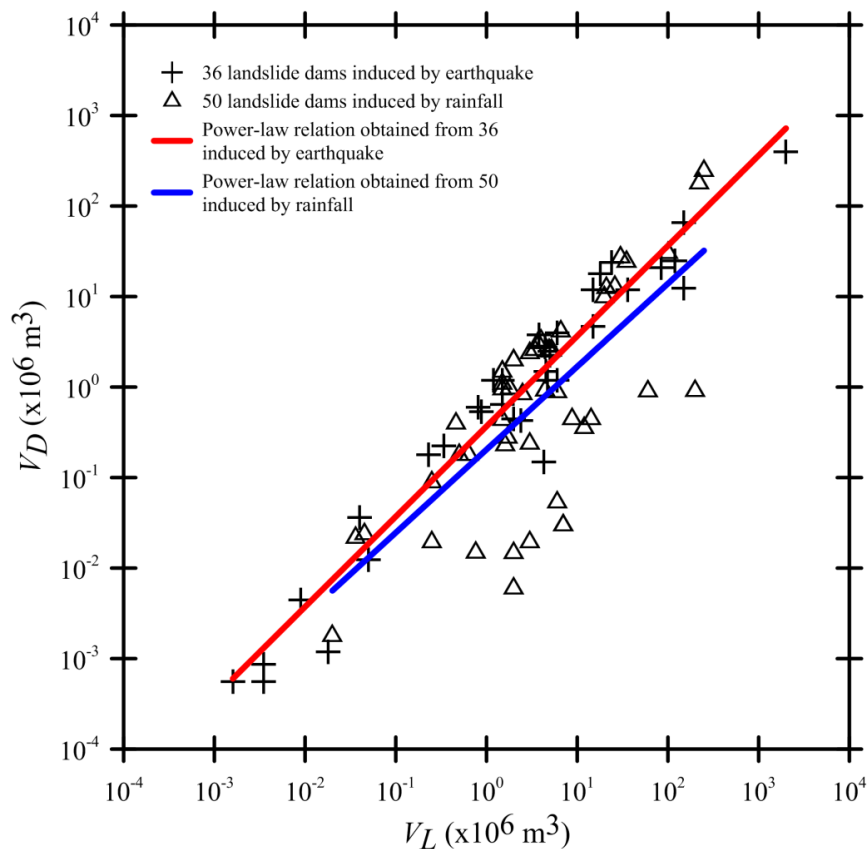
Second is calculate landslide dam volume from landslide volume.

We can choose rainfall or earthquake scenario.

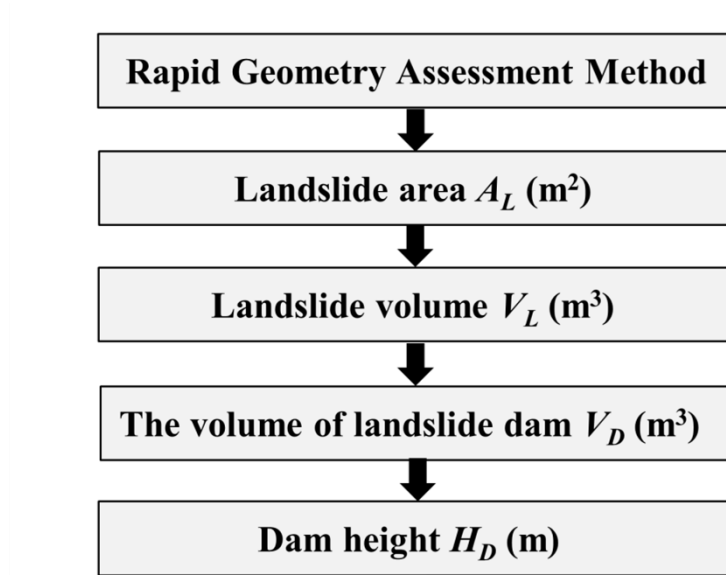


Earthquake : $V_D = 0.368V_L^{0.998}, R^2 = 0.9430$

Rainfall : $V_D = 0.204V_L^{0.917}, R^2 = 0.5124$

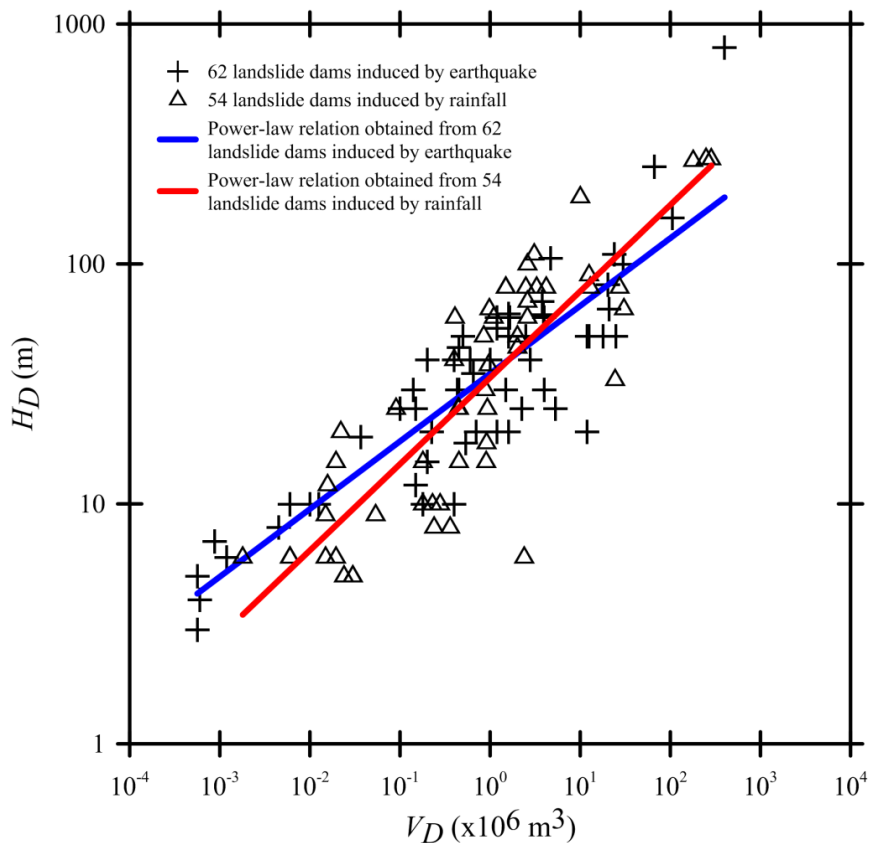


Third is calculate the height of the landslide dam from landslide dam volume.

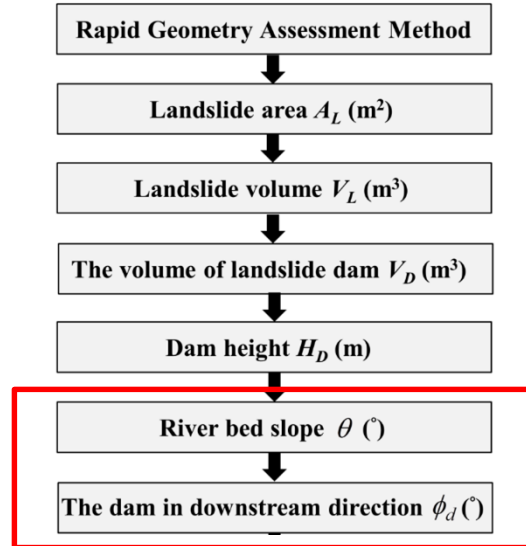


Earthquake : $H_D = 34.921V_D^{0.282}, R^2 = 0.7648$

Rainfall : $H_D = 33.570V_D^{0.360}, R^2 = 0.7207$

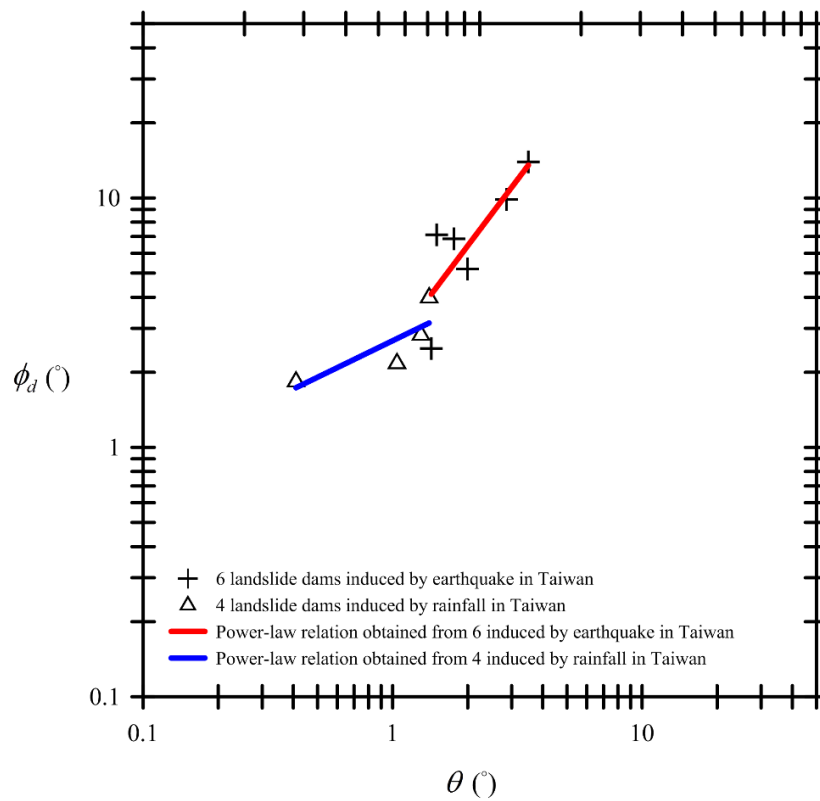


Next is calculate the downstream angles of the landslide dam
from the river bed slope.

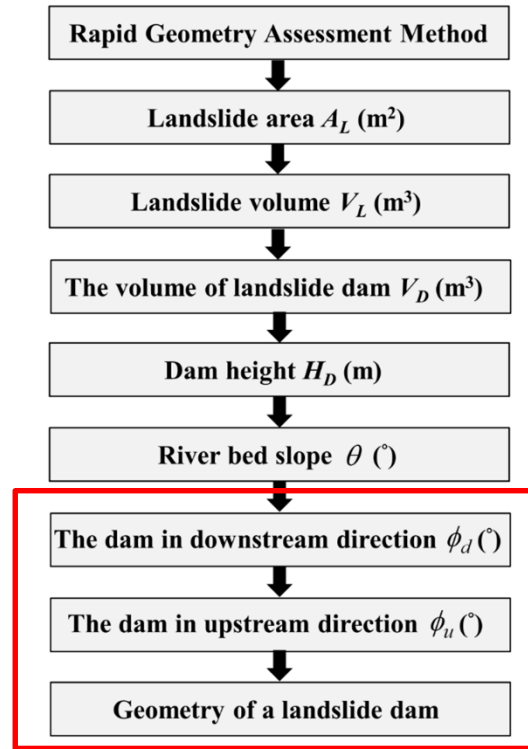


Earthquake : $\phi_d = 2.559\theta^{1.330}$, $R^2 = 0.6601$

Rainfall : $\phi_d = 2.677\theta^{0.486}$, $R^2 = 0.6632$

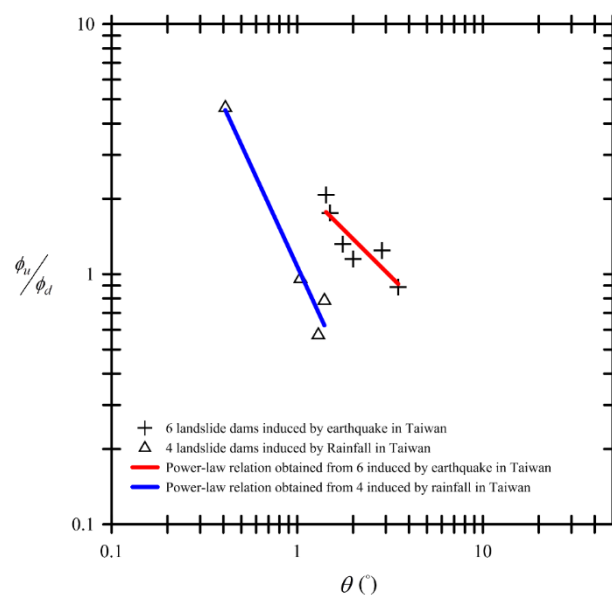


Finally is calculate the upstream angles of the landslide dam from the river bed slope and the downstream angles of the landslide dam. We will be able to draw the shape of the dam.



Earthquake : $\phi_u = 2.308\phi_d\theta^{(-0.739)}, R^2 = 0.7719$

Rainfall : $\phi_u = 1.075\phi_d\theta^{(-1.613)}, R^2 = 0.9625$

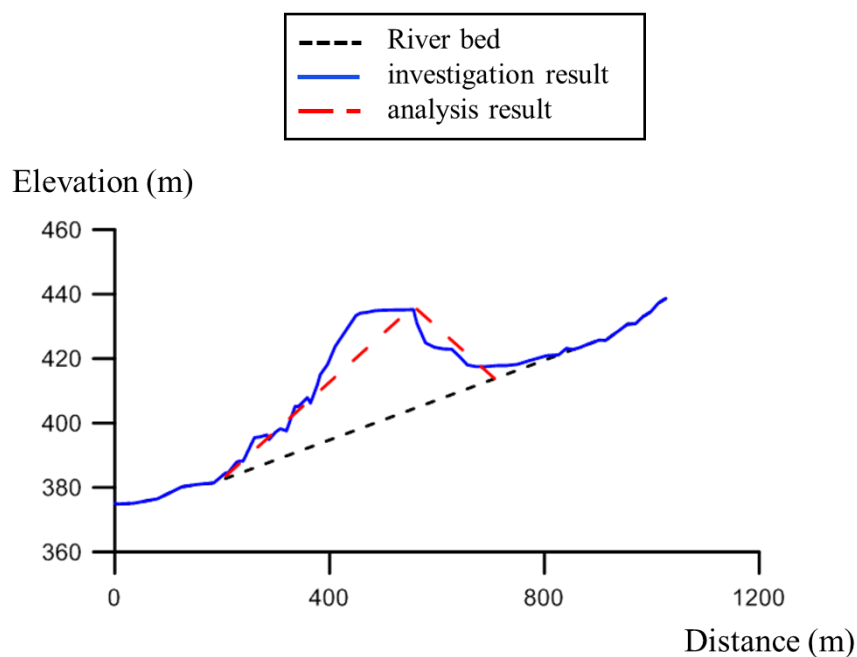


- ✚ Time : July 16, 2006
- ✚ Location : Lung-Chuan river, Taitung
- ✚ Trigger : Earthquake
- ✚ Area of landslide : $160 \times 10^3 \text{ m}^2$
- ✚ Volume of landslide : $600 \times 10^3 \text{ m}^3$
- ✚ Height of landslide dam : 35 m
- ✚ Volume of landslide lake : $800 \times 10^3 \text{ m}^3$
- ✚ Type of dam failure : Overtopping

Chen et al. (2014)

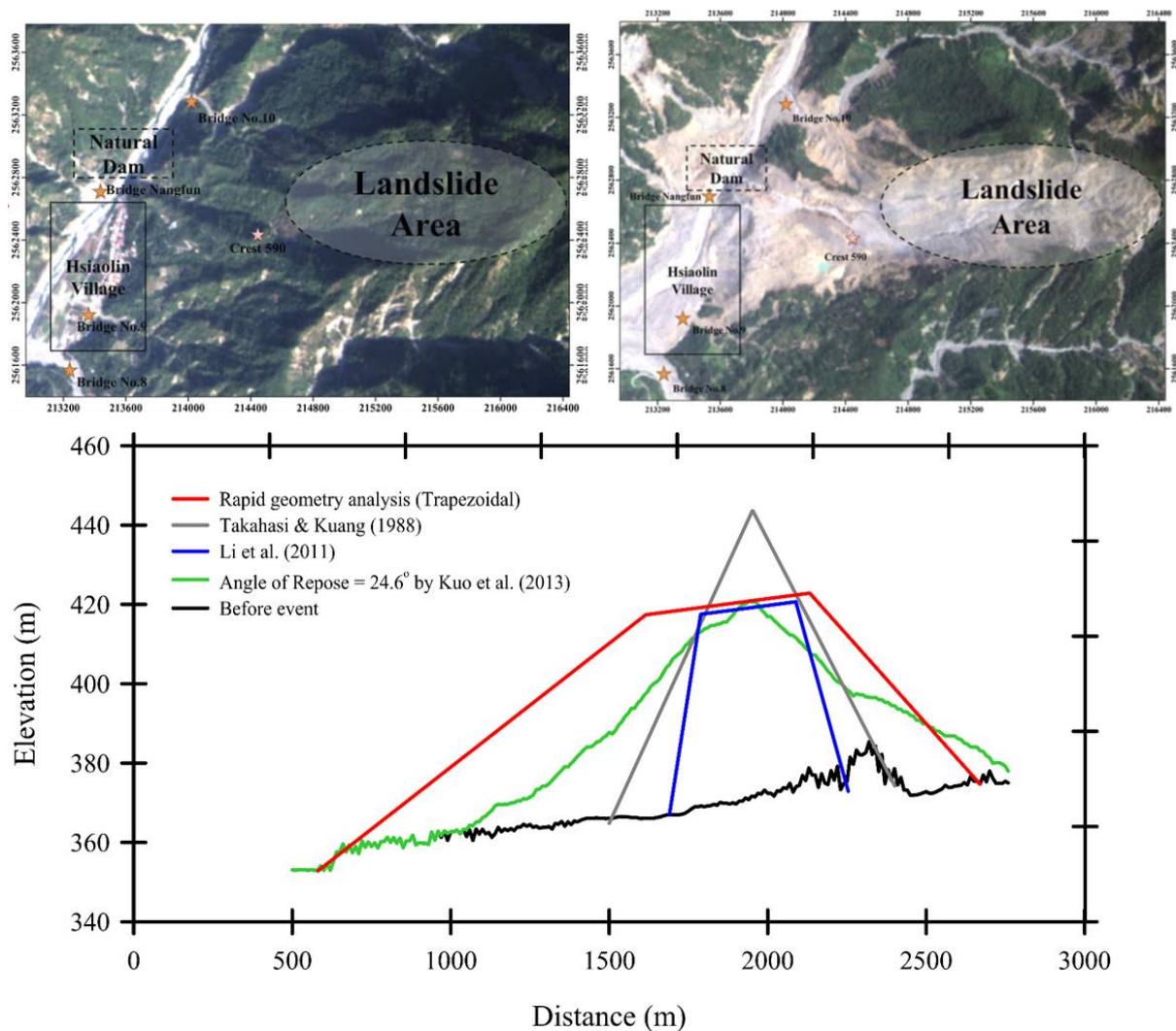


Photos provided by DPRC, NCKU



- ✚ Time : August 8, 2009
- ✚ Location : Hsiaolin Village , Kaohsiung
- ✚ Trigger : Rainfall
- ✚ Area of landslide : $609 \times 10^3 \text{ m}^2$
- ✚ Volume of landslide : $23580 \times 10^3 \text{ m}^3$
- ✚ Height of landslide dam : 50 m
- ✚ Type of dam failure : undefined

Kuo et al. (2013)



Conclusions

The obtained the potential location and dam geometry of landslide dam, provides important information for further dam stability analysis and emergency response plans.

In the future, we still necessary to update our knowledge of related topics such as landslide-dammed lake failure, disaster assessment, prevention, early warning and evolution trend etc.

Disaster prevention ~ Hope for the best, but prepare for the worst. And learn from experience.

The hazards of landslide dam

Affected by rainfall or earthquake on both sides of the valley, it will be occurred the collapse, landslide, debris flow, etc. The soil mass of the landslide could not be immediately carried downstream by the river flow, and accumulated in the river to form a dam.

Multiple landslide dams may form within a mountainous area and pose an additional potential danger to the region.

The backwater upstream of the dam will be destroyed the buildings, roads and farmland etc.

It is not easy to predict the dam break time of barrier lake which makes the disaster suddenly, large impact and wide impact which seriously threatens the safety of life and property of downstream residents.

The formation of landslide dams occurs over a short time, and often causes large disasters that are sudden and may have a high impact over a large area, thus seriously threatening lives and properties both upstream and downstream.

When a landslide dam suddenly fails, the material of the dam and the river flow rapidly transport to downstream. The momentum of the flow can cause serious damages.

As a result of a breach of a landslide dam an anomalous flood wave may propagate downstream. The higher the peak discharge originated by the dam failure, the more devastating the effects.

Therefore, we must understand the mechanism of its damage, and further improve the countermeasures of disaster prevention and mitigation.

A landslide dam by the accumulation of soil behind the river channel due to landslide

Landslide dam formation



Water storage above the dam



As water continued to accumulate behind the dam, overflow began to occur. The flow also begins to increase.



This is the dam failure of the Tainan River dam in Taitung, Taiwan.

We can see that the water level continues to elevated and the flow rate becomes faster.



We can see the driftwood in the water flow.

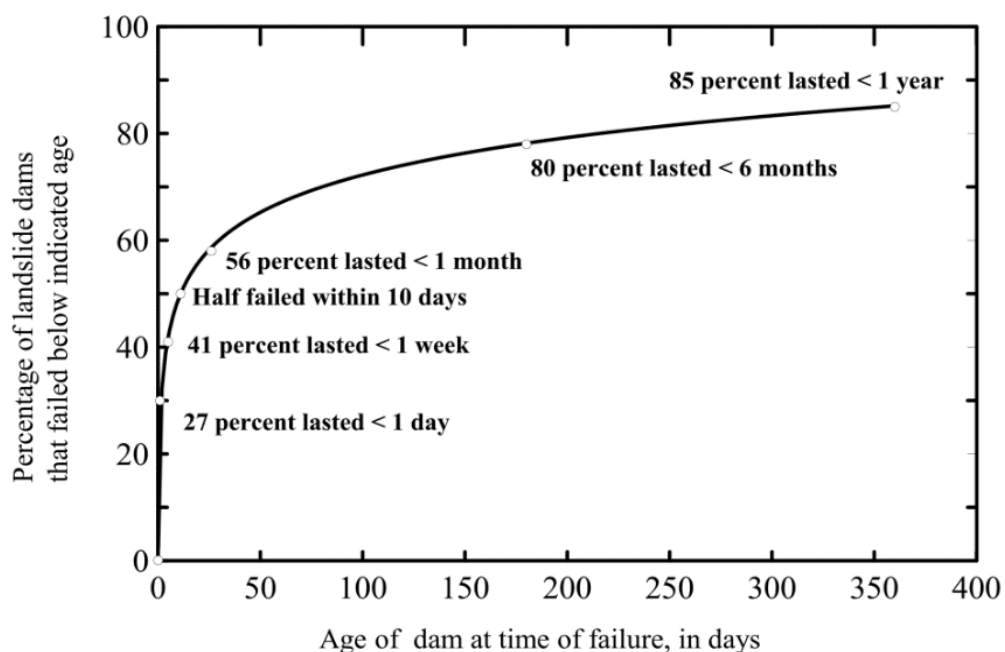


Eventually, the flow of the dam failure flooded the earthen embankment of the river.



Costa and Schuster studied 73 landslide dams throughout the world. The result shows that 27% of these dams failed within a day and 41% of these dams lasted less than a week. Only 15% of the dams last a year or longer. Peng and Zhang studied of the 204 recorded landslide dam cases with failure information, 87% failed within 1 year, 71% within 1 month, 51% within 1 week, and 34% within 1 day.

The results are showed that most of the dams had a life span of less than 1 year. This also shows that dam failure disasters are not easy to prevent, especially under time constrained conditions.



Costa & Schuster (1988)

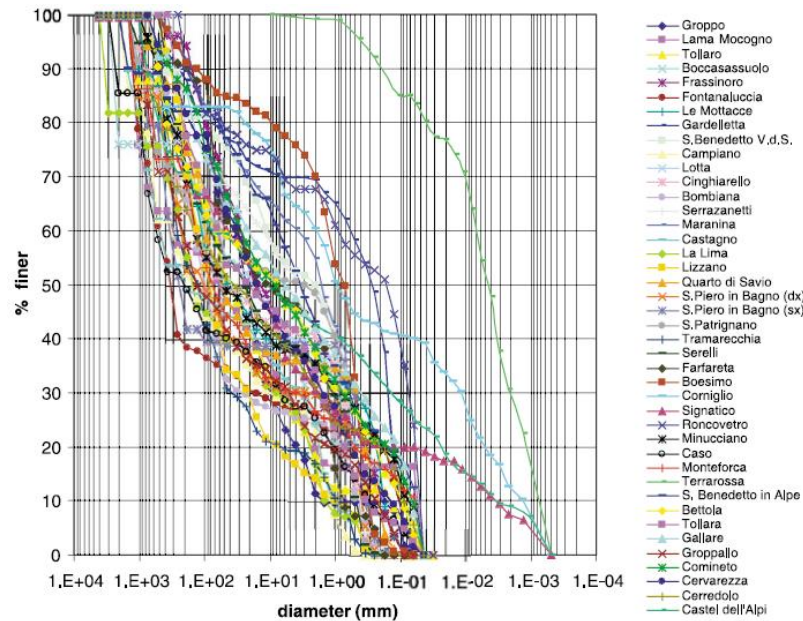
Costa and Schuster (1988) suggested that factors affecting the duration of natural dams can be assessed by dam volume, geometry, material properties, composition size, infiltration rate, and post-dam impoundment supply rate, etc.

Three of these factors are most important in relation to the existence time of natural dams:

1. the rate of inflow supply to the impoundment area behind the dam.
2. the shape and size of the natural dam.
3. The characteristics of the soil and sand materials that make up the natural dam.

Material properties of landslide dam

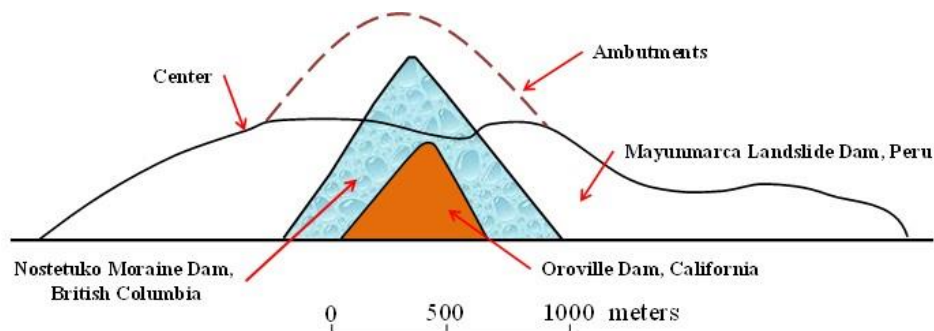
The distribution of dam materials varies from very large particles to very small particles, which results in different accumulation and destruction patterns.



Casagli et al. (2003)

Artificial dams are denser because they are compacted, while landslide dams are loose and have uneven granularity.

So landslide dam have a smoother and larger shape than artificial dams.



Dam material properties can be distinguished by three types of triggering causes

The first one is earthquake-induced landslides form dams.

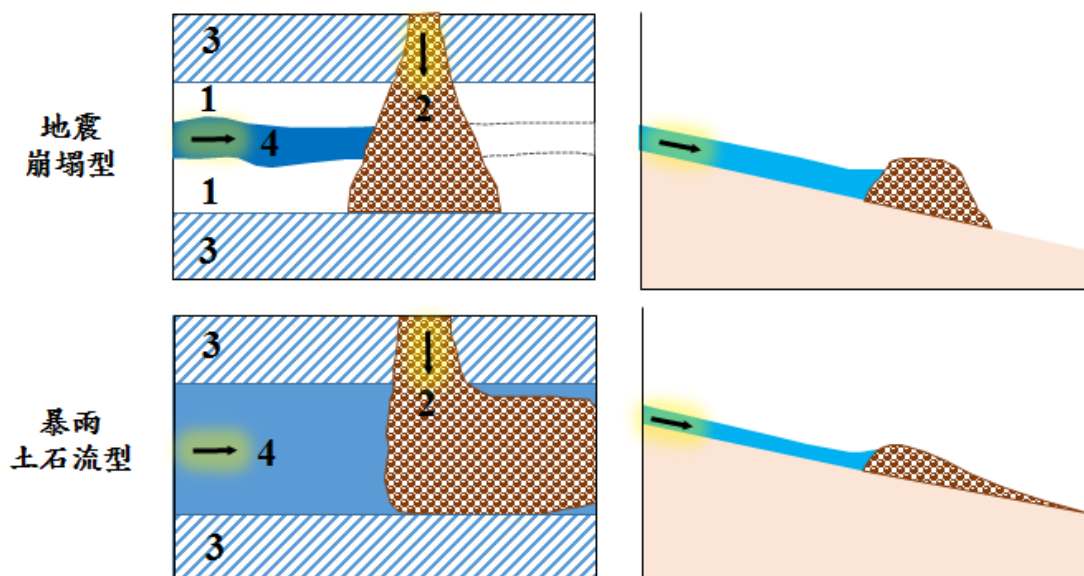
Characteristic : Dam structure is loose, low water content, high porosity, low cohesion and uneven distribution of grain size.

The second type is rainfall-induced landslides form dams.

Characteristic : High water content, low porosity, low internal friction angle, high cohesiveness and uneven particle size distribution.

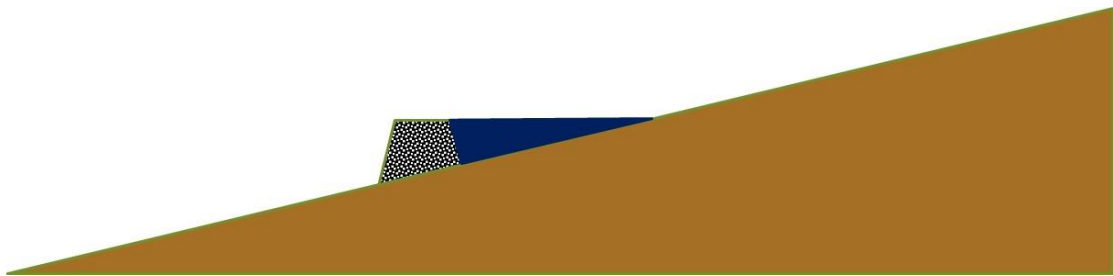
The third type is rainfall-induced debris flow form dams.

Characteristic : High water content, low porosity, low permeability, high cohesiveness and uneven particle size distribution.

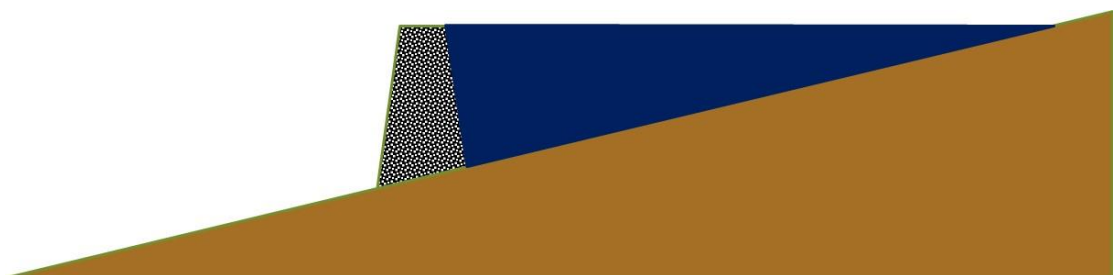


Height characteristics of landslide dam

Under fixed river bed slope conditions, when the height of the dam is short, the volume of water behind the dam is limited, so even if a dam failure occurs, it is not dangerous.



When the height of the dam is higher, the volume of water behind the dam will gradually increase, and when the volume of water reaches a certain amount, once a dam failure occurs, it may result in a hazard to the downstream preservation target.

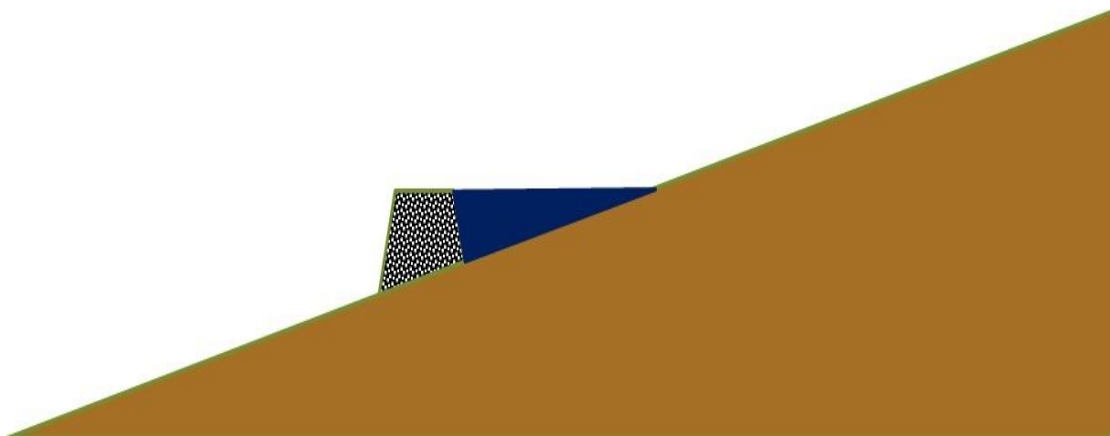


River slope characteristics of landslide dam

Under the fixed dam height condition, when the river bed slope is gentle, even if the height of the dam is not high, the volume of water that can be stored behind the dam will be quite large, and if a dam failure occurs, it may lead to a hazard to the downstream preservation objects, and if the height of the dam is higher, the danger after the failure will be larger.



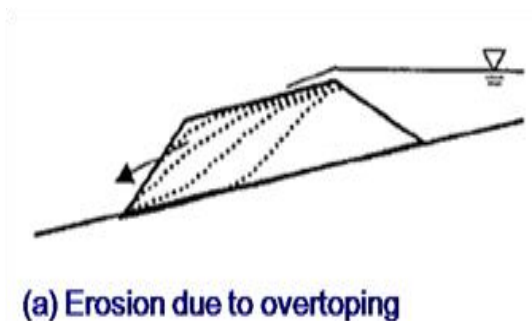
The steeper the river bed slope, the more limited the dam height, and therefore the less water can be stored behind the dam, the less the risk of a dam failure.



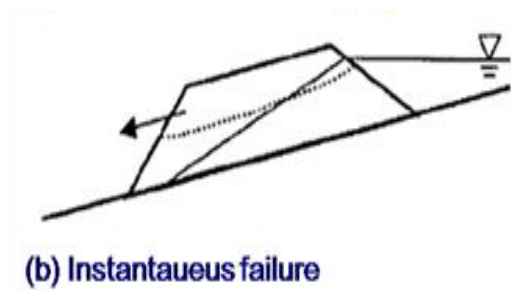
Failure types of landslide dam

Takahashi and Kuang proposed three types of natural dam damage patterns, including erosion due to overtopping, instantaneous failure, and progressive failure, based on experimental results.

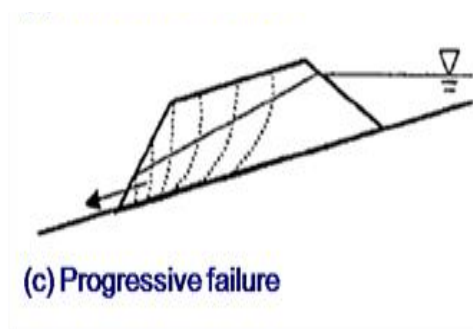
Erosion due to overtopping: The overflow flood will continue to scour the top of the dam and the downstream face of the dam to entrain the body material downstream, causing the dam body to become thinner and eventually collapse.



Instantaneous failure: The infiltration in the dam causes the dam body to increase its own load, so that the frictional resistance between the soil particles decreases and reaches the critical shear stress and then suddenly slips and breaks.



Progressive failure: The toe of the dam is hollowed out due to the phenomenon of pipe welling and the foot of the downstream slope of the dam body, and the damage has been gradually developed along the slope in the direction of the top of the dam to the top of the dam eventually leading to the damage of the dam body.



Other scholars also put forward different views and divide the mechanism of damage into three types of damage.

Overtopping: It is a primary mechanism of landslide dam failure which occurs after the overfilling of the dammed reservoir.

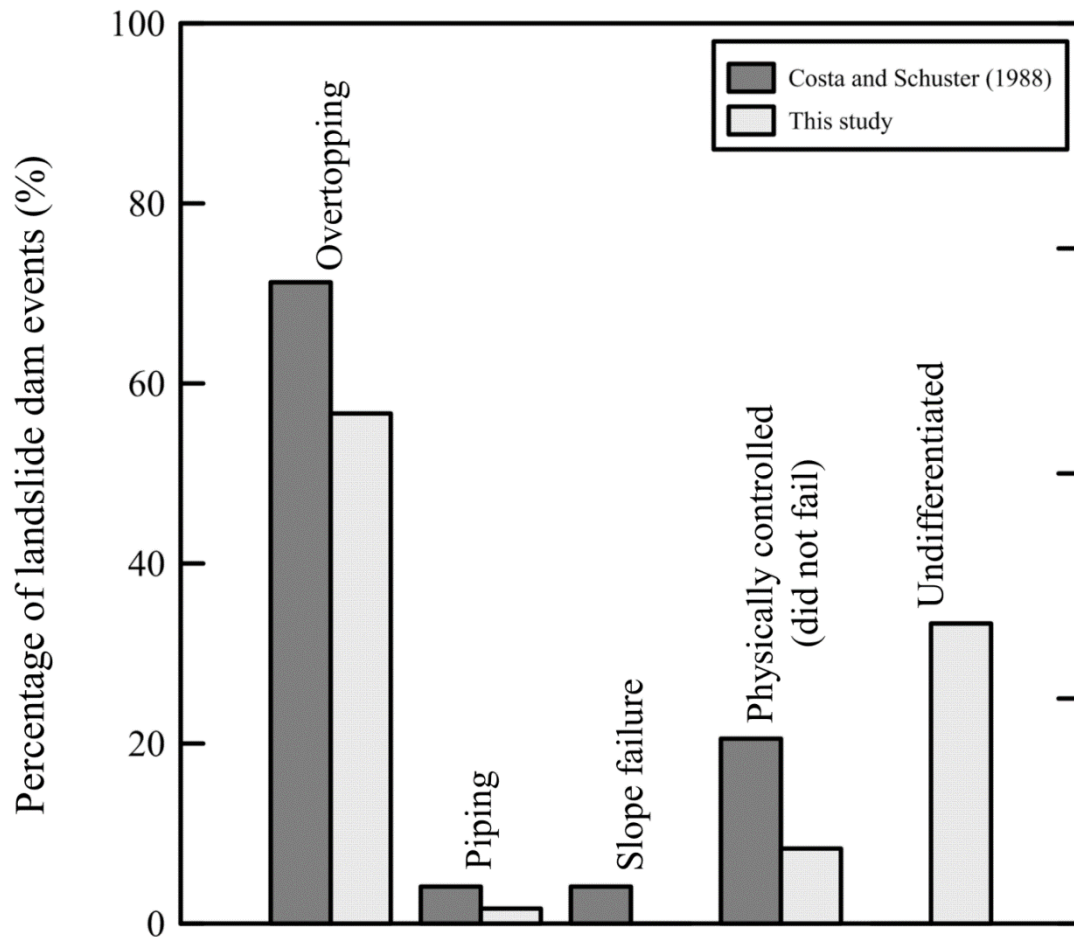
Piping: It is a kind of internal erosion caused by the migration of particles to free exits or by the uncontrolled saturation and seepage forces.

slope failure: It can easily occur when a landslide dam has steep upstream and downstream faces, as well as high pore-water.

Costa and Suhuster classified 55 natural dams from around the world into four types of damage patterns, including overtopping, piping, slope failure, and engineering control. The statistical result of damage type is shown in Figure, which shows that overflow damage is the most important damage type of natural dam.

A landslide dam in its natural state differs from a constructed embankment dam in that it is made up of a heterogeneous mass of unconsolidated or poorly consolidated earth material and has no engineered water barrier, filter zones to prevent piping, nor drain zones to control pore pressures.

It also has no channelized spillway or other protected outlet; consequently, landslide dams commonly fail by overtopping, followed by breaching from erosion by the overflowing water.



Costa & Schuster (1988)

Overtopping process

After the formation of the landslide dam, the water storage continued to increase, and it began to infiltrate the of the dam.



After the water overflows, it begins to erode the dam itself



eventually lead to the destruction of the dam



Stability assessment of landslide dam

To reduce the hazards caused by landslide dams, two important risk assessments must be conducted immediately upon the formation of a landslide dam, i.e., an assessment of dam stability and an assessment of dam-break discharge.

Hence, several researchers have proposed methods to conduct a preliminary risk assessment of dam stability based on morphological and watershed characteristics.

Also, some have used the geometrical and hydrological parameters of a dam to establish an empirical formula for evaluating landslide dam-break discharge.

The dimensionless blockage index

Ermini and Casagli proposed geomorphic index using watershed area, dam height, dam volume thus allowing the proposal of a preliminary method for assessing the degree of stability of a landslide dam.

All the inventoried landslide dams into two broad classes, on the basis of their observed evolution:

stable dam (SD): landslide dam that has remained stable and has not encountered a breach thus still impounding an existent or relict lake;

unstable dam (UD): landslide dam that has undergone erosion or collapse leading to a catastrophic breach, with the subsequent release of the impounded lake waters.

From geomorphic analysis, best results were reached through the definition of the dimensionless blockage index.

The diagrams of Figure show the results obtained by the log–log plot of events. three main domains can be separated as follows:

DBI < 2.75 stability domain

2.75 < DBI < 3.08 uncertain domain

DBI > 3.08 instability domain

$$DBI = \log \left(\frac{A_b \times H_d}{V_d} \right)$$

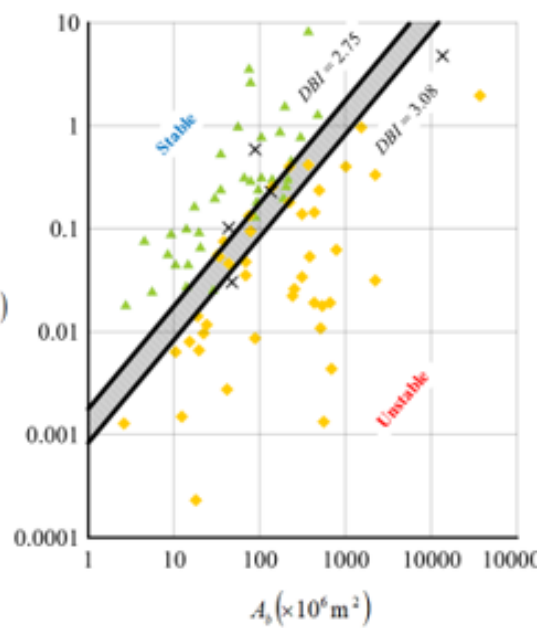
$$DBI \begin{cases} < 2.75 & \text{stable} \\ > 3.08 & \text{unstable} \end{cases}$$

$$\frac{V_d}{H_d} (\times 10^6 \text{ m}^2)$$

A_b : watershed area (m²)

H_d : dam height (m)

V_d : dam volume (m³)



Discriminant and logistic regression model

Dong used 43 natural dams in Japan to statistically analyze the stability assessment of natural dams and developed a discriminant analysis model using discriminant analysis. The parameters used in the model were catchment area upstream of the natural dam, dam height, natural dam volume, dam width, and dam length.

After substituting the natural dam data into the analytical model, the value of the discriminant is obtained. When the value > 0 , it means that the natural dam is in the stable range, while the value < 0 means that the natural dam is in the unstable range.

Dong also used the logistic regression model to establish the evaluation method, when the value is greater than 0, it means that the natural dam is in the stable range, while the value is less than 0, it means that the natural dam is in the unstable range.

Discriminant analysis

$$AHLW_Dis = -2.62 \log(A_b) - 4.67 \log(H_d) + 4.57 \log(L) + 2.67 \log(W) + 8.26$$

$$AHV_Dis = -2.13 \log(A_b) - 4.08 \log(H_d) + 2.94 \log(V_d) + 4.09$$

AHLW_Dis & AHV_Dis < 0 unstable

Logistic regression model

$$AHLW_Log = -2.22 \log(A_b) - 3.76 \log(H_d) + 3.17 \log(L) + 2.85 \log(W) + 5.93$$

$$AHV_Log = -4.48 \log(A_b) - 9.31 \log(H_d) + 6.61 \log(V_d) + 6.39$$

AHLW_Log & AHV_Log < 0 unstable

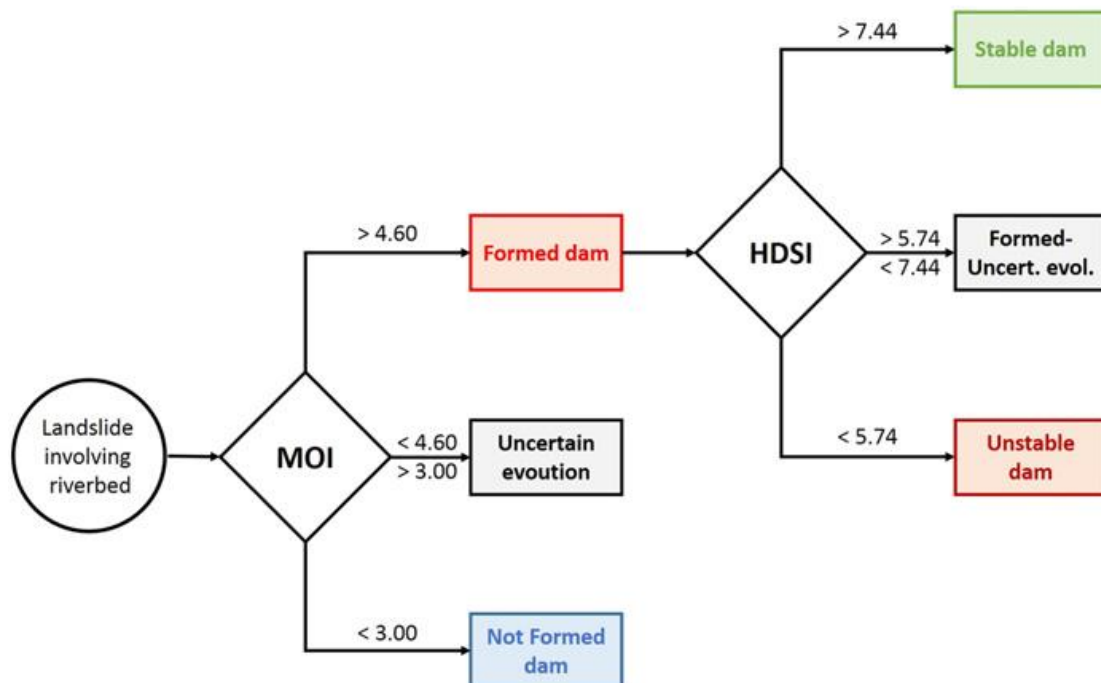
A_b : watershed area (m^2) L : dam length (m)

H_d : dam height (m) W : dam width (m)

V_d : dam volume (m^3)

Hydromorphological dam stability index-1

Stefanelli in 2016 proposed a combined landslide dam formation and stability assessment index, the formation assessment index is called Morphological Obstruction Index, MOI and the stability assessment index is called Hydromorphological dam stability index, HDSI. When the MOI is greater than 4.6, the dam will be formed by the landslide, and then the HDSI will be evaluated. When the HDSI is less than 5.74, there is a risk of damage to the dam.



Hydromorphological dam stability index-2

The MOI is evaluated using two factors: the landslide volume and the river width. When the MOI is less than 3, the landslide will not form a dam, and when the MOI is greater than 4.6, the landslide will form a dam.

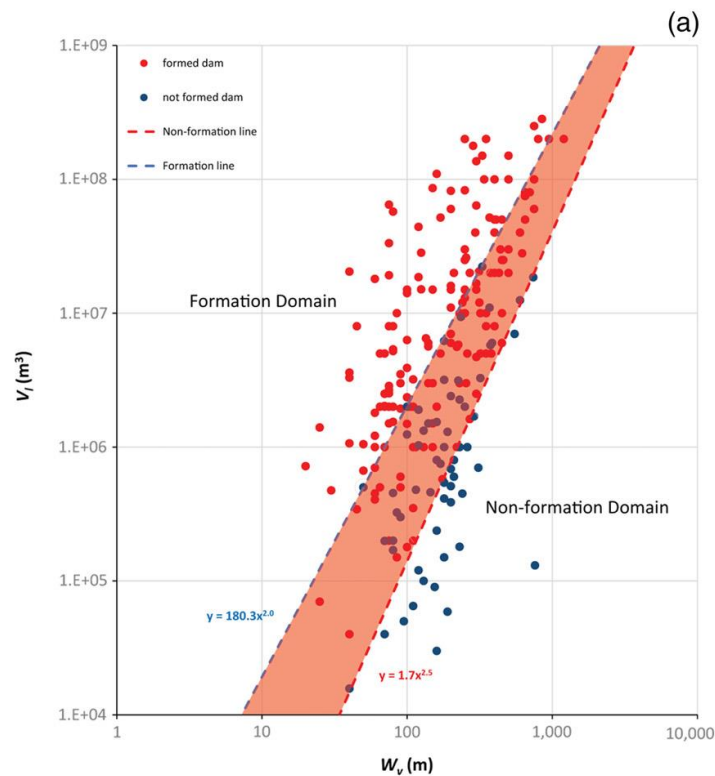
$$\text{MOI} = \log \left(\frac{V_L}{W_V} \right)$$

MOI < 3.00 not formed

MOI > 4.60 formed

VL : landslide volume (m³)

WV : river width (m)



Hydromorphological dam stability index-3

HDSI is mainly used to evaluate the stability of the dam by the landslide volume, watershed area, and river slope, when the HDSI is less than 5.74, the dam is in a stable state, when the HDSI is greater than 7.44, the dam will likely be damaged.

$$\text{HDSI} = \log \left(\frac{V_L}{A_b S} \right)$$

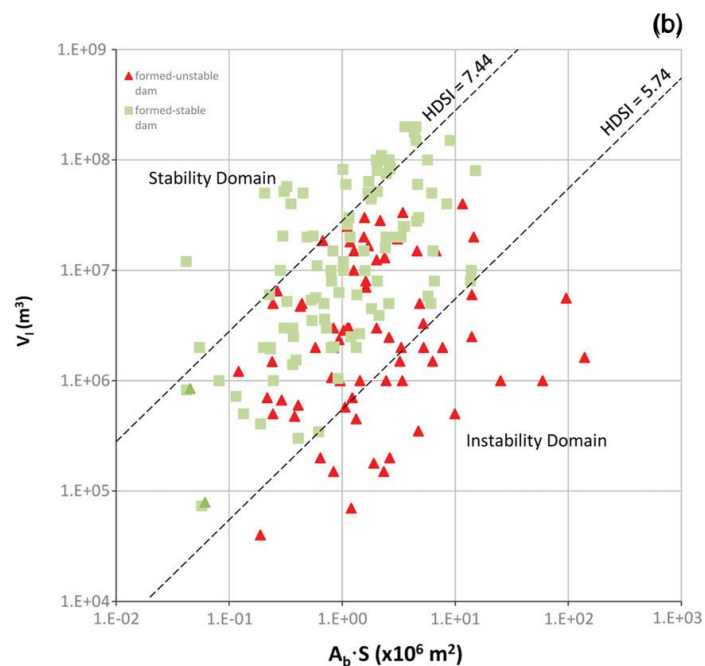
HDSI < 5.74 stable

HDSI > 7.44 unstable

V_L : landslide volume (m^3)

A_b : watershed area (m^2)

S : river slope (°)



Conclusions

- ✧ Landslide dams remain a physical process which is not well understood, because they are the result of the complex interaction between river and slope dynamics. The prevailing factor out of these two is often fundamental in controlling the fate of the landslide dam.
- ✧ Usually, landslides triggered by earthquakes are capable of carrying a greater amount of material to the river channel, thus forming a more substantial landslide dam.
- ✧ Three failure mechanisms typically caused the instability and failure of landslide dams, including overtopping failure, piping failure, and slope failure.
- ✧ The clarification of the potential damage pattern of landslide dams will facilitate the formulation of disaster prevention and response strategies, and help improve disaster prevention and response capabilities.