



UNIVERSITI
KEBANGSAAN
MALAYSIA
*National University
of Malaysia*



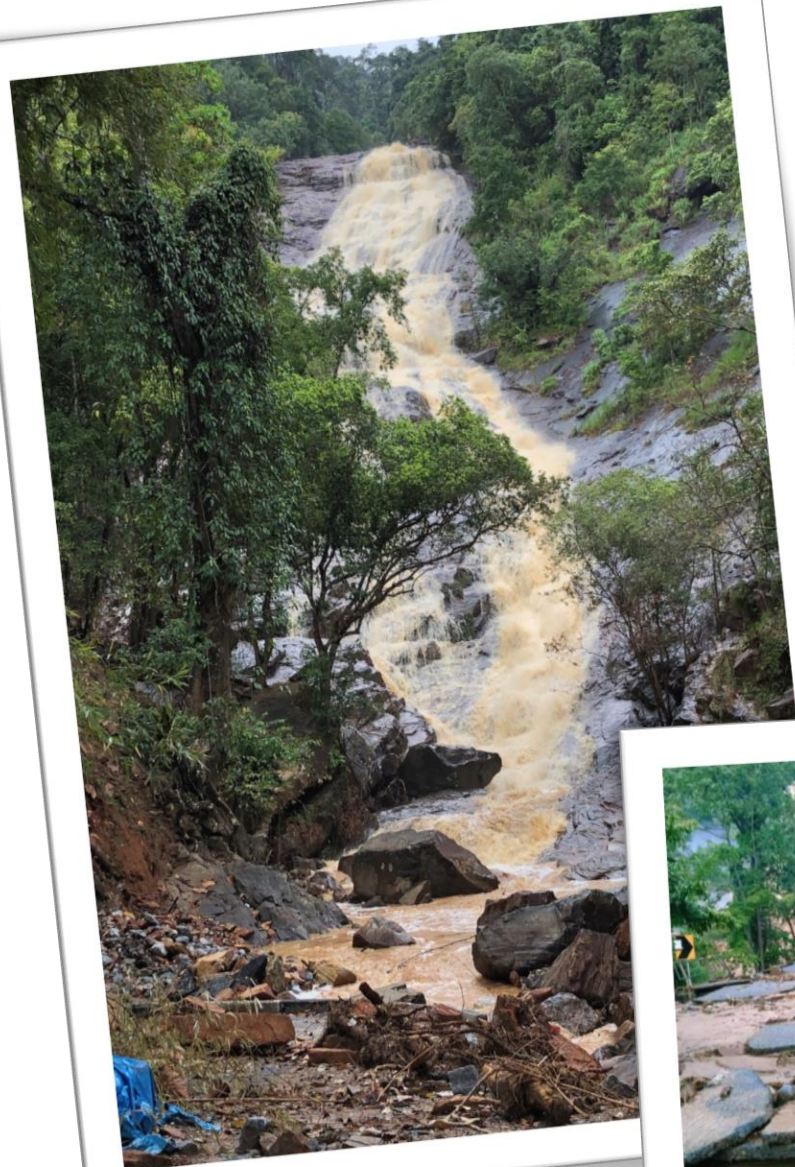
NATIONAL WATER INSTITUTE OF MALAYSIA (NAHRIM)
MINISTRY OF ENVIRONMENT AND WATER (KASA)

SEAL PROJECT: DISCUSSION ON GUIDELINES

HEADWATER PHENOMENON: MITIGATION MEASURES AND WAY FORWARD IN RESEARCH AND DEVELOPMENTS

Ir. Ts. Dr. Safari Bin Haji Mat Desa
Director of River Basin Research Centre,
National Water Institute of Malaysia (NAHRIM)
Ministry of Environment and Water (KASA)

8:00 AM London/ 4:00 PM Malaysia
7 January 2022



CONTENT



1

BACKGROUND

2

NARHIM'S ROLES

3

**PROPOSED SABO DAM
CONSTRUCTIONS**

4

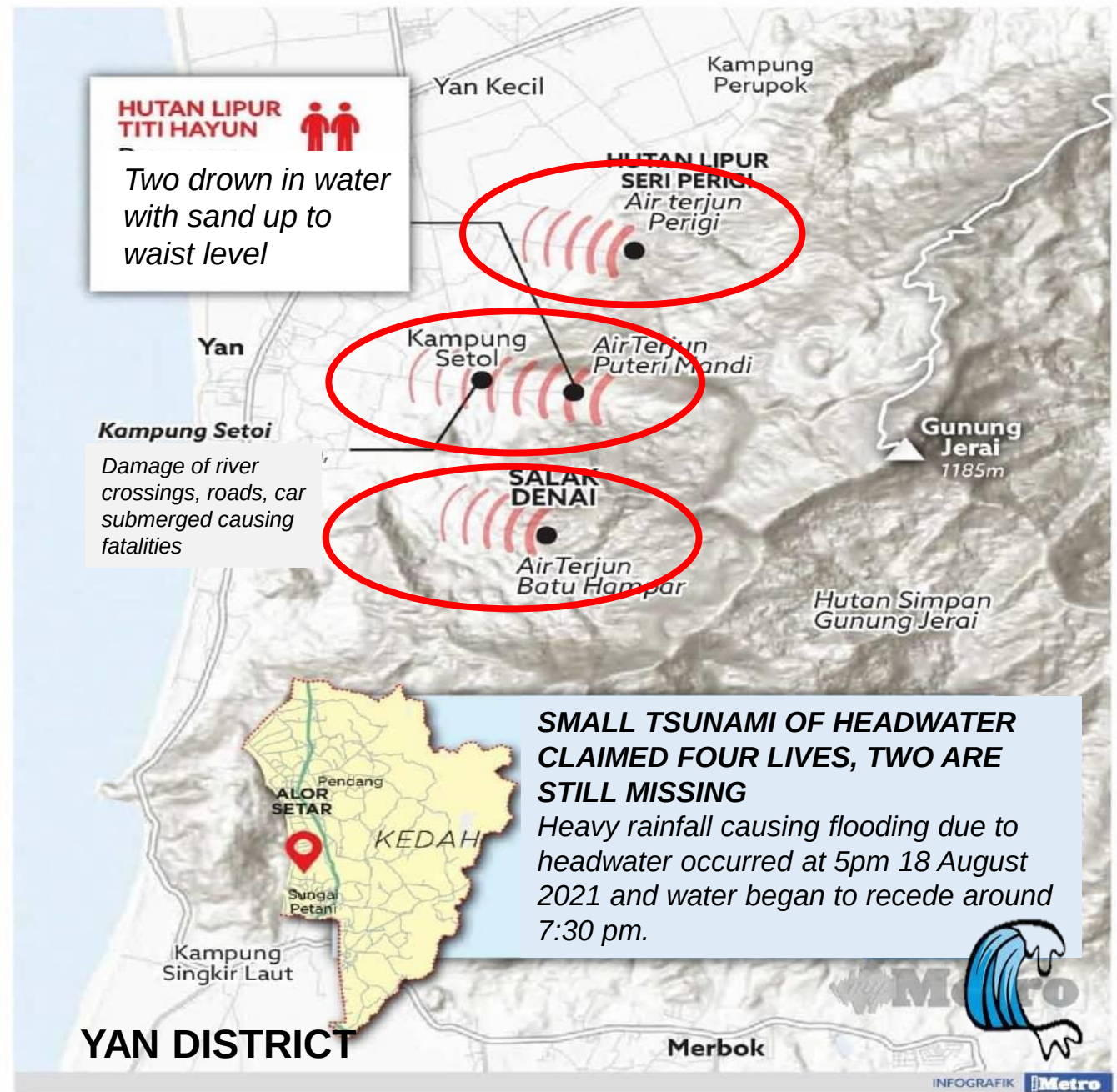
WAY FORWARD

- **HEADWATER PHENOMENON AT MOUNT JERAI – 18 AUGUST 2021**
- **DISASTER LOCATIONS**
- **SITE VISIT- INITIAL OBSERVATIONS FROM 27 TO 28 AUGUST 2021**
- **POST DEBRIS FLOW CONDITIONS**

HEADWATER PHENOMENON AT MOUNT JERAI – 18 AUGUST 2021

- On **18 August 2021** around 2.30 pm, heavy rainfall occurred in the northern region of Peninsular Malaysia covering the states of Perlis, Kedah, Penang and Perak
- **Unusual rainfall intensities** at the top of Mount Jerai (Total rainfall: **281 mm in 6 hours** exceeding **70-year** Average Recurrence Interval (ARI))
- The daily rainfall reading at Gunung Jerai Station on 18 August 2021 is above the average monthly rainfall
- **Serious flooding incidents** were reported at several areas in Kedah (Yan, Kota Muda, Gurun), Pulau Pinang (Balik Pulau, Seberang Perai Selatan) and Perak (Kerian, Selama, Larut Matang, Mualim)
- The **rapid flow** has **swept away logs, boulders and debris** which stucked at bridges causing the river to overflow into nearby settlements (Kampung Tupah and Taman Tupah)
- The morphological factor of Mount Jerai (**Old dormant landslide**) contributes to the frequency of landslide events

A satellite map of Mount Jerai, Kedah (1207 m). The map shows the mountain peak in the center, surrounded by green forested areas. To the left is a large body of water (the sea). To the right and top are agricultural fields and some built-up areas. Several locations are marked with yellow pins and labels: Teror, Gurun, Hutan Lipur Sungai Teror, Air Terjun Sungai Kunyit, Hutan Lipur-Seri Perigi, Yan, Hutan Lipur Titi Hayun, Air Terjun Putei Mandi, Gunung Jerai (marked with a red triangle), Hutan Lipur Rekreasi Tupah, and Singkir. The text 'Mount Jerai, Kedah (1207 m)' is prominently displayed in the center. The Google Earth logo is in the bottom right corner. Small copyright text at the bottom center reads: 'Image © 2020 CNES / Airbus', 'Image © 2020 Maxar Technologies', 'Image © 2021 TerraMetrics'.



Disaster area

Headwater
phenomenon
recorded at Tupah
Water Treatment
Plant (SADA),
Kuala Muda
District on 18
August 2021



Source: Syarikat Air Darul Aman Sdn. Bhd. (SADA), 2021

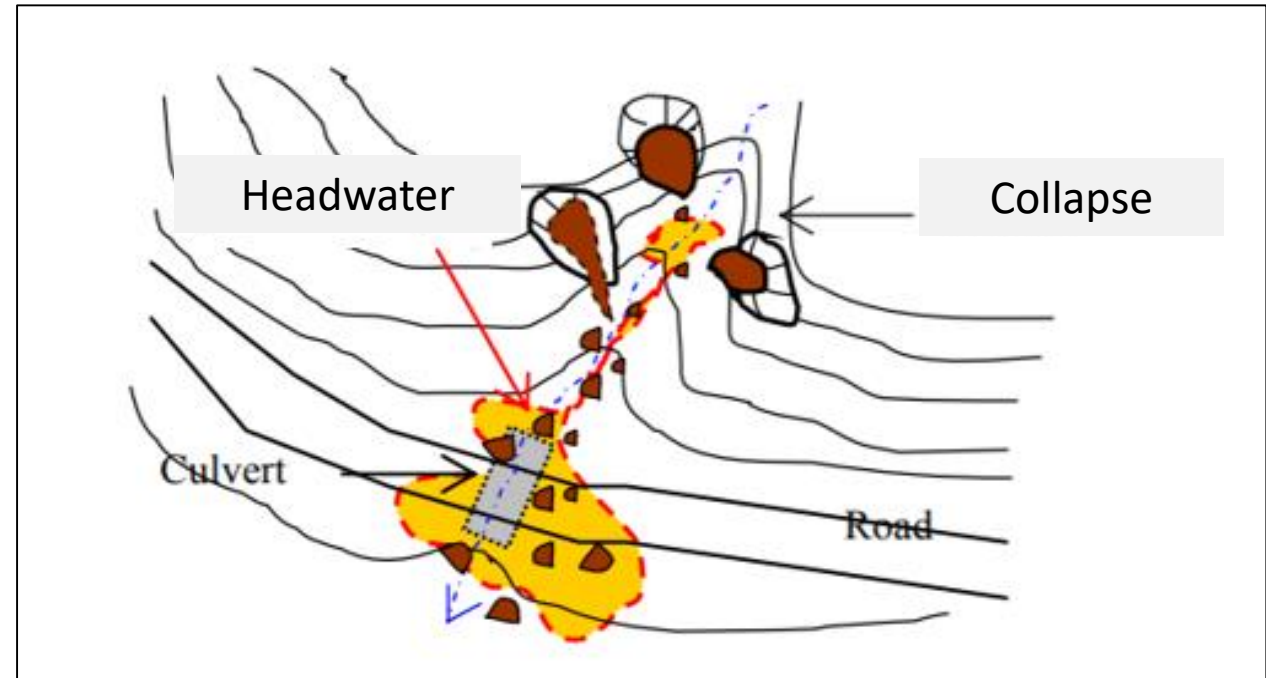


RAINFALL RECORDS ON 18 AUGUST 2021

Maximum rainfall
records (mm) for rainfall
stations at Mount Jerai
and Singkir Genting on
18 August 2021

Rainfall duration	Name and Coordinate of Stations	
	Mount Jerai (5.797820 N, 100.437340 E)	Singkir Genting (5.733183 N, 100.375699 E)
	Maximum rainfall (mm)	Maximum rainfall (mm)
1-hour	91.0	55.5
2-hour	166.5	83.0
3-hour	212.0	118.5
4-hour	237.0	142.0
5-hour	270.5	155.5
6-hour	277.0	164.5
7-hour	280.0	165.0

HEADWATER PHENOMENON



Headwater Schematic Illustration (JICA, 2007)

1

Headwater is the rapid movement of fragments of rocks/ boulders/ soil/ mud/ logs mixed with water along a river

2

Headwater occur when weakened soils were loaded or disturbed and saturated with water flowing down a slope with response of gravity. Therefore, flows usually begin from upstream in mountainous areas

3

Headwater has a high velocity (i.e: velocity increase gradually due to gravity and at steep slope area)

4

It leads to significant morphological changes along the river bed and mountain slope. Headwater often reported to cause loss of lives and damage of properties

WATER QUANTITY ESTIMATION

Total rainfall= 281 mm (6 hours)
Estimated water quantity:
~6,197,631 m³



~ Can fill **1/4 Klang Gate Capacity**
~ **2479 x Olympic-size swimming pool**



IMPACT OF DEBRIS FLOW

Estimated Force for a total of 50 boulders (~ 1 meter in diameter with a mass of 2691kg, moving with a velocity of 14 m/s)
~471kN



~ **3** x impact of trailer collision (Weight with Load = 50 ton moving with a speed of 50 km/hr)

SITE VISIT-INITIAL OBSERVATIONS

FROM 27 TO 28 AUGUST 2021



LAND AND RIVER MORPHOLOGY CHANGES DUE TO HEADWATER PHENOMENON



**TITI HAYUN RECREATIONAL FOREST, YAN
DISTRICT, KEDAH**

Source: DID Kedah, 2021



BATU HAMPAR RECREATIONAL PARK, YAN DISTRICT, KEDAH



**TUPAH RECREATIONAL FOREST, KUALA MUDA DISTRICT,
KEDAH**

Source: NAHRIM, 2021

POST DEBRIS FLOW CONDITIONS



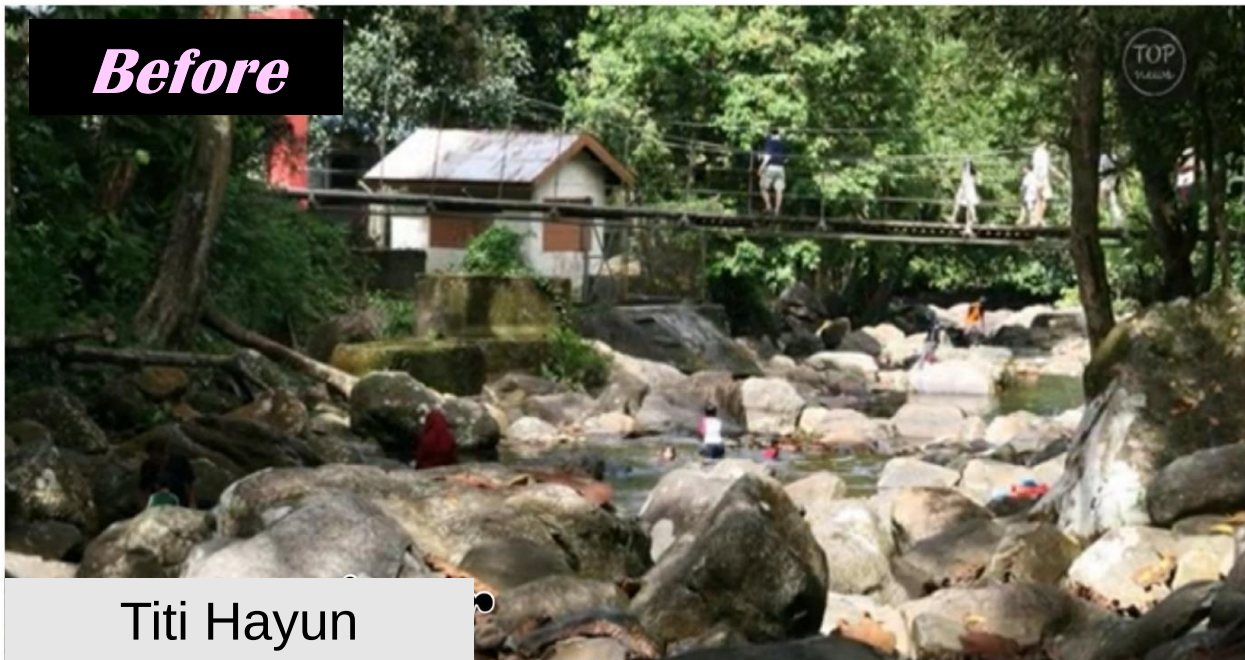
Location: Puteri Ayu Chalet, Yan District, Kedah



Properties, facilities and infrastructures were damaged due to mud floods

Sumber: NAHRIM, 2021

Before



Titi Hayun
Recreational
Forest



After

PIC•COLLAGE

Before



Tupah Water
Treatment Plant
(SADA)



After

20/08/2021 11:22:16

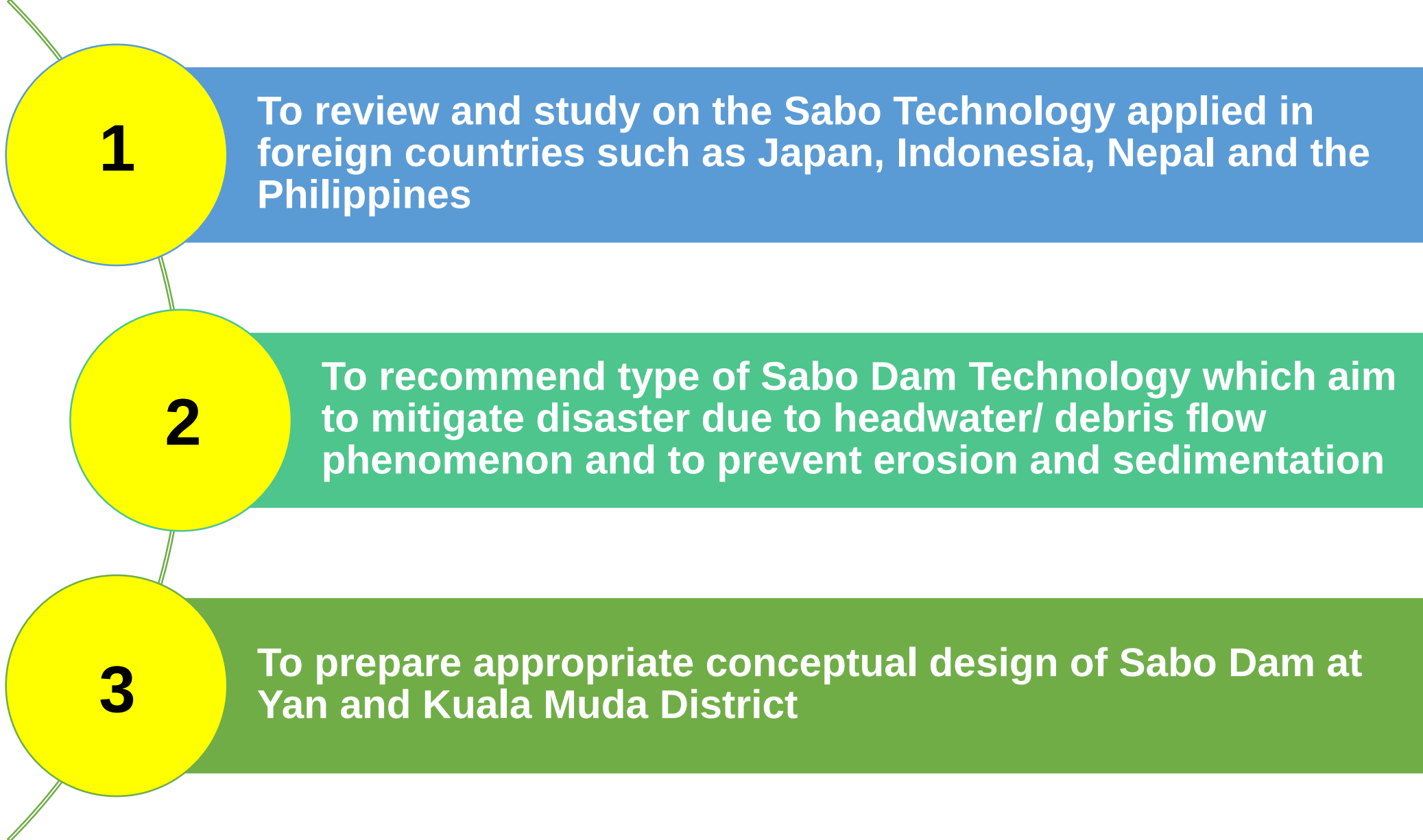
**IMPACTS OF
DEBRIS FLOW
AT PUTERI
MANDI
WATERFALLS
TTI HAYUN
RECREATIONAL
FOREST, YAN
DISTRICT,
KEDAH**



Source: Kedah State Forestry Department, 2021

2

NARHIM'S ROLES



1

To review and study on the Sabo Technology applied in foreign countries such as Japan, Indonesia, Nepal and the Philippines

2

To recommend type of Sabo Dam Technology which aim to mitigate disaster due to headwater/ debris flow phenomenon and to prevent erosion and sedimentation

3

To prepare appropriate conceptual design of Sabo Dam at Yan and Kuala Muda District

- **DEFINITION OF SABO DAM**
- **FUNCTION AND APPLICATION**
- **TYPE OF SABO DAMS**
- **MAIN COMPONENTS OF SABO STRUCTURES**
- **APPLICATION IN FOREIGN COUNTRIES**
- **SABO FACILITIES IN MALAYSIA**
- **CONTRIBUTING FACTORS FOR DAM SITE SELECTION**
- **PROPOSED LOCATION FOR SABO DAM CONSTRUCTION**
- **DATA COLLECTIONS AT SITE**



DEFINITION OF SABO DAM



- ✓The word SABO originated from Japanese languages “Sa” and “Bo” which means *erosion and sediment control works*
- ✓The term SABO means a reaction of rocks and sands which bringing the efforts of land and soil erosion control at mountainous areas; protecting humans and infrastructures at downstream in particular from the treat of erosion and sedimentation disasters.
- ✓There are two (2) types of Sabo Dam namely Open Sabo Dam and Closed Sabo Dam.

FUNCTION AND APPLICATION



a

To trap erosion/ debris flow till discharge decreased

b

To decrease erosion/ debris flow rate

c

To serve as a *sediment settling* zone

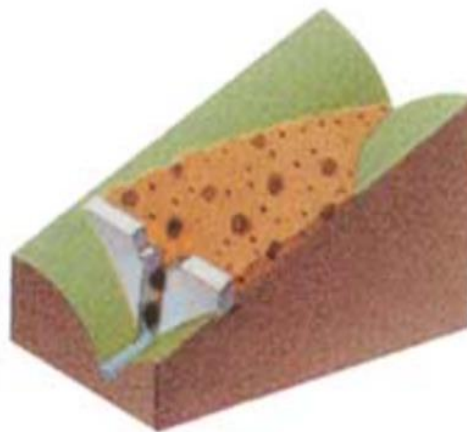
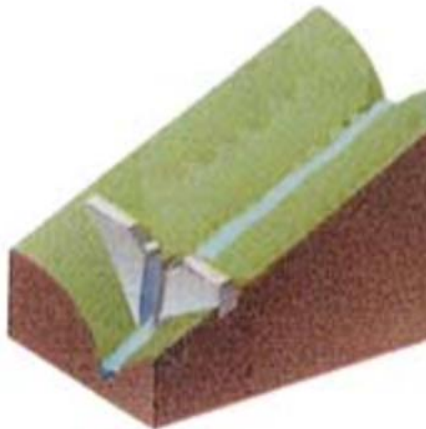
d

To guide the flow in preventing the spread of erosion/ debris flow

e

To control erosion/ debris flow

Sabo Dam allows sediments to flow from upstream to downstream during normal conditions



When a large-scale of debris flow occurs, sediments/ rocks/ boulders will be trapped and temporarily hold at the back of Sabo dam to avoid headwater or debris flow disaster at river downstream

Advantages of Sabo Dam:

- ✓ Avoid headwater/ debris flow phenomenon
- ✓ Control logs, rocks, boulders and sediments flow
- ✓ Stabilize river banks and bed
- ✓ Preserving slope and biodiversity
- ✓ Save lives, minimize property damages and protect the environment

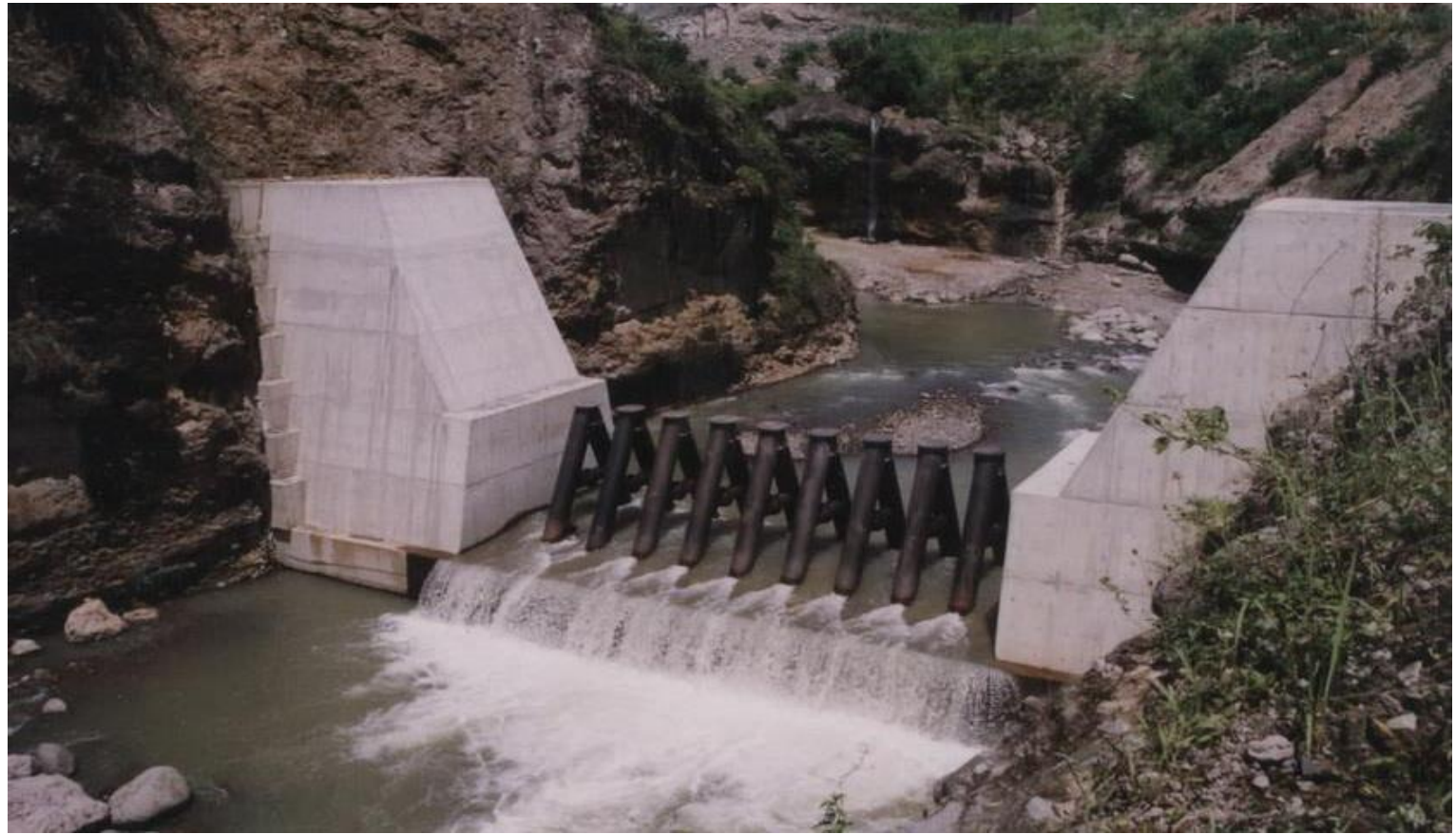
Data from Japan

- Japan has installed more than **50,000** Sabo facilities since **1897** with the introduction of the **SABO Act**
- Overcome an average of 1,000 incidences of erosion and landslides each year

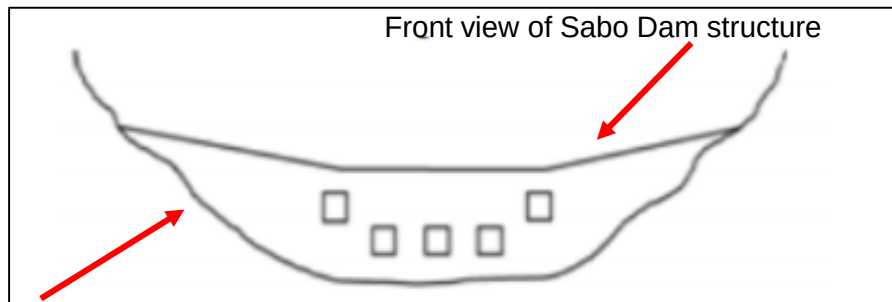
TYPE OF SABO DAM

OPEN SABO DAM

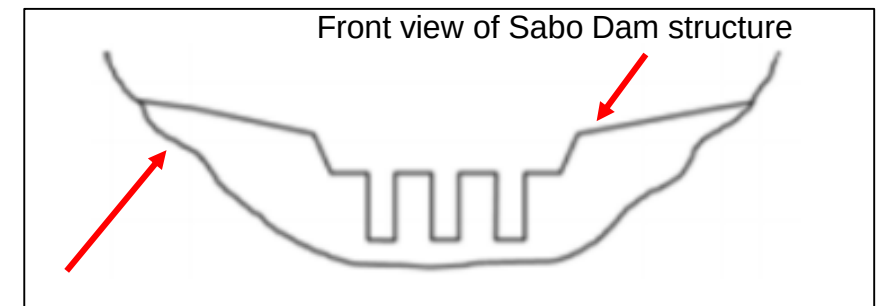
- ✓ Water flow through holes or opening/ slits and large pieces of soil/ rocks/ logs will be retained
- ✓ This type of Sabo Dam slow down the flow of high volume water
- ✓ Typically constructed at upstream and mountainous area



Example of Open Sabo Dam (Segawe) located in Indonesia
(Source: Utusan Malaysia, 2021)



River flow Open Sabo Dam with holes/ openings

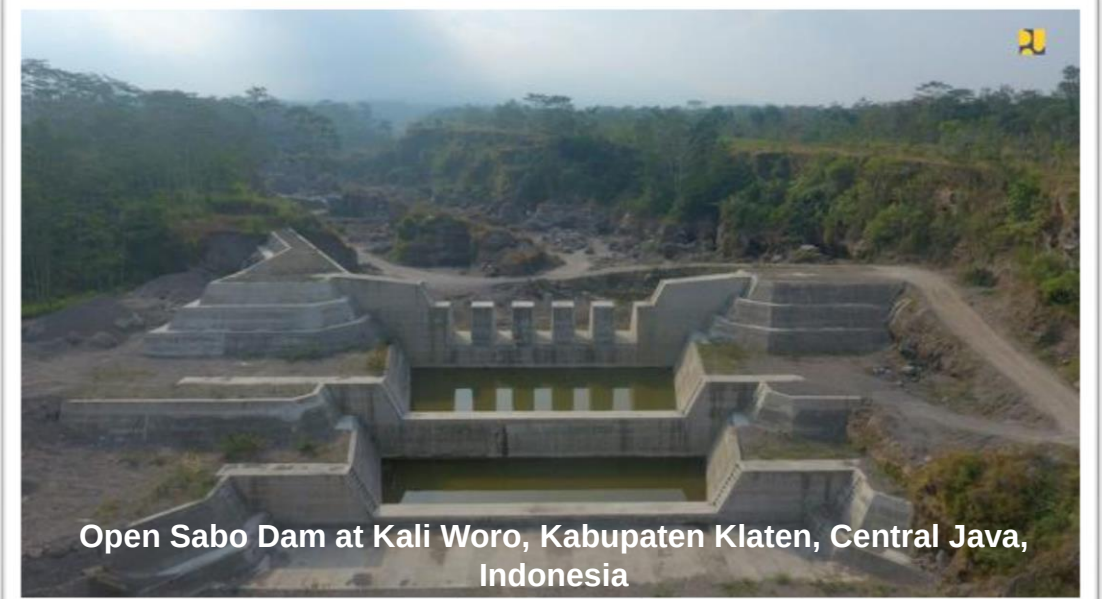


River flow Open Sabo Dam with *slit*

EXAMPLE OF OPEN SABO DAM



Open Sabo Dam at Mount Merapi, Indonesia



Open Sabo Dam at Kali Woro, Kabupaten Klaten, Central Java, Indonesia



Open Sabo Dam at Mount Merapi, Indonesia



Open Sabo Dam at Kabupaten Magelang, Central Java, Indonesia



**Open Sabo Dam at Ishigawa,
Japan**



**Open Sabo Dam at Nagai
River, Japan**



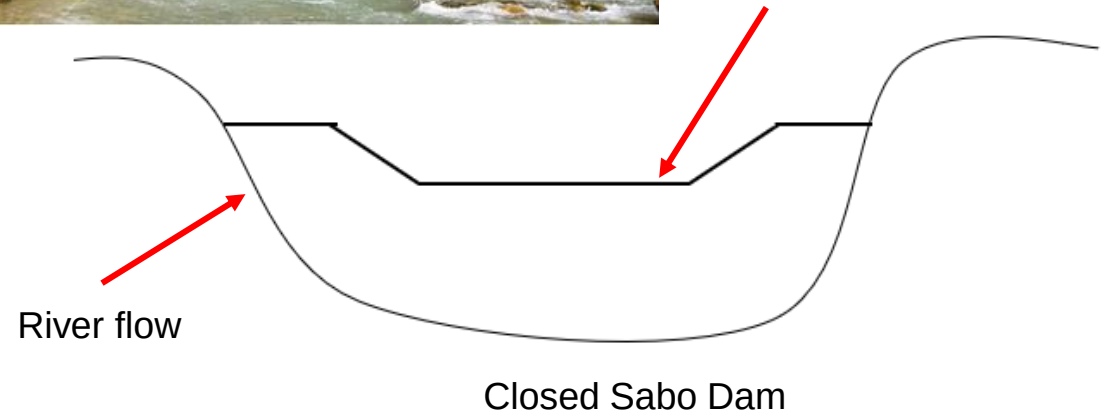
**Open Sabo Dam at Hyogo,
Japan**

CLOSED SABO DAMS

- ✓ Water will flow through the top of the dam and erosion/ sediment/ debris will be trapped
- ✓ Closed Sabo Dam filled up very fast and need frequent and good maintenance works
- ✓ Typically built at river downstream
- ✓ Functioning like a *check dam*



Front view of Sabo Dam structure



MAIN COMPONENTS OF SABO STRUCTURE

✓ Comprises of two (2) main components which are main components and supporting structures:

✓ Main components:

1. Spillway

2. Wing

3. Drain hole

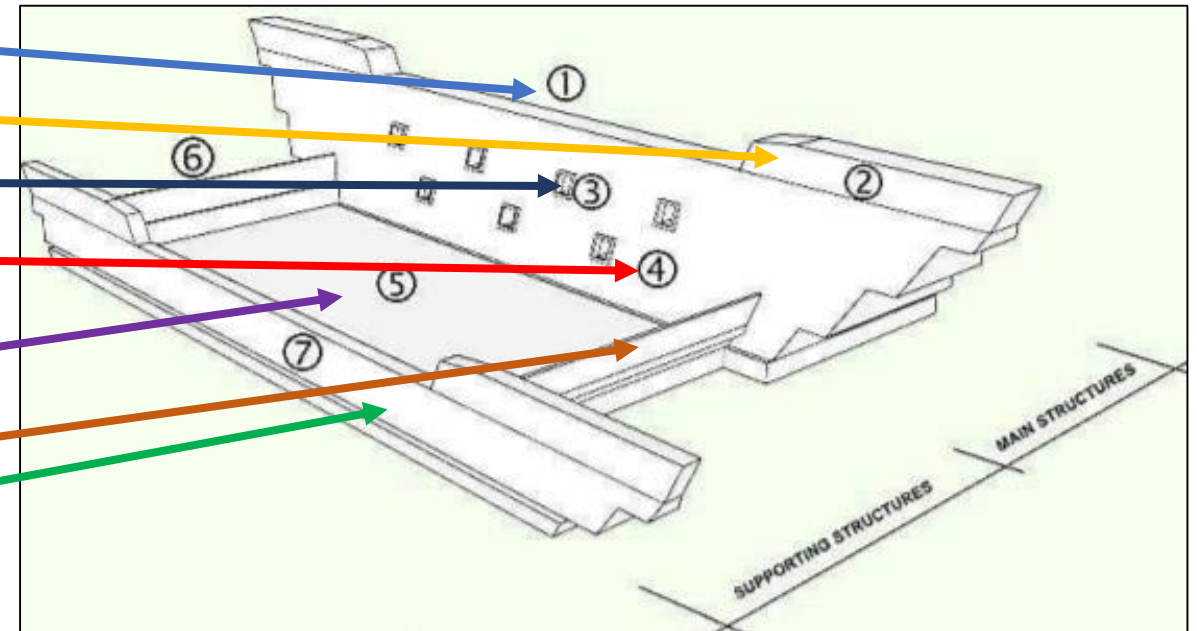
4. Main dam

✓ Supporting structures:

5. Apron

6. Side wall

7. Sub dam

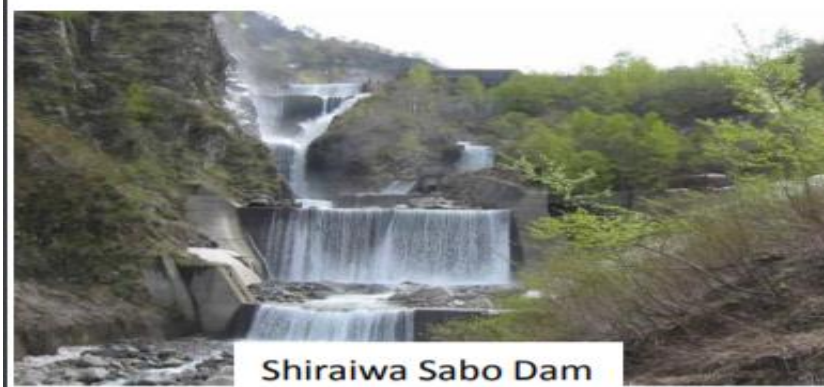


APPLICATION IN FOREIGN COUNTRIES

-SABO DAM IN JAPAN

● Sabo dam

Controls sediment outflow from upstream (adjustment function) and prevents collapse and erosion of the river bed and sides, preventing damage to the downstream area.



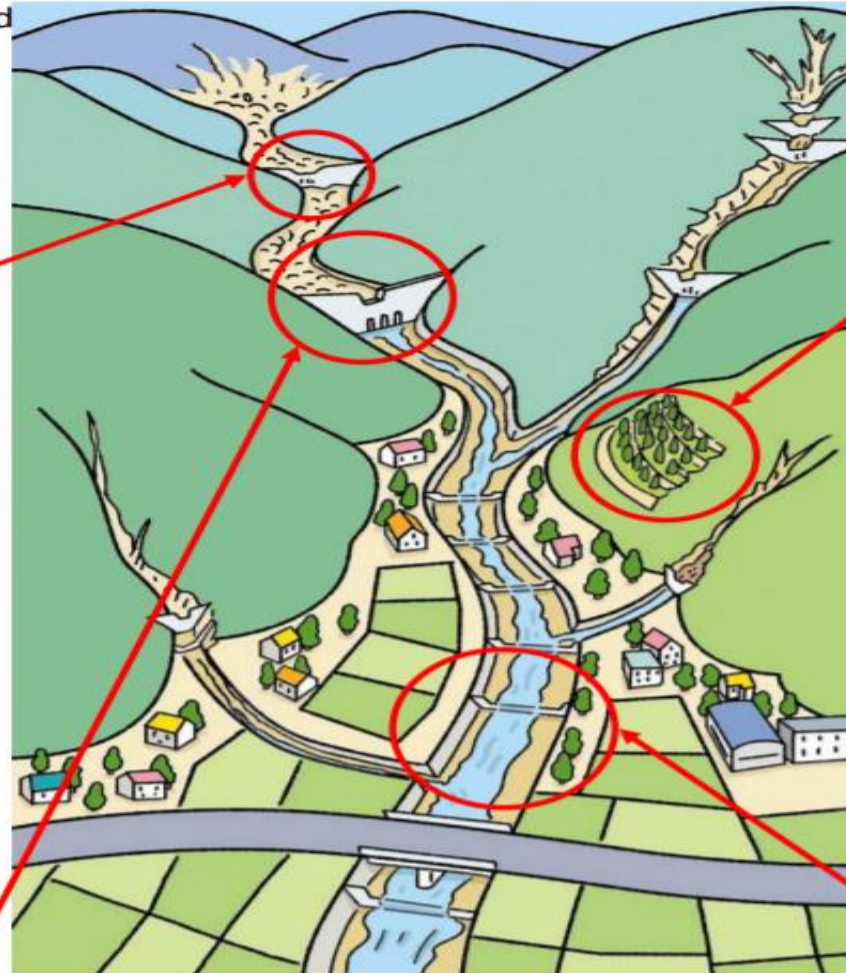
Shiraiwa Sabo Dam

● Sabo dam (Transmission type erosion control dam)

Having an adjustment function by flowing out the sediment with small and medium sized particles, capturing sediment containing large stones and driftwood at the time of massive flooding.



Ohtanasawa No.2 Sabo Dam



Erosion Control Facility
Created by the Sabo Department, MLIT

● Hillside work

To prevent collapse of the hillside and sediment outflow to recover the growth of plants and trees through end dam construction, draining work and planting.



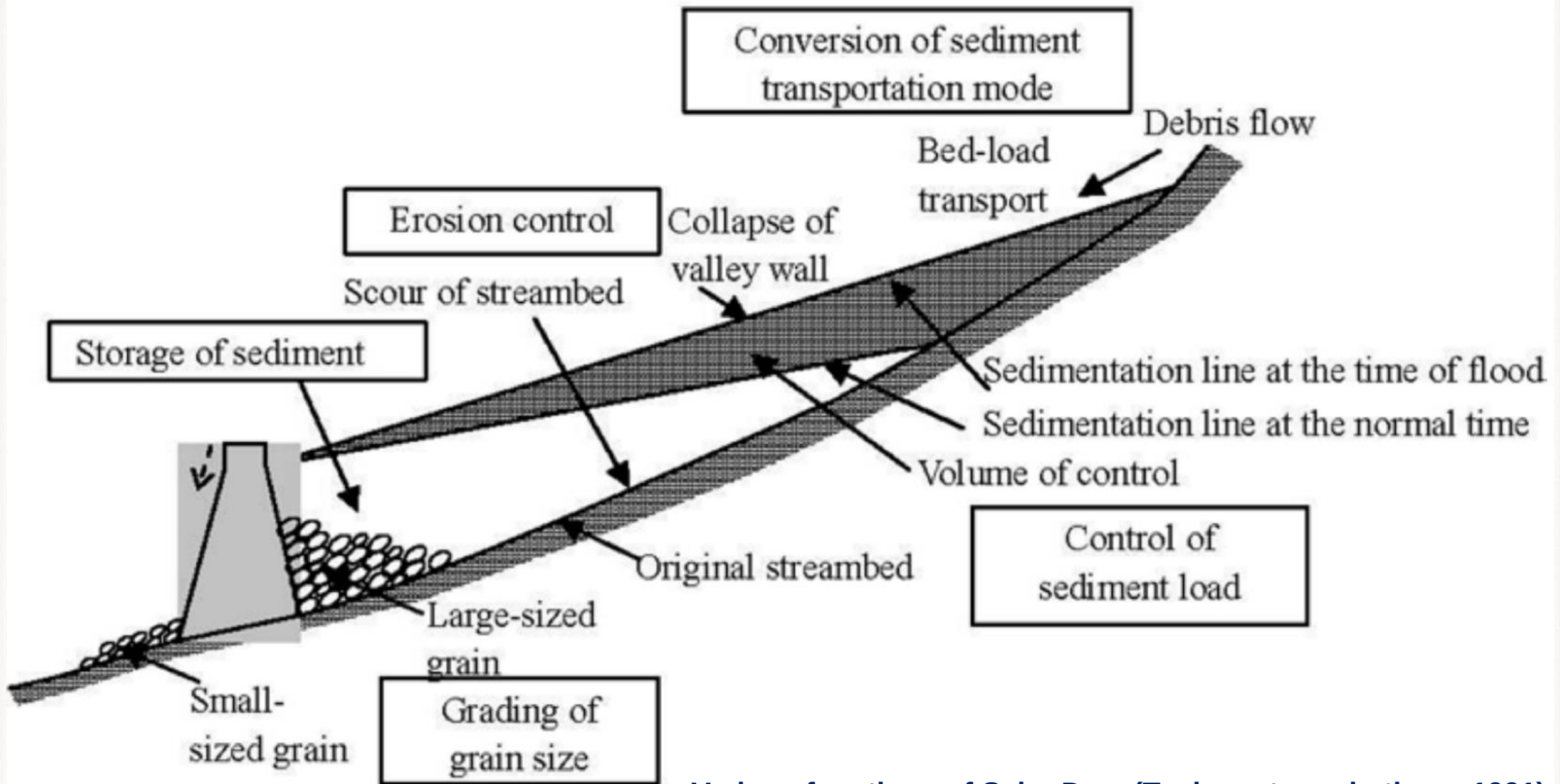
Hillside planted with Pine trees

● Mountain stream conservation work

Control of turbulent flow and drift to prevent erosion of the river bed and side by combining groundsill work and revetment work in the alluvial fan.



Groundsill work for the Otani River



Various functions of Sabo Dam (Tsukamoto and others, 1991)

APPLICATION IN FOREIGN COUNTRIES

-SABO DAM IN INDONESIA

- ✓ In Indonesia, Sabo technology was first introduced by the Japanese expert, Mr. Tomoaki Tokota (1970) to deal with the lava flooding issues in volcanic areas
- ✓ Debris flow originated from headwater will be trapped during heavy rainfall events
- ✓ There were a total of 264 Sabo Dams built along volcanic areas with various functions (Kompas.com, 2020)
- ✓ Others Sabo Dams constructed in Indonesia are located at Mount Kelud, Mount Agung, Mount Galunggung and Mount Semaru
- ✓ In non-volcanic areas, Sabo Dam is built to control erosion and sedimentation issues such as Bengkulu, Dieng and Waduk Mrica



Source: Kompas.com. (2020). *Mengenal Sabo Dam, Solusi Penanggulangan Banjir Lahar Gunung Merapi*. Retrieved August 27, 2021, from <https://www.kompas.com/tren/read/2020/11/22/190500965/mengenal-sabo-dam-solusi-penanggulangan-banjir-lahar-gunung-merapi-?page=all>

APPLICATION IN FOREIGN COUNTRIES

-SABO DAM IN NEPAL



Sabo Dam in Ruwa Khola



Sabo Dam in Khahare Khola

- ✓ In Nepal, Sabo dam was first built in 2006 in the Himalaya Mountains which experienced landslides frequently as a results of soil movement and water flows in mountainous regions
- ✓ Sabo dam serves to protect the river downstream areas where human settlements and urban townships are normally located
- ✓ Apart, Sabo dam helps to protect Marsyangdi Power Station in Ruwa Khola and the highway bridge
- ✓ The effectiveness of Sabo Dam was proven when the highway bridge and nearby settlements were safe during 2006 floods

Source: Adhikari, B. R. (2008). Application of SABO Technology to Control Debris Flow and Landslides: Experience from Mugling-Narayanghat Highway Disaster, Asian Disaster Reduction Center *March 2008*. Retrieved August 27, 2021, from https://www.adrc.asia/publications/TDRM2005/TDRM_Good_Practices/PDF/PDF-2008e/6.Nepal.pdf

APPLICATION IN FOREIGN COUNTRIES

-SABO DAM IN THE PHILIPPINES

- ✓ Sabo Dam Pilot Project in Santa Fe River is built in Santa Fe River and it is the first Sabo Dam in the Philippines *the Department of Public Works and Highways (DPWH)* in 2010
- ✓ JICA experts have been providing the technical guidance needed to the DPWH counterparts from the planning, design, and construction stages in order to effectively carry out the essence of technology transfer
- ✓ Sabo Dam can effectively control sediment transportation, prevent riverbed aggradation and help to mitigate water induced disasters (such as floods) as well as to reduce damages to properties, livelihood and human lives
- ✓ The Local Government Unit on the other hand envisioned that the Sabo Dam will become a famous landmark as the site will be developed as a mini park for recreational purposes



Conceptual Design of Sabo Dam Pilot Project in Santa Fe River



Sabo Dam Construction in May 2010

SABO FACILITIES IN MALAYSIA

-FIRST PROPOSED IN 2018 AT MOUNT KINABALU, SABAH



SUSULAN KINABALU SUDAH 'LONGGAR'
50 TAHUN PULIH SUNGAI TERJEJAS MENDAPAN SISA RUNTUHAN GUNUNG
Ms.9

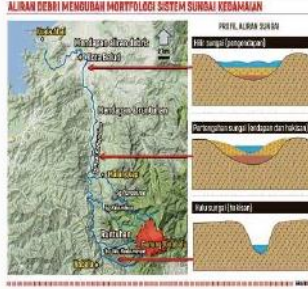
“Banjir berlaku di daerah itu kerana runtuhan gunung akibat kesan gempa bumi, berbeza dengan banjir di kawasan lain kerana pembalakan atau pembangunan tidak



terkawal,” katanya.

Beliau berkata, sisa yang terhasil daripada runtuhan biasanya lumpur dan pokok kayu, tetapi di Kota Belud membabitkan batu dan pasir segar yang merekah dari gunung dan jatuh ke Sungai Kadamaian.

“Banjir besar melanda Kelantan pada 2014 contohnya, hanya sekali dalam tempoh tertentu, tetapi di Kota Belud berulang tanpa kesudahan. Fenomena ini amat luar biasa dan kali pertama terjadi,” katanya



ALIRAN DEBRIS MENURUN MORTYLODI SISTEM SUNGAI KEDAMAIAN

Sementara itu, Ketua Pengarah Jabatan Pengairan dan Saliran (JPS), Datuk Ir Dr Md Nasir Md Noh, percaya usaha menyelamatkan Sungai Kadamaian bukan mudah, apatah lagi kerja mengorek ketika ini tidak banyak membantu menyelesaikan

masalah dialami.

Beliau berkata, kajian pihaknya mengenal pasti 10 juta meter padu mendapan batuan dan pasir memenuhi Sungai Kadamaian ketika ini, diburukkan lagi apabila gempa susulan yang mencetus runtuhan baharu masih berterusan.

Katanya, jumlah mendapan dalam Sungai Kadamaian cukup besar dan luar biasa, setakat ini hanya 1 juta meter padu mendapan berjaya dikeluarkan melalui kerja mengorek yang dijalankan.

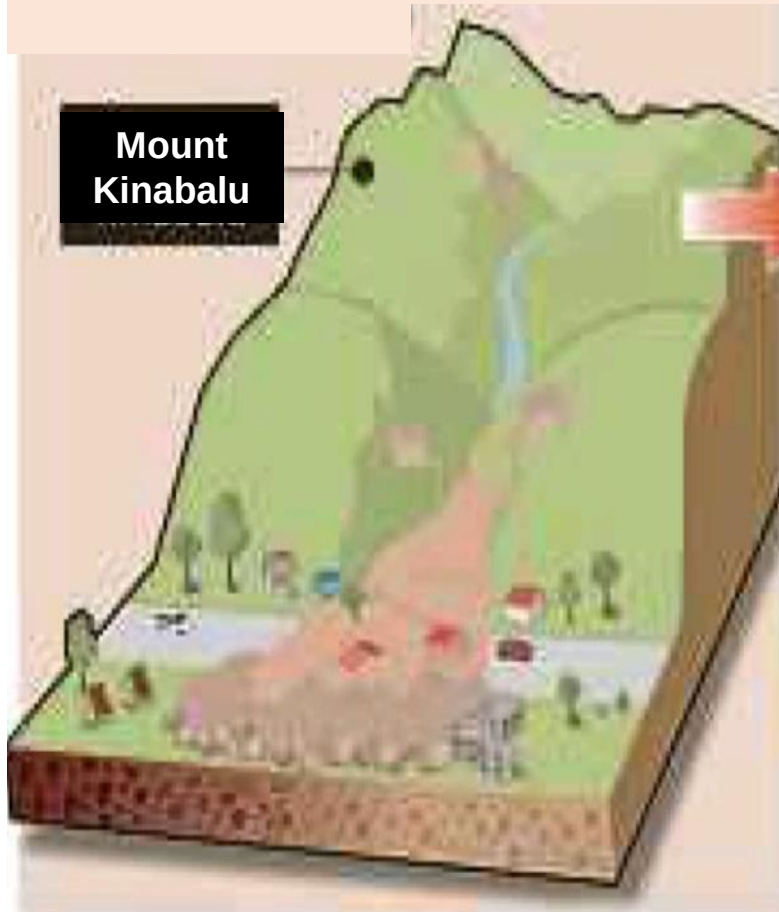
IMPACTS OF EARTHQUAKE ON 5 JUNE 2015

Source: Berita Harian. (2018). Susulan Kinabalu sudah 'Longgak' 50 tahun pulih Sungai terjejas Mendapan Sisa Runtuhan Gunung. Retrieved September 17, 2021, from <https://www.pressreader.com/malaysia/berita-harian-malaysia/20181227/282565904257474/textview>

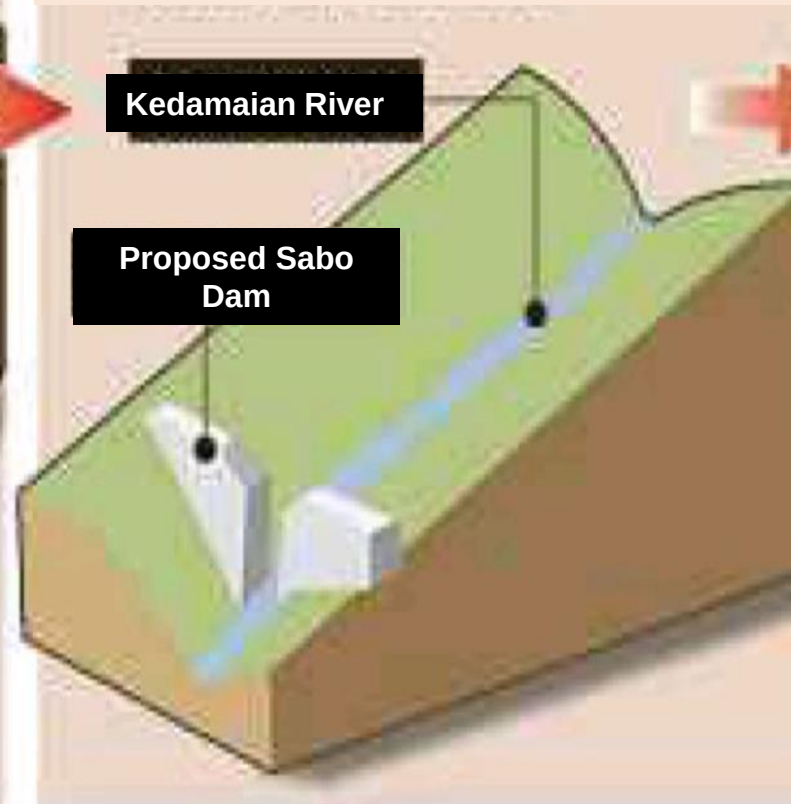
- ✓ The construction of dams using Sabo technology was first proposed in Malaysia to block debris (boulders) from Mount Kinabalu in 2018 due to the need to take into account on the requirements of earthquake -related specifications.
- ✓ It is important because Mount Kinabalu is still active with continuing minor/ small earthquakes, even though its location is far from the Pacific Ring of Fire.
- ✓ The collapse affected the low-lying areas such as Kota Belud, especially the Kedamaian River.
- ✓ During the proposal in 2018, two (2) Sabo Dams were proposed to block the debris from the top of the mountain and if the project goes ahead, it will be the first Sabo dam in Malaysia.
- ✓ The proposed area is 200 to 300 meters in length within the valley of two hills of Mount Kinabalu and estimated to cost RM30 million.
- ✓ In the plan, the Sabo Dam is designed to reduce debris flow from continuing to flow into low -lying areas such as Kota Belud via the Kedamaian River. The debris flow will be accumulated at the top of the dam.

PROPOSED SABO DAM AT FOOT OF MOUNT KINABALU

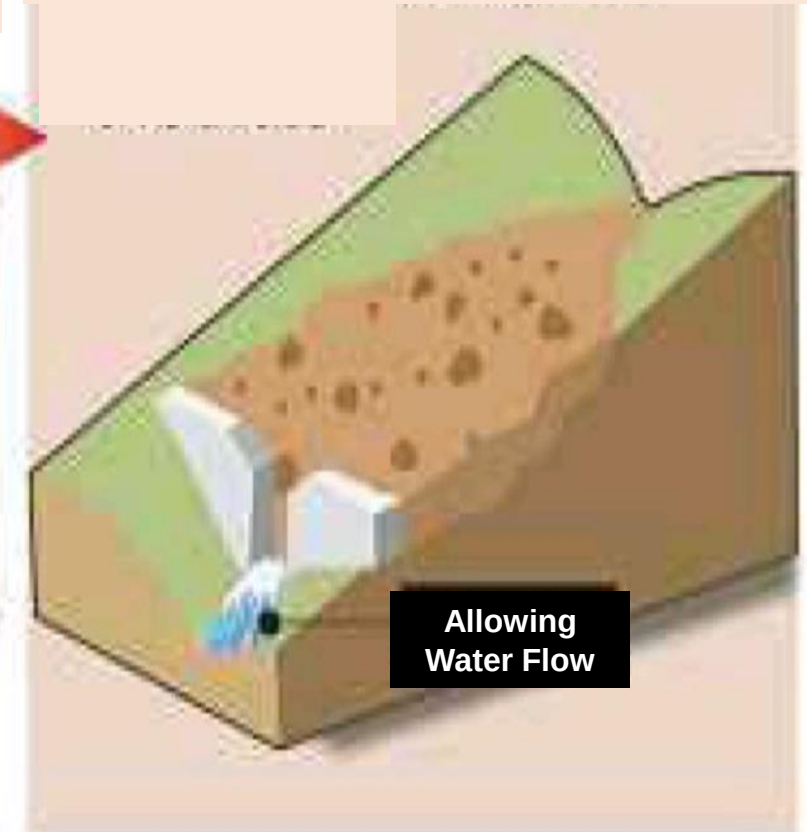
1. Debris from Mount Kinabalu flow towards low-lying area via Kedamaian River



2. Proposed Sabo Dam within the valley of two hills of Mount Kinabalu to block debris flow into Kedamaian River

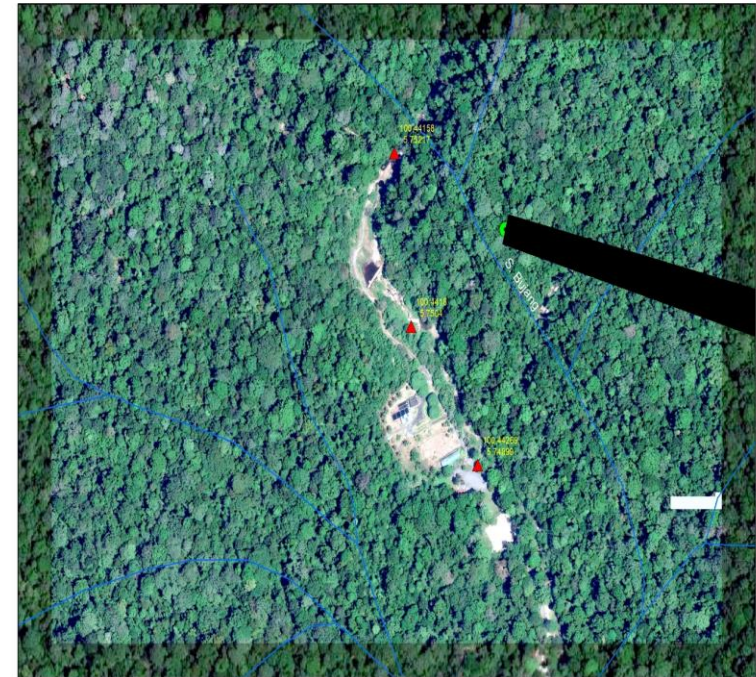


3. Debris flow carrying boulders and sand will be accumulated in the upstream of Sabo Dam while allowing Kedamaian River to flow through low-lying area in Kota Belud



CONTRIBUTING FACTORS FOR DAM SITE SELECTION

- Straight river channel
- Wide river channel
- Steep river bank
- Soil that has good bearing capacity



DATA COLLECTION BY NAHRIM

(River geometry, velocity, grab sample and morphological changes)



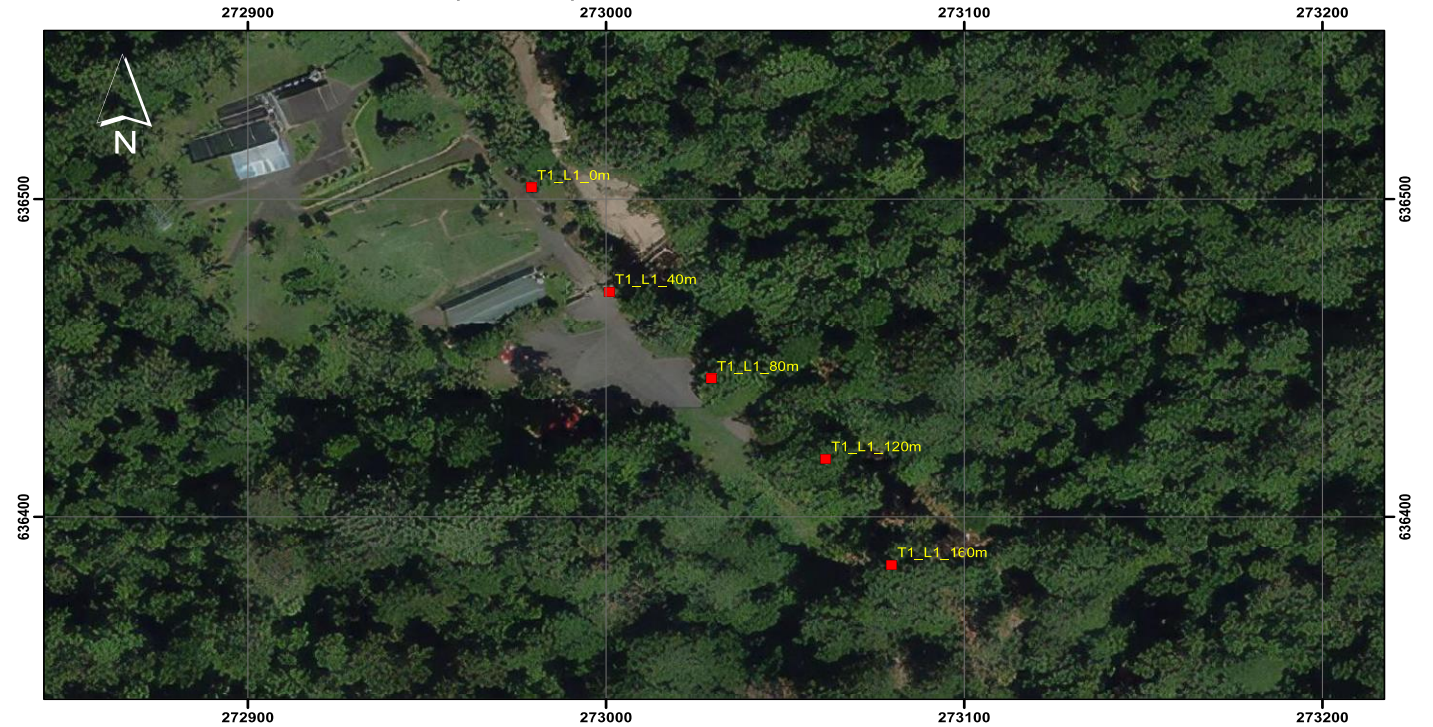
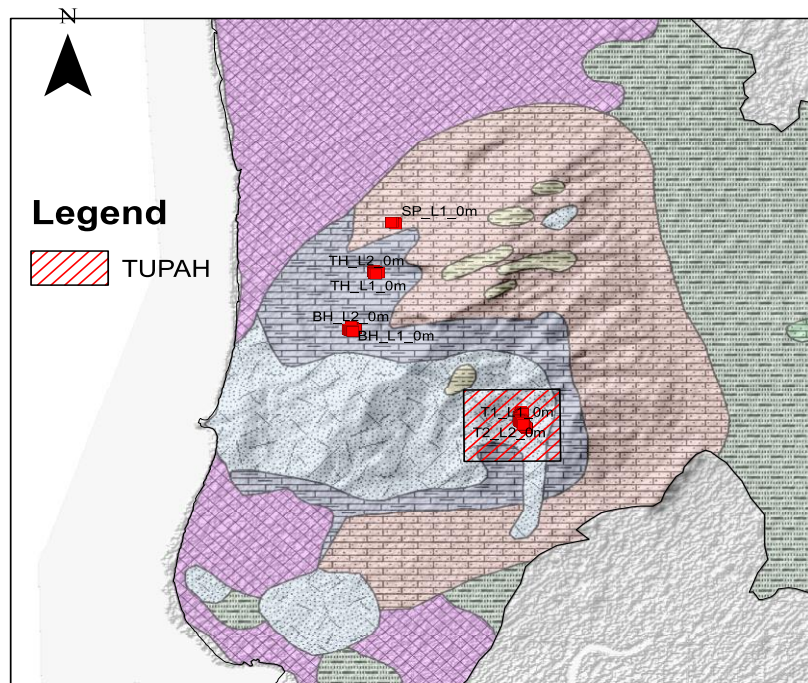
September to October 2021

DATA COLLECTION BY NAHRIM (Geological Resistivity Survey)

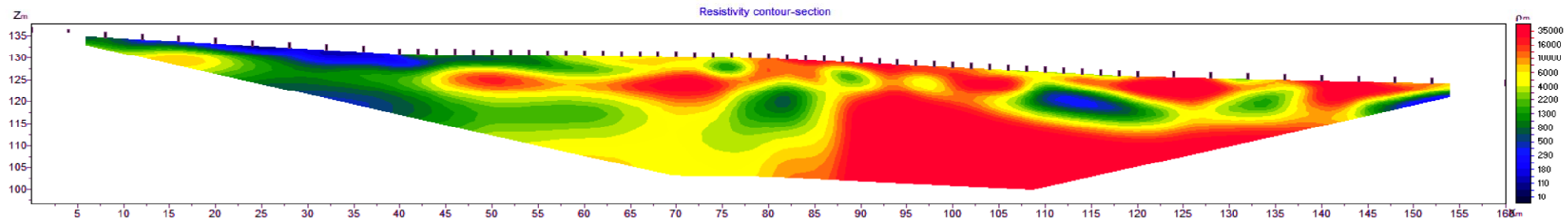


September to October 2021

ELECTRICAL RESISTIVITY TOMOGRAPHY (ERT) at GUNUNG JERAI



TUPAH 3 LINE 1



- Granite bodies are very shallow from surface ($>1,000\Omega m$) at 40-160m($<3m$).
- Low resistivity at 0-80m due to moist and weathered material.

OUTPUT OF GEOLOGICAL RESISTIVITY ANALYSIS

4

WAY FORWARD

1

Establishment of Integrated Management and Monitoring Plan in managing headwater phenomenon in Forest-Eco Park and State Forest Park with the following safety recommendations:

- **Install signage – Warning for headwater incidents in Forest-Eco Park and State Forest Park**
- **Install reliable and accurate forecast and real-time warning system in Forest-Eco Park and State Forest Park**
- **Install monitoring system such as soil movement sensors and CCTV surveillance in key areas**
- **Develop *Debris Flow Forecasting and Warning System***
- **Establish mutual and holistic *Task Force Group in headwater phenomenon monitoring strategies***

2

Formulate Search, Rescue and Evacuation Plan during incidents of headwater in Forest-Eco Park and State Forest Park according to priority and safety of tourists and nearby community

3

Data sharing to expedite Research and Development Projects and enhance research output through strategic collaboration with related agencies namely National Disaster Management Agency (NADMA), Department of Irrigation and Drainage Malaysia (DID), Department of Mineral and Geoscience Malaysia (JMG), Malaysian Space Agency (MySA), Forestry Department Peninsular Malaysia (JPSM) and Kedah State Government.

HEADWATER PHENOMENON DUE TO HEAVY RAIN

WHAT IS THIS PHENOMENON?

An upstream
flood

Mainly caused by
heavy rainfall

Water can rise up to
2 metres in just
5 -10 minutes



The
fast-flowing
water

carries with it
a lot of debris

that collides with
anything in its
path.

Many rivers in
Malaysia are
at risk of this
phenomenon

WARNING SIGNS

A loud sound like
an explosion could
mean:

- Roots losing their grip
- Soil breaking up
- Trees getting uprooted

Changes in the water:

- Black or dark
- Foamy & risen rapidly
- A lot of branches, leaves & silt in the river
- Heaps of rubbish

Leave the waterfall/river
immediately

NAHRIM SAFETY RECOMMENDATIONS

Formulating an
integrated
management &
monitoring plan for:

- Forest eco parks
- State forest parks

Building an
emergency
exit route

Developing an
emergency plan
of search, rescue
& transfer

Installing:



Signage



A forecast/real
time warning
system



Soil movement
sensors



CCTV surveillance
in key areas

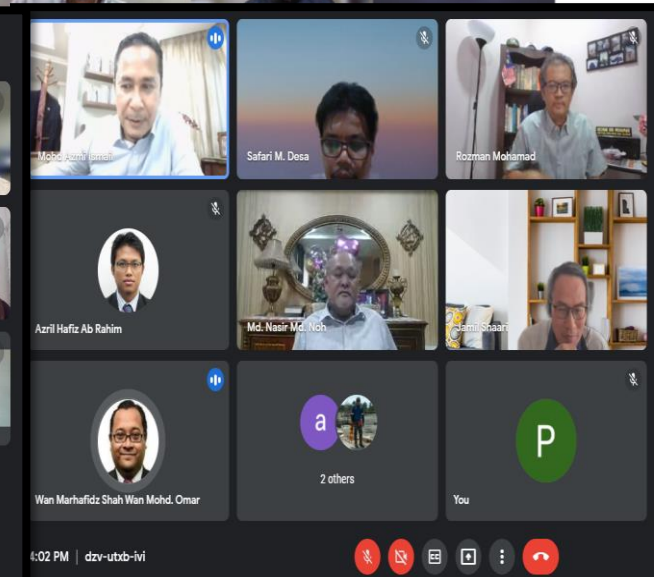
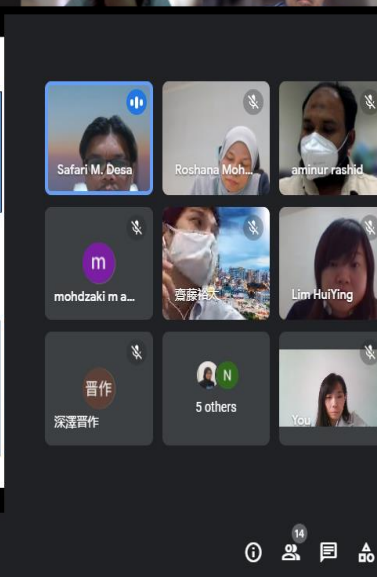
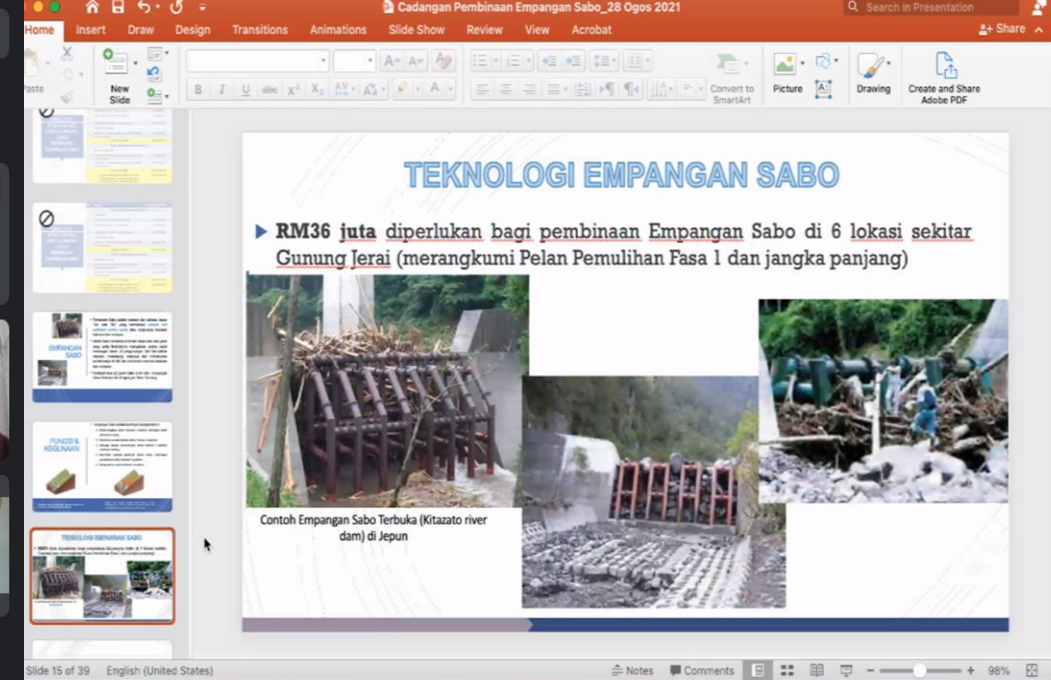
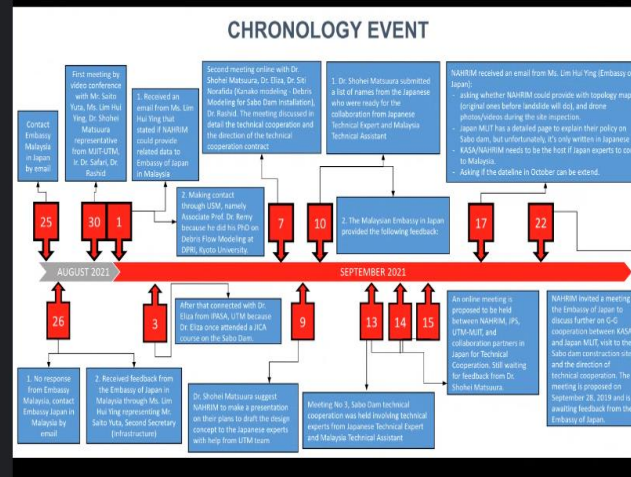
NAHRIM: National Hydraulic Research Institute of Malaysia | CCTV: Closed-circuit television

Source: NAHRIM director-general, Datuk Dr Md Nasir Md Noh

Published: Oct 1, 2021
Bernama Infographics

Strategic cooperation with Government of Japan through Embassy of Japan and collaboration with Ministry and agencies in Japan and Malaysia for technical support as follow:

No.	Japan	Malaysia
1	Ministry of Land, Infrastructure, Transport and Tourism (MLIT), Japan	Ministry of Environment and Water (KASA)
2.	Japan International Cooperation Agency (JICA)	Department of Irrigation and Drainage Malaysia (DID)
3.	Sabo & Landslide Technical Center, Tokyo	Department of Mineral and Geoscience Malaysia (JMG)
4.	Disaster Prevention Research Institute (DPRI), Kyoto University	Forestry Department Peninsular Malaysia (JPSM)
5.	Tsukuba University	Malaysian Space Agency (MySA)
5.	Public Works Research Institute (PWRI)	National Water Research Institute of Malaysia (NAHRIM)
6.	National Research Institute for Earth Science and Disaster Resilience (NIED)	University of Technology Malaysia (UTM)
7.	Nippon Koei, Ltd.	Malaysia-Japan International Institute of Technology (MJIT)







**NATIONAL WATER INSTITUTE OF MALAYSIA (NAHRIM)
MINISTRY OF ENVIRONMENT AND WATER (KASA)**

THANK YOU

**Lot 5377, Jalan Putra Permai
43300 Seri Kembangan, Selangor
Tel: +603-89476400 Fax: +603-89483044
www.nahrim.gov.my**