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การพัดพา หิน ดิน ทราย ขอนไม้ เนื่องจากฝนตกหนักและไหล่เขาถล่ม

DEBRIS FLOW CAUSED BY HEAVY RAINFALL AND LANDSLIDES

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บทคัดย่อ

การพัดพาหินดินทรายขอนไม้ (Debris Flow) เนื่องจากฝนตกหนักและไหล่เขาถล่มเกิดขึ้นในภูมิประเทศที่มีเขาสูงชัน ทำให้เกิดความเสียหายต่อชีวิตและทรัพย์สินอย่างใหญ่หลวง เช่นที่เกิดในภาคใต้ของประเทศไทยที่จังหวัดนครศรีธรรมราช ในเดือนพฤศจิกายน พ.ศ. 2531 Debris Flow นี้ยังไม่มีผู้ทำการศึกษามาก จึงต้องมีการค้นคว้าวิจัยเพิ่มเติมอีก การควบคุมหรือป้องกัน **Debris Flow** ทำได้ 2 วิธีใหญ่ ๆ คือ วิธีใช้สิ่งก่อสร้างและวิธีไม่ใช้สิ่งก่อสร้าง ซึ่งรายละเอียดได้อธิบายไว้ในบทความนี้ ความเหมาะสมของวิธีใดวิธีหนึ่ง หรือวิธีผสมขึ้นอยู่กับขนาดและลักษณะของพื้นที่ที่พิจารณา สภาวะทางด้านเศรษฐกิจและสังคม ค่าใช้จ่ายงบประมาณและการเมือง บทความนี้ได้ให้ข้อสรุปและเสนอแนะไว้

ABSTRACT

Debris flow caused by heavy rainfall and landslides occur in steep mountainous areas. It results in severe losses of lives and damages to private properties and public utilities such as that occur in Nakhon Sri Thammarat Province in the South of Thailand in November 1988. There are not so many studies made on debris flow and there is a lack of comprehensive knowledge of this natural phenomenon. Further research works are necessary in order to have a better knowledge in this aspect.

The control of debris flow can effectively reduce losses of lives and severe damages. Two principle methods of controlling debris flow are discussed namely: structural control measures and non-structural control measures. The details of these two measures are further elaborated and discussed in this report. The suitability of these two methods or their combinations depend on the size and characteristics of the area considered, the socio-economic condition and the financial and political factors. Conclusions and recommendations are given in this study.

INTRODUCTION

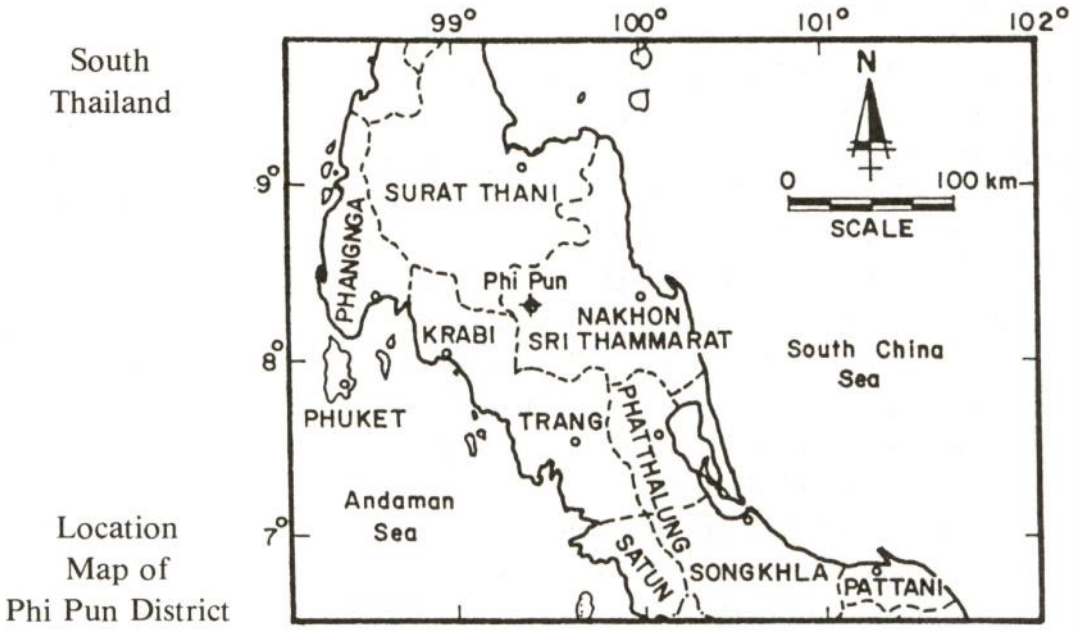
Heavy rainfall in steep mountainous areas causes overland flow to occur at high velocities and at large depths which result in heavy surface soil erosion and landslides especially in the areas where deforestration is significant. This phenomenon occurs in the South of Thailand in November 1988 in Khao Luang Area as shown in Figs. 1 and 2 (1). Debris consisting of stones, sand and clay particles including logs and fallen trees is carried by torrent streams down the hillslopes towards villages in foothill areas. The very strong impact of flash flood and debris flow to the obstructions such as houses caused severe losses of lives and damages to private and public utilities. During the tragic flood in the South of Thailand in November 1988, severe damages occurred in many districts in the foothill areas of Khao Luang such as the districts of Pun Pin, Lansaka and Chawang, in Nakhon Sri Thammarat Province. About 370 people lost their lives, 50,000 houses were destroyed, 3.7 million rai of agricultural area was damaged, 950,000 animals were killed and a lot of public utilities were damaged. The total cost of damages estimated by the Ministry of Interior is Baht 6,500 million (2). Stones of sizes larger than 30 cm are carried by flash floods and deposited in the region not far from foothills. Stones of smaller sizes including sand, silt and clay are carried and deposited at a further distance downstream. Logs or woods float at water surface and move as fast as the flood wave. In some rivers, bank erosion occurs due to high flow velocity causing the river channel to be widened such as Klong Tha Dee at the Kiriwong Village, Lansaka District, Nakhon Sri Thammarat Province. The width of the channel was increased from about 10 m to 200 m and the channel meandering path has been changed. Figs. 1 and 2 show the conditions of landslides and floodings and the resulting damages in South Thailand in November 1988. Debris flow occurs in many countries in steep mountainous areas such as in Japan, China, Philippines, Indonesia etc. In Thailand, flash floods occur in headwater areas of many river basins such as Quae Yai and Quae Noi Rivers in Kanchanaburi Province, Pasak River in Petchabun Province and Chi River in Loei Province. The worst disaster due to natural hazards in the last 27 years (1962-1988) in the South of Thailand was due to storm surges at the Talum Phuc Peninsula, Nakhon Sri Thammarat Province in 1962. Eight hundred people were killed with severe damages to private and public properties. The second worst damage is due to the flash flood in November 1988. From the statistics, it is shown that at least three provinces namely: Nakhon Sri Thammarat, Surat Thani and Songkhla are subjected to severe damages due to flash floods and landslides in every 2 or 3 years (3).

The purpose of this report is to provide the knowledge and principles of debris flow caused by heavy rainfall and landslides. Two principle methods of protection of debris flow namely: structural measures and non-structural measures are given and discussed. In addition, this report discusses briefly about the planning of land use and land development after hazards due to floods and debris flow. It is expected that this report would be useful to civil engineers, researchers, geologists and the people who are facing these hazard problems.

SEDIMENT TRANSPORT AND DEBRIS FLOW

Sediment Transport

Usually, floods under a normal condition will not cause severe damages. The transport of sediment due to normal floods consists of stones of 20-30 cm in size, gravel, sand, silt and clay with a smallest size less than 50 micron. Stones are carried and deposited not far away from foothills while sand normally deposits in the middle reach of the river. Silt and clay normally deposit in the estuary, at the river mouth or even in the sea. The amount of sediment



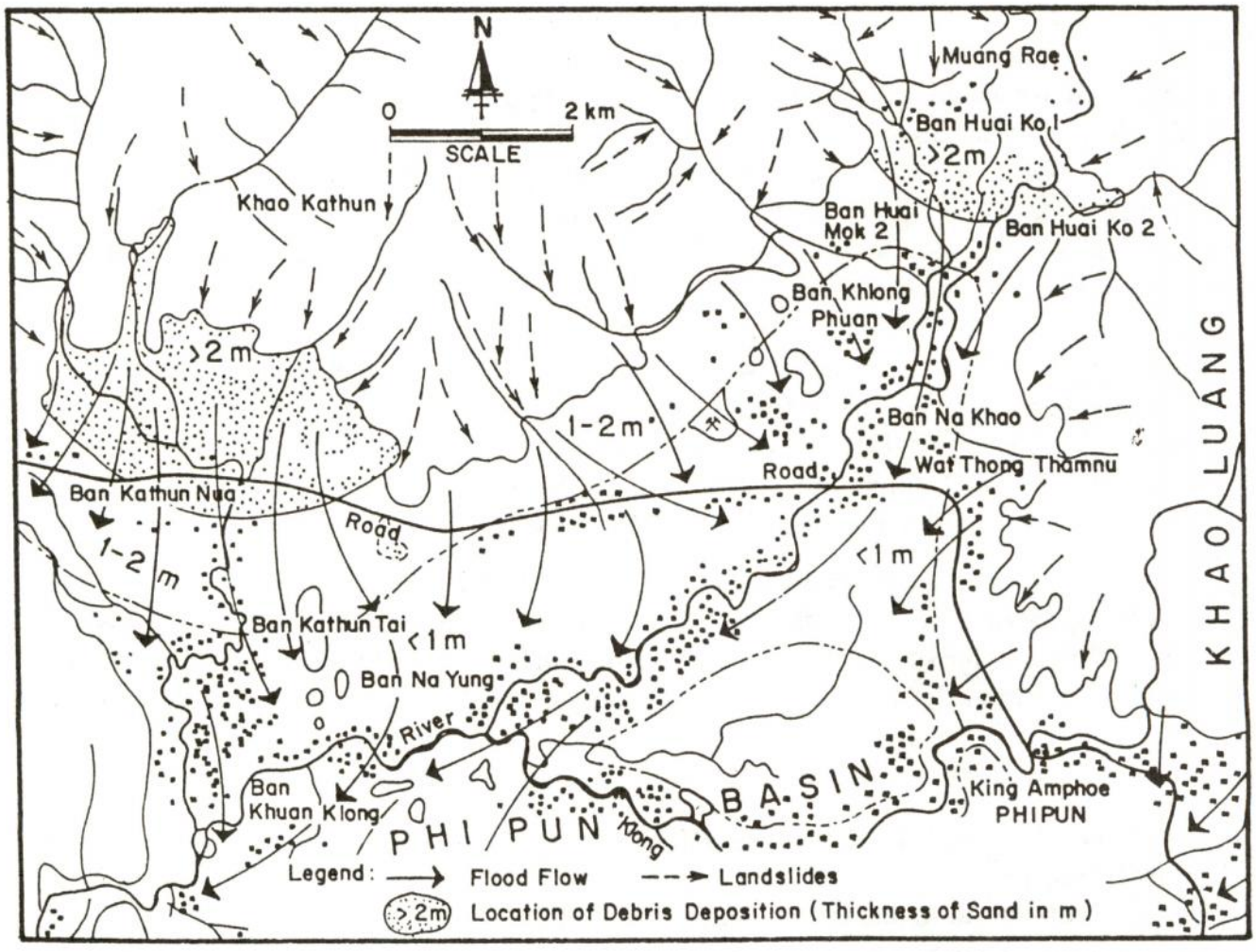


Fig. 1 Location Map of Phi Pun Basin, Nakhon Sri Thammarat Province (Above), Direction of Flash Floods and Debris Flow (Below) Nov. 20 - 23, 1988 (1)

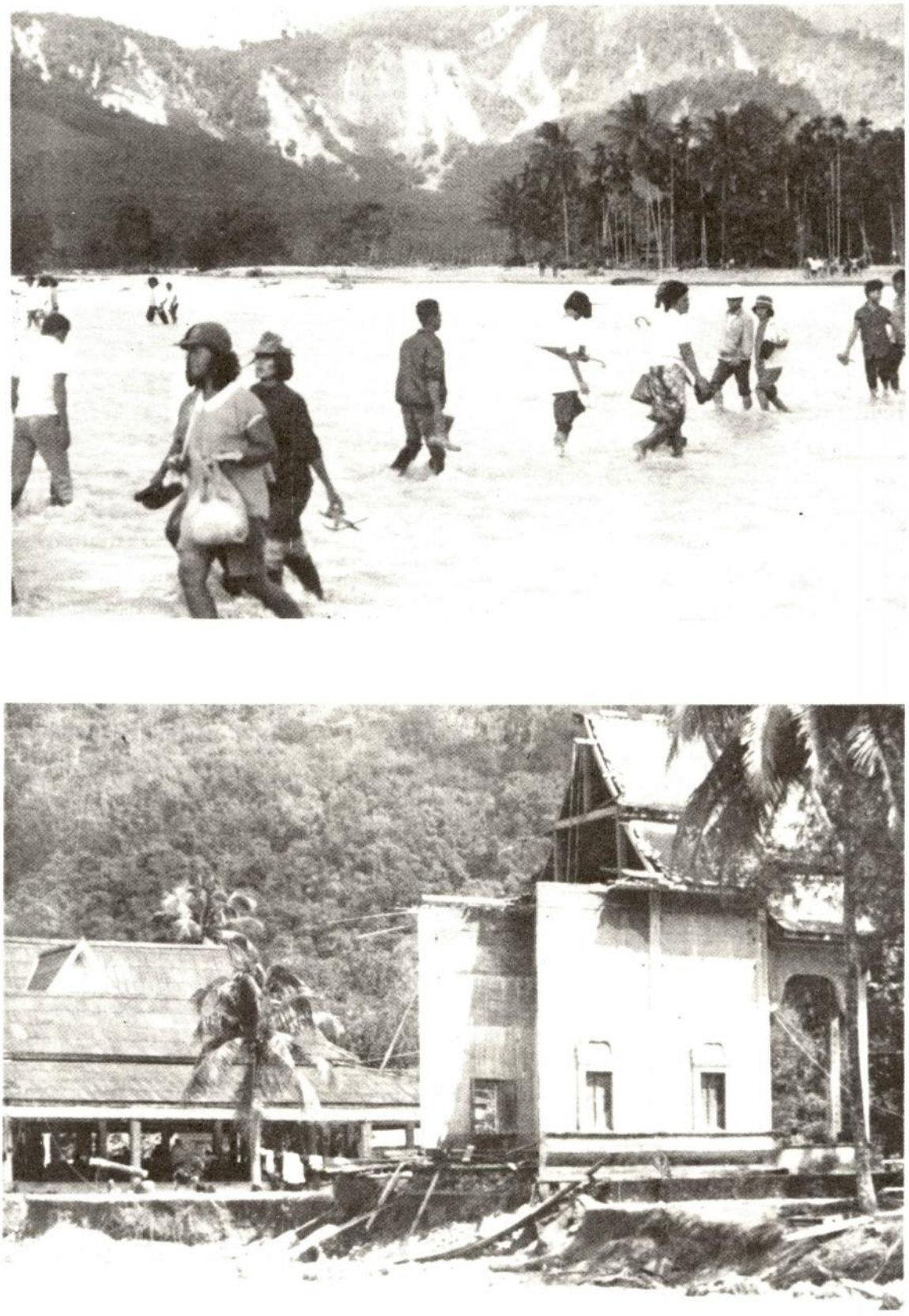


Fig. 2 Typical Landslides and Flooding at Ban Krathun (Above) and Severe Damages Due to Floods and Debris Flow at Ban Kiriwong (Below), Nakhon Sri Thammarat Province

Takahashi (5) also gave other formulae for debris flow as follows:
Tsubaki's (1972)

$$U_D = 2.5(gh\sin\theta)^{0.5} \tag{3}$$

Syanozhetsky's (1973)

$$U_D = 2[gh\cos\theta(1+1.5\sin\theta)]^{0.5} \tag{4}$$

Sribniy's (1966)

$$U_D = 6.5h^{2/3}(\sin\theta)^{1/4}\left[\frac{\sigma}{\rho}\,\frac{(\sigma-\rho)C_d}{(\sigma+\rho)(1-C_d)} + 1\right]^{-1/2} \tag{5}$$

Takahashi made experiments in 1977 and compared his experimental results with Eqs. 2, 3, 4 and 5. The agreement was found to be only fair. Further researches are needed to have a better prediction of the speed of debris flow.

For the deposition of debris flow, Fig. 5 shows the deposition cone which has its slope nearly equals to the average of the ground surface slopes upstream and downstream of the debris cone.

CONTROL AND PROTECTION OF DEBRIS FLOW

There are two major methods namely; structural and non-structural control measures. The suitability of each method or their combination depends on the size and characteristics of the area considered, the socio-economic condition, the financial and political considerations. The details of the structural and non-structural control measures are given as follows:

Structural Measures

The structural measures can be done in various ways such as:

a. Diversion of flash flood to less steep areas.
b. Construction of debris dams to protect debris flow or decelerate it (7) as shown in Fig. 6.
c. Reduction of hill slopes by building of check dams in steps (4) as shown in Fig. 7.
d. Construction of storage dams (Fig. 8) downstream of foothill areas to delay the flood peak arrival time and to decrease the peak discharge. Sediment flushing tunnels should be provided to flush deposited sediment in the reservoir to downstream of the dam. Most of the sediment deposited in the reservoir due to flash floods consists of sand, silt and clay. Without provision of sediment flushing tunnels, the reservoir may be filled up by the deposited sediment within few years.

Non-structural Measures

For the non-structural measures, these includes the followings:

a. Control of forestration and deforestration.
b. Preparation of landslide maps and hazard area maps for protection planning (8).
c. Preparation of risk maps for flood and debris flow for planning and classification of land use (8).

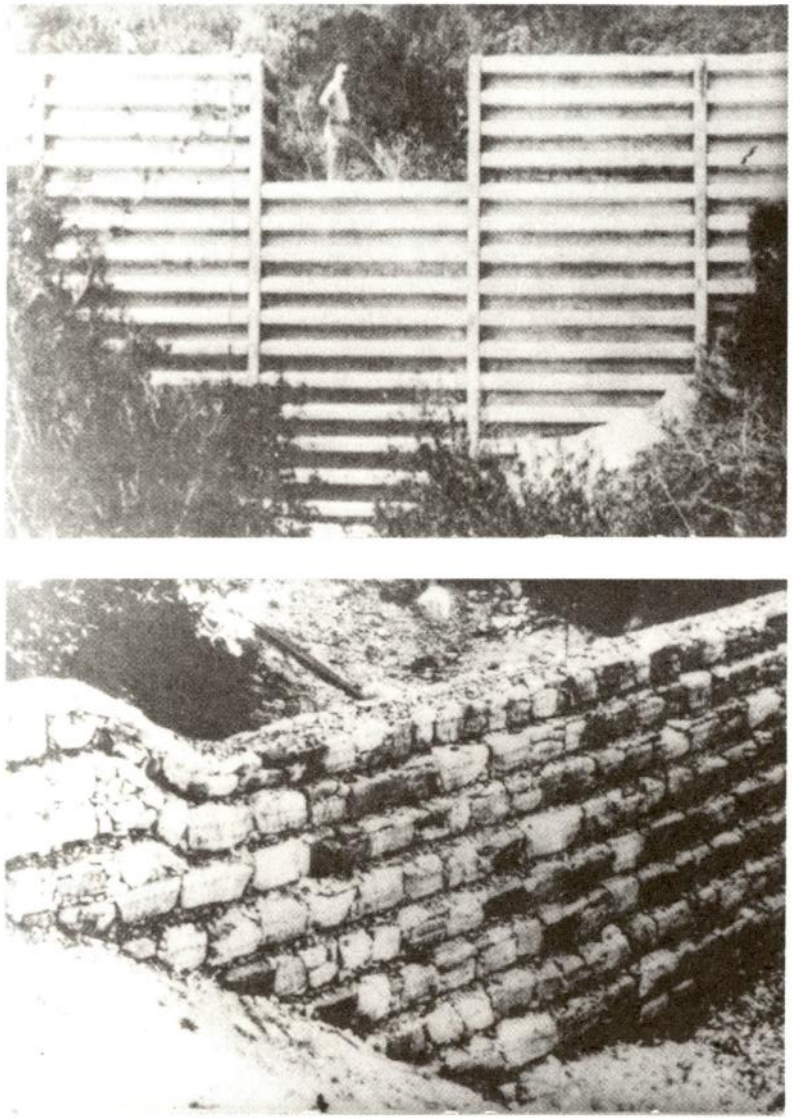


Fig. 6 Debris Dams Made of Metal (Above) and of Stones and Wires (Below)

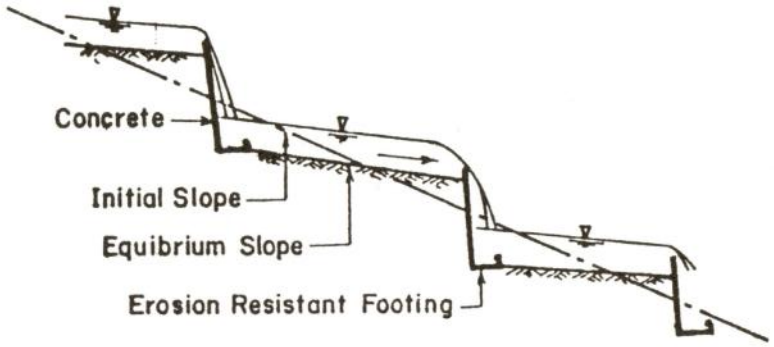


Fig. 7 Headwater Control by Construction Series of Check Dams Upstream of A Storage Dam

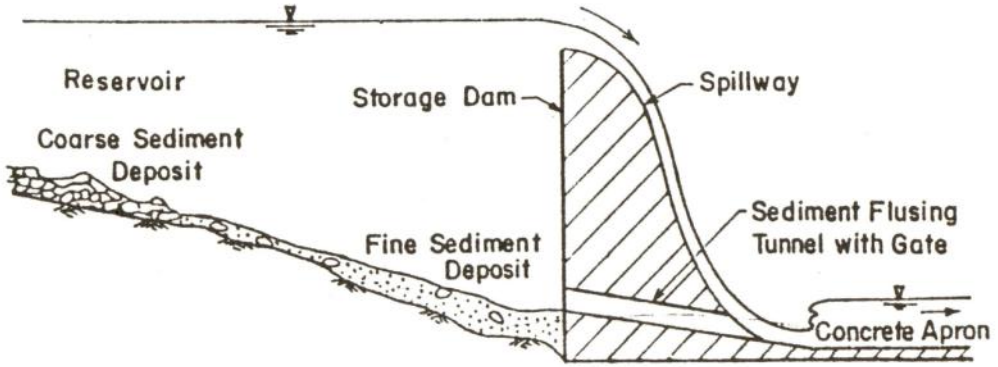


Fig. 8 Storage Dam and Reservior with Spillway and Sediment Flushing Tunnel for Flood Control Downstream of Foothills

d. Development of land after the hazards for resettlements and for agriculture.
e. People migration and resettlement. In some areas subjected to flood hazards, there is not sufficient time for the people to escape due to flood warning. It is necessary to evacuate the people from these high potential hazard areas and resettle them permanently in the flood safe areas.
f. Forecasting and warning of heavy rainfall and floods. This method is applicable only in the areas which are located far from the foothills where there is sufficient time for the people to escape or to protect themselves against the coming floods.

CONCLUSIONS AND RECOMMENDATIONS

1. Flash floods and debris flow caused severe losses of lives and heavy damages to private and public properties. The deposited debris cannot be removed easily. Therefore, the control and protection of flash floods and debris flow would effectively reduce the damages and improves the socio-economic condition of the hazard region as well as the psychological condition of the people living in the potential hazard areas.

2. The control of flash floods and debris flow can be done by using two principle methods namely: structural measures and non-structural measures. Their combinations often yield the best results.

The structural control measures are the construction of debris dams, check dams, storage dams and reservoirs. The implementation of these measures require land reclamation and large amount of budget. Therefore, it can be done only in limited or important areas which are subjected high risks.

The non-structural control measures can be done in many ways such as a) the control of forestration and deforestration, b) land development and land use classification, c) people migration from high potential hazard areas in headwater regions and resettlement in flood safe areas, d) rainfall and flood forecasting and warning.

3. The transport rate of debris flow depends on the flow velocity, depth of flow and the physical characteristic of debris. From the surveys of landslide areas, the direction of debris flow and the deposition area of debris, it is possible to identify the locations and the design of debris control structures such as debris dams, check dams, storage dams and reservoirs.

4. Studies should be carried out in controlling flash floods and debris flow in headwater regions of river basins which are subjected to high risks such as the headwaters of Quae Yai and Quae Noi Rivers in Kanchanaburi Province, Pasak River in Petchabun Province, Tapi River in Nakhon Sri Thammarat Province etc. Training and education of staff and villagers who are living in the concerned areas on the cause and the control measures of flash floods and debris flows are necessary. Both structural and non-structural measures should be taught in the training program.

REFERENCES

1. United Nations (1989), "ESCAP Technical Assistance to the Flood Affected Areas in Southern Thailand", **Mission Report,** Multidisciplinary Mission to Surat Thani and Nakhon Sri Thammarat Provinces, 12-16 December 1988, ESCAP, Bangkok, Thailand, January.
2. สมาคมอนุรักษ์ศิลปกรรมและสิ่งแวดล้อม (พ.ศ. 2532). อุทกภัยภาคใต้ โศกนาฏกรรมที่น่าจะหลีกเลี่ยงได้?, **เอกสารประกอบการสัมมนาเล่มที่** 1, กรุงเทพมหานคร, 18-19 มกราคม.
3. ปริญญา นุตาลัย, สุภัทท์ วงศ์วิเศษสมใจ และอภิสิทธิ์ เอี่ยมหน่อ (พ.ศ. 2532). "แนวทางการแก้ไขปัญหาน้ำท่วมจังหวัดนครศรีธรรมราช", **รายงาน**, สถาบันเทคโนโลยีแห่งเอเชีย, ปทุมธานี, กุมภาพันธ์.
4. Jansen, P.Ph et al. (1979), **"Principles of River Engineering",** Pitman Publishing Ltd., London, U.K.
5. Takahashi, T. (1981), "Debris Flow", **Annual Review of Fluid Mechanics,** Annual Reviews Inc., Vol. 13, California, U.S.A.
6. Hsu, K.J. (1975), "Catastrophic Debris Streams Generated by Rockfalls", Bulletin, Geological Society of America, Vol. 86, **Document No. 50117,** U.S.A., pp. 129-140.
7. Reihsen, G. (1964), "Debris Control Structures", **Hydraulic Engineering Circular No. 9,** U.S. Department of Commerce, Bureau of Public Roads, Washington D.C., U.S.A.
8. Osterkamp, W.R., Hupp, C.R. and Blodgett, J.C. (1986), "Magnitude and Frequency of Debris Flows, and Areas of Hazard on Mount Shasta, Northern California", **U.S. Geological Survey Professional Paper 1396-C,** U.S. Department of Interior, U.S.A.