CHAPTER 5

EVIDENCES AND PARAMETERS AFFECTING DEBRIS FLOW-FLOOD PROCESSES IN NAM KO YAI SUB-CATCHMENT

In this chapter, evidences of geotechnical properties of rocks and soils, as well as evidence of the channel configuration and suspected temporary dam location in Nam Ko Yai sub-catchment are presented.

5.1 Evidences of geotechnical properties of rocks and soils in Nam Ko Yai sub-catchment

For supporting the relationship between the influencing parameters of soil properties and geology, and the flow-flood occurrence in Nam Ko Yai sub-catchment, the detailed field investigation to identify, and collect soil and rock samples for geotechnical analyses had been conducted. The traverse lines of field investigation and sample locations are presented in Figure 5-1. The tabulated data of sample numbers, sample locations, type of samples, rock unit of rock samples, rock grade testing values, and type of laboratory analysis for each sample were summarized in Table 5-1. Some study results and actions are illustrated in Appendix I-III.

The specimens are of two groups, namely, (1) three group-samples of rock units (ten specimens for each group-sample) for a point load testing of the engineering properties (strength), and (2) six soil samples for determining the engineering soil properties. Rock and soil samples were generally collected from the weathered zone of volcanic unit of Lom Sak Formation (Ls). The location photographs were illustrated in Appendix A.

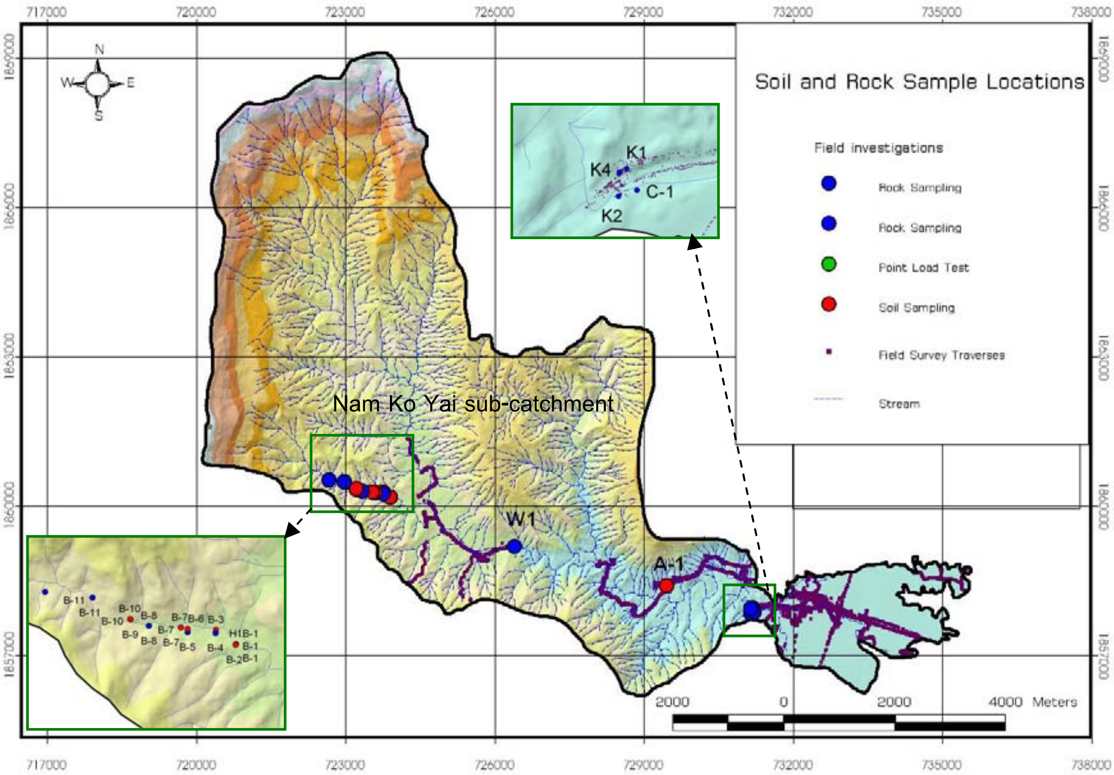

Figure 5-1 Field traverses and sample locations in Nam Ko Yai sub-catchment.

5.1.1 Geotechnical study of point load testing

5.1.1.1 Point load testing overview

The point load testing (PLT) is a generally-accepted rock mechanics testing procedure used for verifying a rock strength index in geotechnical practice. The index can be further used to estimate other rock strength parameters. The point load test apparatus and procedure enables an economical testing of core or lump rock samples in a field or laboratory setting. The rock specimens used for the test can be in either geometric regular or irregular shape. This test is to present a data analysis to be used to correlate the point load strength index (Is) with the uniaxial compressive strength (σ_c). The rock strength determined by the point load testing certainly is an indication of an intact rock strength of the rock samples which of course is not necessarily the strength of the entire rock mass.

Table 5-1 The referenced data of sample numbers, sample locations, type of samples, rock unit of rock samples, rock grade testing values, and type of laboratorial analysis for each sample in the study area.

Specimen number	Location		Sample Type	Rock Unit	Rock Grade Testing Value	Samples Collected for	
						Point Load Test	Soil Test
A-1	Q47 0728840	1858259UTM	Soil	-	-	-	6L
B-1	Q47 0723292	1860034UTM	Rock (Volcanic Complex)	Ls	(H) 5R	(Floated Rock) 10-01Pw	-
						(Floated Rock) 12-01Pk	
						(Floated Rock) 10-01Ls	
B-2	Q47 0723290	1860028UTM	Soil	-	-	-	1L
B-3	Q47 0723164	1860126 UTM	Soil	-	-	-	2L
B-4	Q47 0723160	1860105UTM	Rock (Volcanic Complex)	Ls	4R	-	-
B-5	Q47 0722980	1860110UTM	Rock (Volcanic Complex)	Ls	4R	-	-
B-6	Q47 0722980	1860132UTM	Soil	-	-	-	3L
B-7	Q47 0722937	1860140UTM	Soil	-	-	-	4L
B-8	Q47 0722730	1860152 UTM	Rock (Volcanic Complex)	Ls	3R	-	-
B-9	Q47 0722610	1860192UTM	Rock (Volcanic Complex)	Ls	3R	-	-
B-10	Q47 0722609	1860196UTM	Soil	-	-	-	5L
B-11	Q47 0722364	1860335UTM	Rock (Volcanic Complex)	Ls	3R	-	-
B-12	Q47 0722058	1860371UTM	Rock (c ComplexVolcani)	Ls	5R	-	-
C-1	Q47 0730574	1857811UTM	Rock (Volcanic Complex)	Ls	(L) 5R	-	-
C-2	Q47 0730543	1857709UTM	Rock (Volcanic Complex)	Ls	1R	-	-
C-3	Q47 0730612	1857733UTM	Rock (Volcanic Complex)	Ls	2R	-	-
C-4	Q47 0730547	1857799UTM	Rock (ic ComplexVolcan)	Ls	1R	-	-

Note - All codes are referred to accordingly in the appropriate parts in the text.

The point load tester consists of a hydraulically powered ram and two pointed-platens. One of the platens is stationary while the other is free to move through the application of pressure, delivered via the hydraulically powered ram. The rock specimen to be tested is placed between the two pointed platens and force applied to the rock is increased and eventually caused the rock to fail. The peak pressure applied or the pressure at the rock failure is recorded. This peak applied load is used to calculate the point load strength index (Is), using the equation ASTM D5731-95 and ISRM below.

$I_S = P/D_e^2$ .... (Equation 5-1)

Where

P = highest force recorded by the instrument to just break the rock

D_e = equivalent diameter (of sample)

The force recorded by the instrument to just break the rock (P) is converted to a strength value, equivalent to a 50 mm diameter rock. This produces the so-called $I_{s(50)}$ value or Size-Corrected Point Load Index. The equation to convert the force reading to $I_{s(50)}$ value is as follows: (Brook, 1985)

$I_{s(50)} = FP / (D_e)^2$ .... (Equation 5-2)

Where

F = size correction factor = $(D_e/50)^{0.45}$

P = applied load (MN)

D_e = $(4A/p)^{0.5}$

A= minimum cross sectional area of the specimen (mm^2)

The unit of point load index is MPa. Though the test is considered to cause a tensile failure, this could be converted to compressive strength (σ_C) by the equation below.

$(\sigma_C) = 24\ I_{s(50)}$ .... (Equation 5-3)

5.1.1.2 Rock specimen sampling

In this study, the rock specimens were collected from the location B1 (the locations shown in Figure 5.1 and photographs in Appendix I). They were from three rock units below.

1) Ten specimens of Phra Wihan sandstone/siltstone (rock unit Pw)

2) Twelve specimens of Phu Kradung sandstone (rock unit Pk)

3) Ten specimens of Lom Sak volcanic complex (rock unit Ls).

5.1.1.3 Point load testing results

The results of point load testing of three groups of rock units are concluded in Table 5-2. Photographs illustrating the rock samples, before and after the test, technique, and results of point load testing in the laboratory were also illustrated in Appendix II.

It was noted that $I_{s(50)}$ of Pw unit is 1.74 - 3.18 MPa, average 2.66 MPa while σ_C is 41.8 – 76.2 MPa, average 63.9 MPa. $I_{s(50)}$ of Pk unit is 1.03 – 3.11 MPa, average 2.04 MPa while σ_C is 24.8 – 74.8 MPa, average 49.0 MPa. $I_{s(50)}$ of Ls unit is 2.76 – 6.65 MPa, average 4.80 MPa while σ_C is 66.3 – 159.6 MPa, average 115.2 MPa. The study results reveal that the volcanic rocks of Ls is the strongest while the Pk sandstone the weakest among the 3 groups. The Pw sandstone has an intermediate σ_C value, though not much higher than that of the Pk specimens.

5.1.2 Geotechnical study of soil properties

5.1.2.1 Soil sampling preparation

Six soil specimens (number A-1, B-2, B-3, B-6, B-7 and B-10 as shown in Figure 5-2 and Appendix I) were collected from the natural soil layer (1-2 meter thick) that were the weathered products of volcanic rocks (mainly basalt) of Lom Sak Formation (Ls). The soil samples were collected in a way to avoid the top soils and were of about 0.5 m deep laterally from the outer soil surface to retain the natural moisture content. The collected soil samples were well-packed in plastic bags for further study in the laboratory.

5.1.2.2 Laboratorial study of soil properties

The six soil samples were collected for the laboratorial geotechnical studies which include grain size analysis, determination of Atterberg limits and indices, natural moisture content, and shear strength according to the standard of ASTM (ASTM D 4318-00, D 422-63). Photographs illustrating laboratorial instruments and samples for soil-geotechnical testing are illustrated in Appendix III.

5.1.2.3 Study results of soil geotechnical properties

The analytical results of the soil samples geotechnical properties were summarized in Table 5-3. The soil sample number B-2, B-3, B-6 and B-7 are clay whereas number B-10 and A-1 are clayey sand. Natural water content (w_N) in these samples are generally between 21 - 50 %, with plastic limit and liquid limit of soil between 17- 31 and 24 – 55 %, respectively. Plastic index varies from 6 to 26 %.

It was noted that the grain sizes smaller than 0.075 mm (Mesh no.200) were especially of a high content, more than 50 percents of total soil weight. This property is different from the other normal soils that were weathered from the quartz-contained rocks that generally had the grain sizes smaller than 0.075 mm (Mesh no.200) being less than 50 percent of total soil weight. The uniformity coefficient ($C_u = D_{60}/D_{10}$) as $C_u < 5$ - very uniform, $C_u = 5$ medium uniform, $C_u > 5$ – non-uniform, of these six soil samples is higher than 5 indicating a non-uniform characteristic of soil grain size.

It is summarized here that all specimens are non-uniform clay to clayey sand, with natural water content of 21-50 %, and with plastic limit and liquid limit between 17-31 and 24-55 %, respectively. The clayey soils illustrated a low permeability value of about 10^{-2} to 10^{-7} m/sec. This indicates that the natural moisture could hardly be drained out of the soils in many cases, which naturally staying close to the liquid limit. If the soils receive more water, their weight increases while the shear strength decreases, thus the soils would be liquefied and easily be liquefied. These soils had varied shear strength values from about 10-100 kPa. Ls Formation soils, however, shear strength values lower than other common soils and thus are highly movable.

Table 5-2 Analytical results of soil engineering properties of the soil samples.

Sample No.	Location	Percent Finer #200 (% clay and silt)	Natural Water Content, % w_N	Plastic Limit, % w_P	Liquid Limit, % w_L	Plastic Index, % $PI = w_L - w_P$	Activity, $A = PI/\%Clay$	Liquidity Index, $LI = (w_N - w_P)/PI$	C_u	Soil Type 1*	Soil Type 2*	Soil Type 3*	Shear Strength (kPa)
B-2	47 Q 0723290/ UTM 1860028	67.6	27.0	20.8	40.5	19.7	0.76	0.31	>5	Clay	CL	A-7-6 (Clayey soils)	40
B-3	47 Q 0723164/ UTM 1860126	87.1	44.9	29.2	54.6	25.4	0.53	0.62	>5	Clay	CH	A-7-6 (Clayey soils)	10
B-6	47 Q 0722980/ UTM 1860132	87.4	33.8	30.6	54.9	24.2	0.53	0.13	>5	Clay	CH	A-7-6 (Clayey soils)	93
B-7	47 Q 0722937/ UTM 1860140	77.3	34.4	25.4	45.6	20.2	0.67	0.44	>5	Clay	CL	A-7-6 (Clayey soils)	22
B-10	47 Q 0722609/ UTM 1860196	62.0	26.7	24.7	38.4	13.7	0.62	0.15	>5	Clay sand	CL	A-6 (Clayey soils)	87
A-1	47 Q 0728840/ UTM 1858259	38.1	21.8	17.4	24.20	6.8	0.31	0.65	>5	Clay sand	ML	A-4 (Silty soil)	9

Note: 1*. Classification of the Mississippi River Commission

2*. Classification of Unified Soil Classification System

CL – inorganic clays of low to medium plasticity, gravelly clay, sandy clays, silty clays, lean clays.

CH – inorganic clays of high plasticity, fat clays

ML – inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity.

3*. Classification by AASHTO Soil Classification System

5.2 Evidences of a suspected temporary landslide dam location and channel configurations in the central part of Nam Ko Yai sub-catchment

5.2.1 Evidences of a temporary landslide dam location

It was always suspiciously how the settlement on the alluvial fan was flooded with muddy water and high quantity of plant debris. One theory was that there could have been a natural landslide dam forming somewhere along the water course, followed by the failure of the dam to have the temporary impound water with debris to flow in a huge amount down below. If this theory was possible, there should be evidences of such dam somewhere upstream from the flooded village.

From the field investigations and orthophotograph interpretation, there was a specific location along the course of Nam Ko Yai stream in the central part of the study area that was looked suspiciously. Here the stream issues from a flat open land behind (upstream) to a very narrow V-shape channel with a sudden change of elevation at Tad Fa waterfall (Figure 5-2). It could be hypothesized that this specific location is suitable for an accumulation of sediments composed of plant debris, soils, and rock boulders to form a natural landslide dam of at least 10 m high (Figures 5-3, 5-4 and 5-5). A field check revealed fallen trees and vegetation traces. This probably indicated that the temporary natural dam was broken, sending the debris and water to flood further downstream, eroding the channel along the way, and finally dropping its loads on the alluvial fan at the canyon mouth.

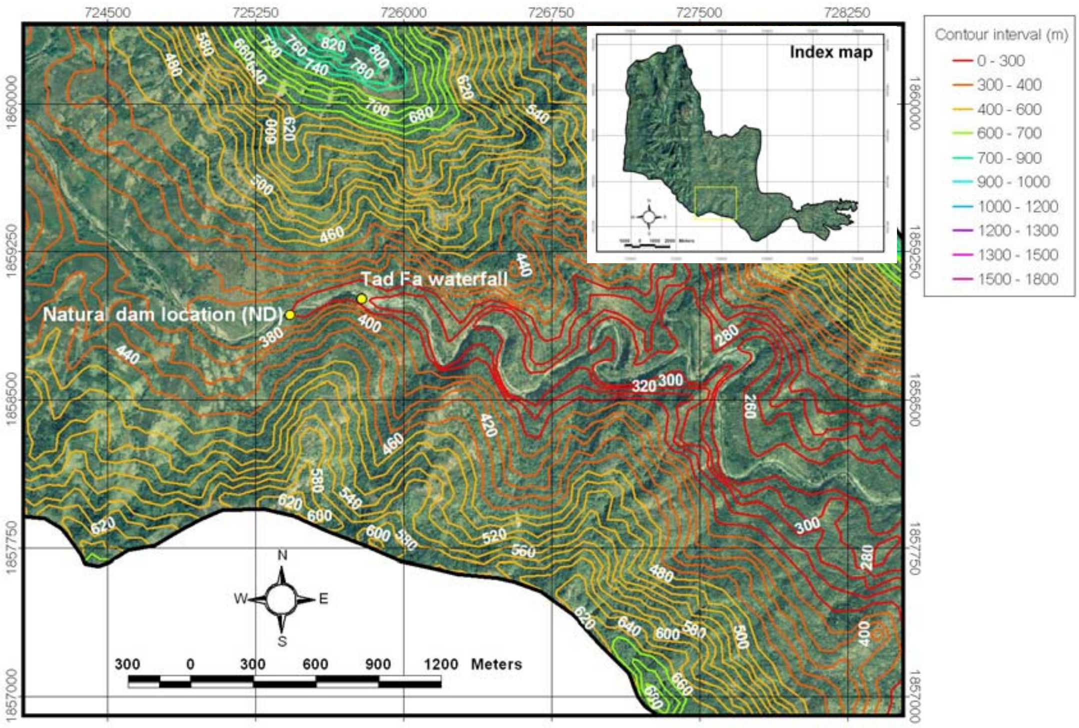

Figure 5-2 Orthophotograph (1:25,000 scale, 9th January 2002 after the 8/11 event) illustrating the specific configuration of Nam Ko Yai stream in the central part of the study area.

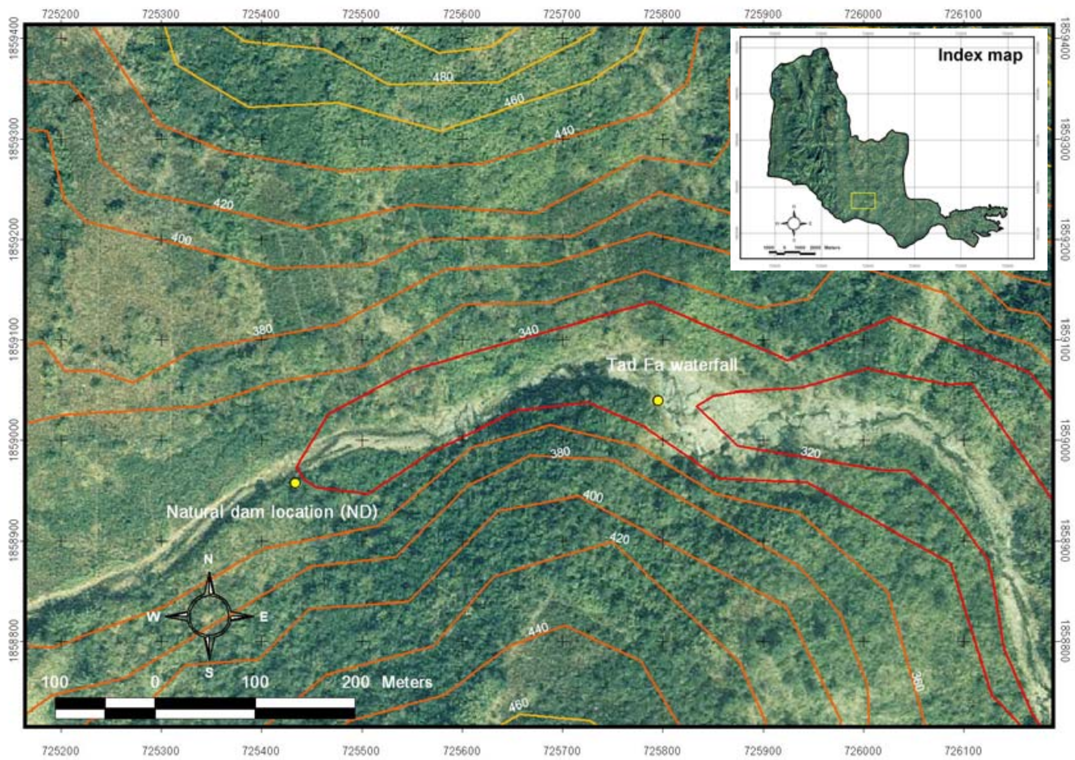

Figure 5-3 Closed-up orthophotograph in Figure 5-2 illustrating the local geography of Nam Ko Yai stream that is suspected to be a natural temporary landslide dam location (ND) in front of the location of Tad Fa waterfall.

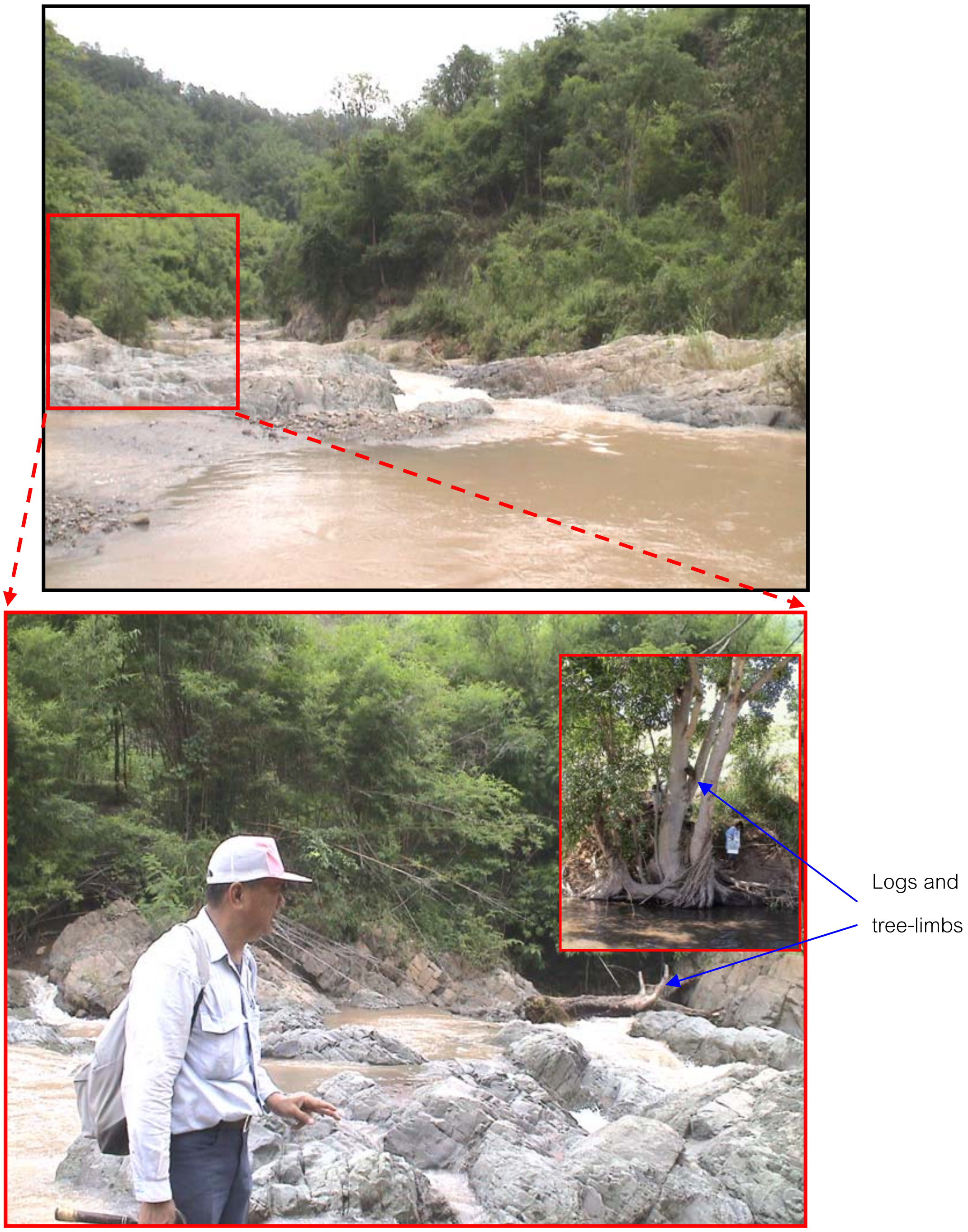

Figure 5-4 Photographs (looking eastward direction) illustrating the configuration of Nam Ko Yai stream channel at location ND (referred to Figure 5-3) that is suitable for accumulated sediments for blockage a torrent stream and formed a natural temporary landslide dam. Note: The evidence of transported timbers was still found not only in the channel as a large one but also left as a smaller one at the higher level of the tree-branches (as shown in the inserted photograph that taken at the upstream of Nam Ko Yai stream, 2.5 km. far away from this point).

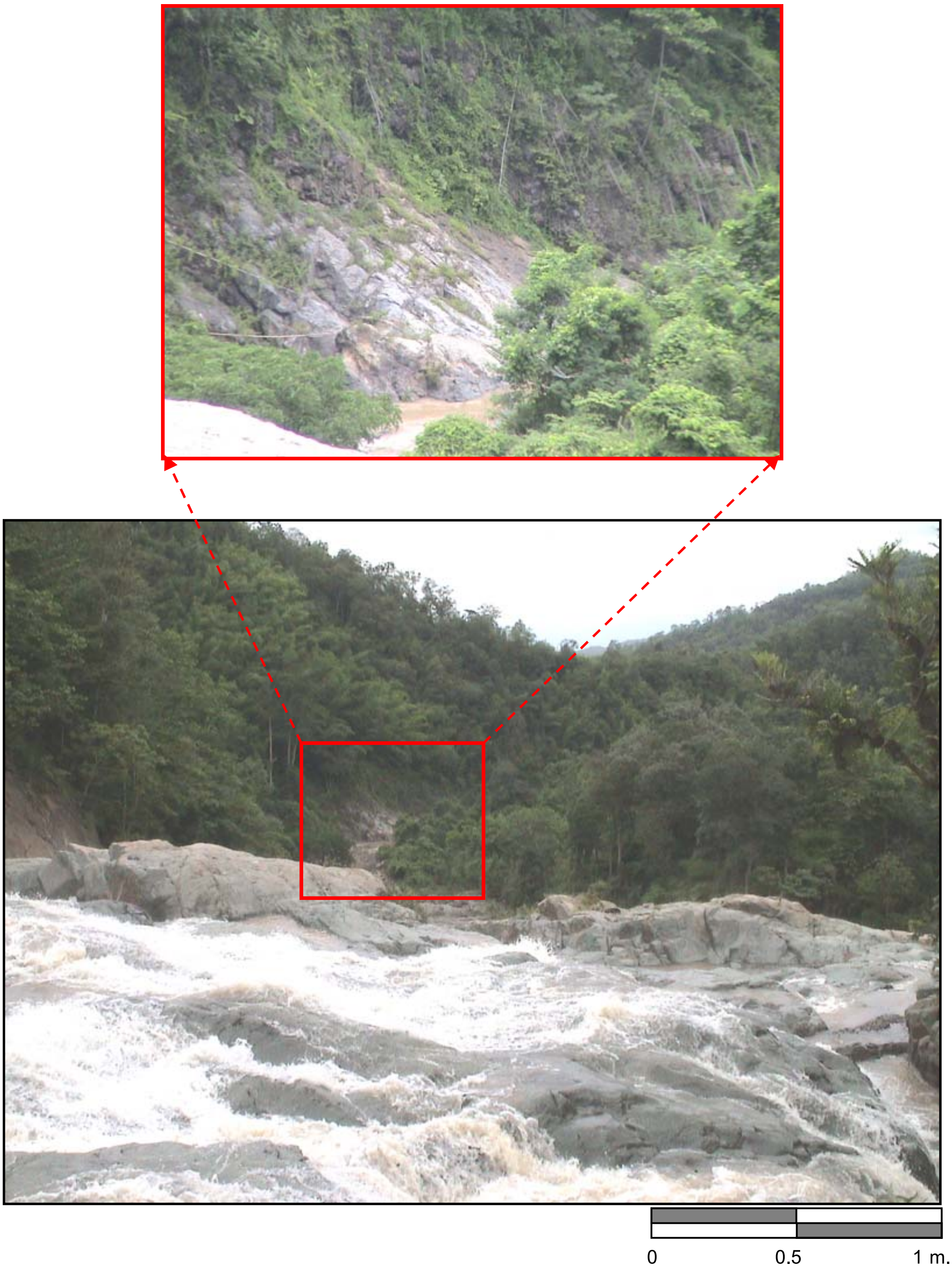

Figure 5-5 Photographs (looking eastward direction) showing the different relief of about 20 m between Tad Fa waterfall (location referred to Figure 5-3) and the downstream V-shape channel that is suitable for increasing water turbulent to form flow-flood occurrence.

5.2.2 Evidences of channel configurations

Topographically, the area of Nam Ko Yai sub-catchment immediately upstream from this suspected natural temporary dam location is a flat basinal shape area that can retain the water of about 1,200,000 cubic meters if the dam is 10 m high from the ground surface. This is a flat terrain of very gentle slope, less than 5 degrees (Figure 5-6), surrounded by the steeper slope with abrupt change in elevation (Figs. 5-7 and 5-8). The stream here is of a wide U-shape and was straight for about 2.5 km. The area is suitable for forming a reservoir, a dam was built at the location. Downstream from the waterfall, the stream changes to a narrow V-shape with strong sinuosity for about 8 km to the canyon mouth area (Figure 5-8). This narrow V-shape and strong sinuosity channel is accompanied by increasing energy of torrent stream flow. The observation suggested that this type of destructive mass movement was certainly not caused in the 8/11 occurrence alone. Instead it suggests general repeated strong debris flow-floods in several occasions in the past.

From the base rocks in the upstream from this suspected natural temporary dam location, it is interesting to note that lithilogy of Lom Sak Formation is mainly composed of non-resistant rocks of volcanic complex as shown in Figure 5-9. So the U-shape upstream of Nam Ko Yai channel is generally controlled by the soft and non-resistant volcanic rocks that are easily eroded as a flat area.

From the channel configuration of Nam Ko Yai stream up- and downstream from the suspected natural dam location (Figure 5-10), the 8/11 flow-flood should follow the pre-existing drainage way. Downstream from the dam, the stream has a V-shape or nearly rectangular cross-section as shown in the cross-section lines of G-H and I-J (Figure 5-11). This narrow V-shape and strong sinuosity channel configuration of Nam Ko Yai stream here also indicates as one of the most influent parameters that allow increasing energy for the torrent stream caused from the broken natural dam to be formed as a severe flow-flood. This destructive form of mass movement strongly eroded and transported sediments (plant debris, soils and rock boulders) along the downstream

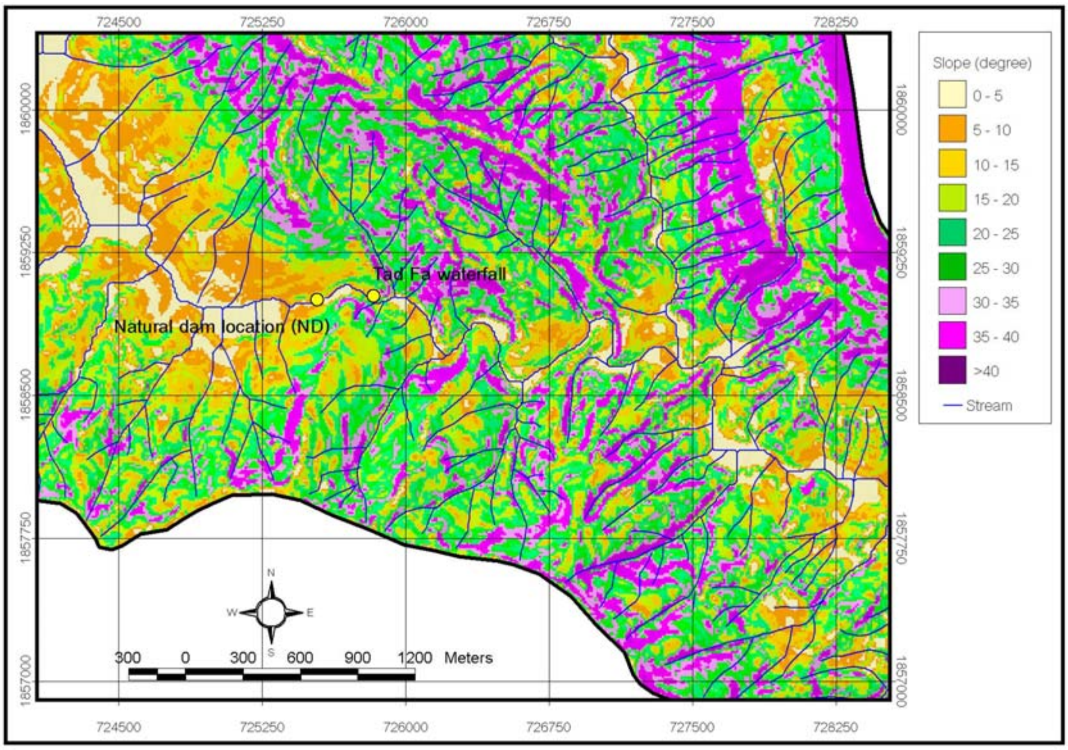

Figure 5-6 Slope map of the upstream and downstream area above and below the suspected natural landslide dam location (ND) in Nam Ko Yai stream channel.

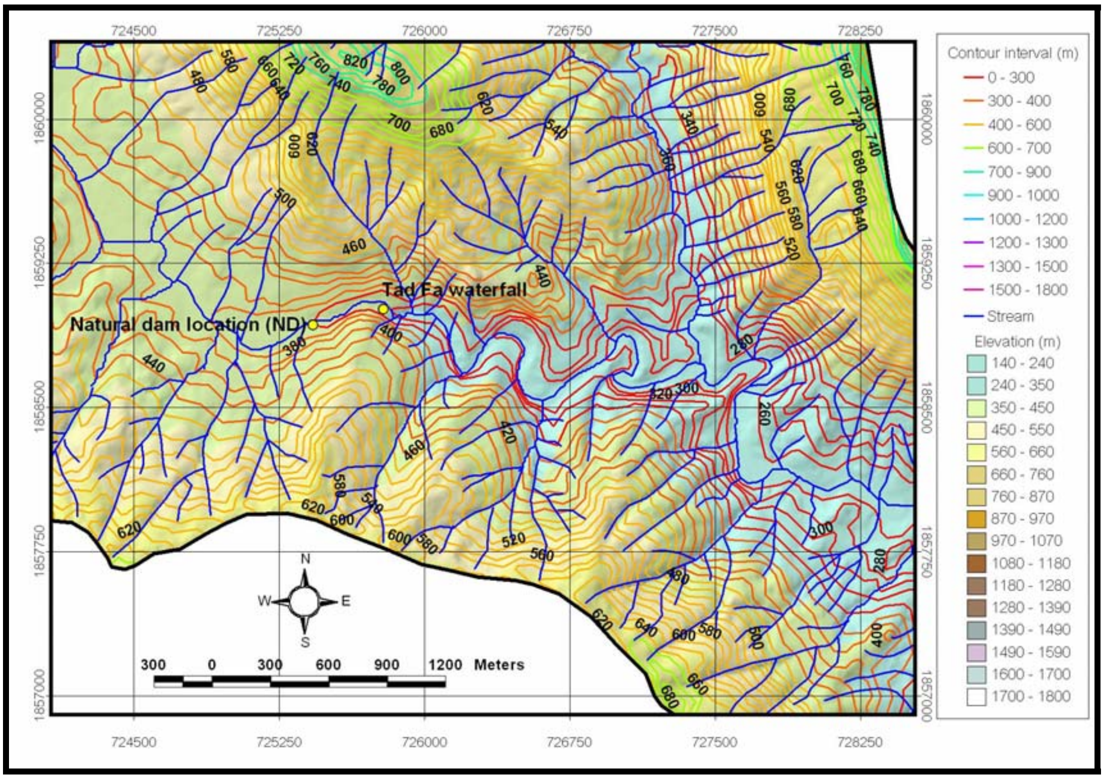

Figure 5-7 Elevation map of the upstream and downstream area above and below the suspected natural landslide dam location (ND) in Nam Ko Yai stream channel.

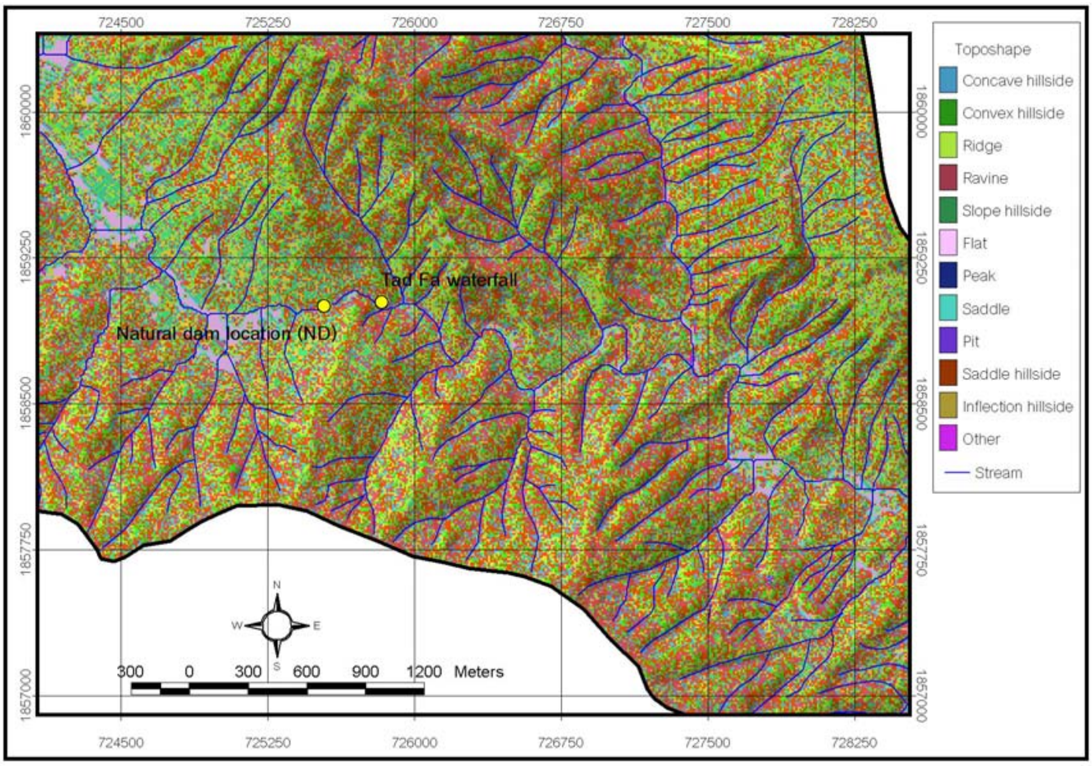

Figure 5-8 Topographic shape of upstream and downstream area away from the suspected natural landslide dam location (ND) in Nam Ko Yai stream channel.

Figure 5-9 Photograph showing the soft and non-resistant volcanic rocks of Lom Sak Formation in the upstream from the suspected natural temporary dam location.

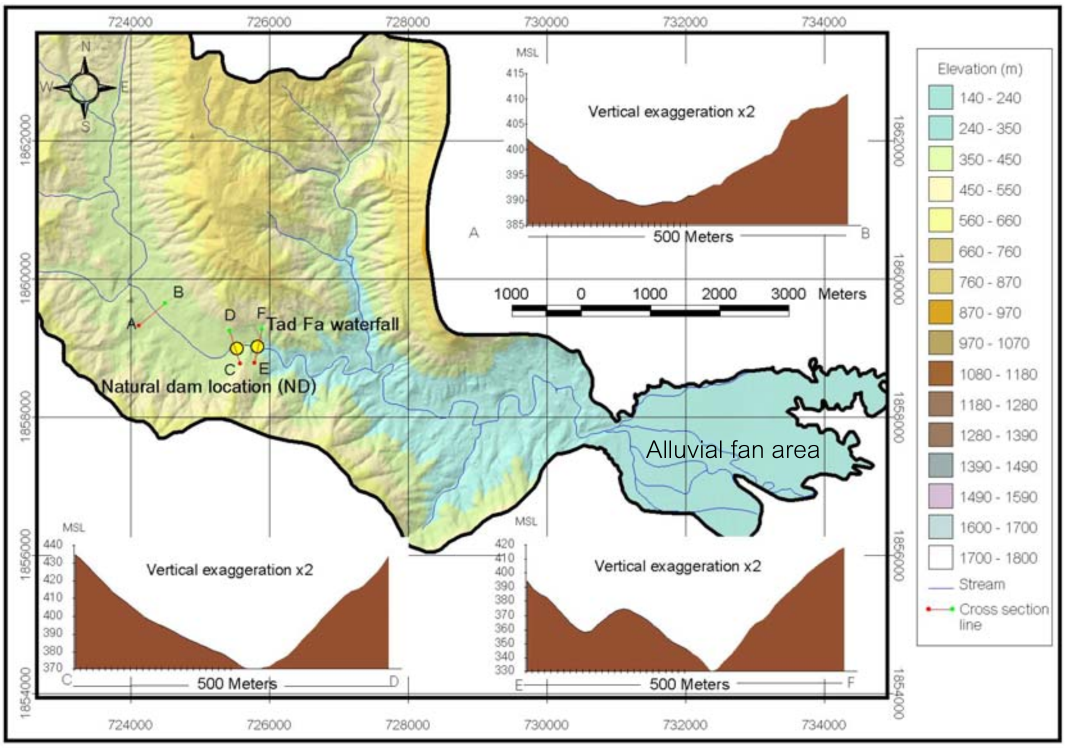

Figure 5-10 Three cross-sections (line A-B, C-D and E-F) across Nam Ko Yai stream channel and its valley at the upstream area, the suspected natural landslide dam location, and Tad Fa waterfall, respectively.

channel, especially in the outer-curvature bank of steep slope and incorporated them into the flow-flood. The evidences of 8/11 event could be observed in the field visit where Nam Ko Yai stream had a steep V-shape cross-section downstream. The traces of the erosional feature in the outer curving-bank were common. Some huge logs or intertwined bamboo clumps were left in the channel or up high on the tree splices as they were not all transported by the torrent stream flows (Figure 5-12).

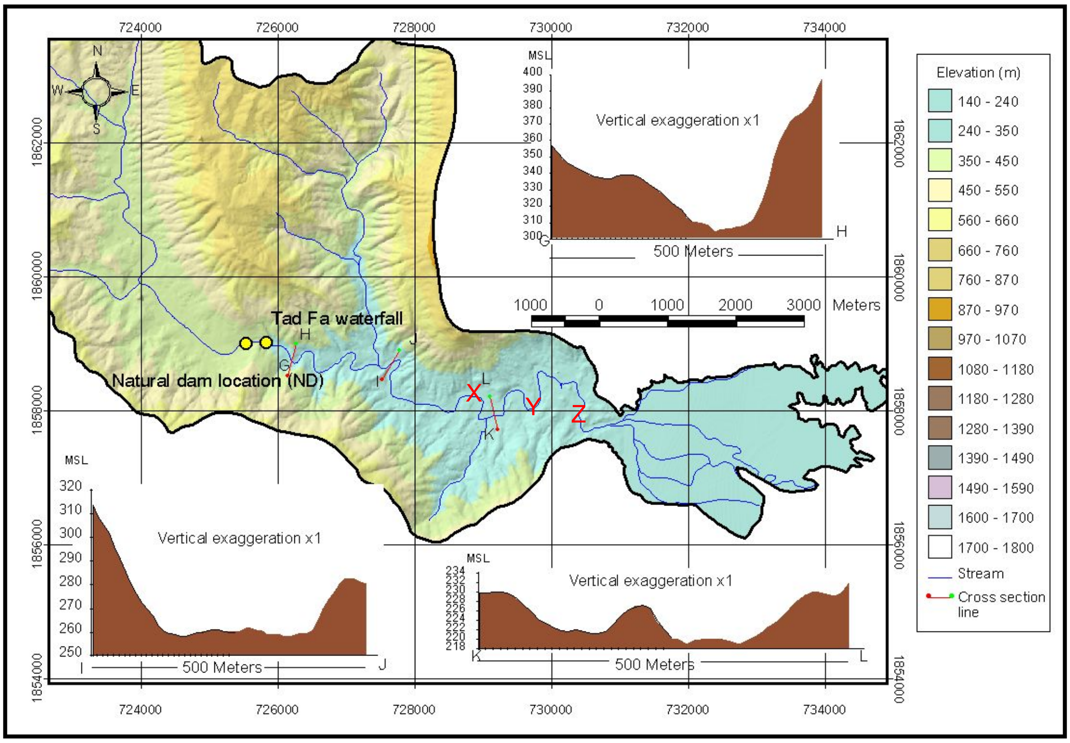

Figure 5-11 Three cross-sections (line G-H, I-J and K-L) across Nam Ko Yai stream channel and its valley at the downstream areas from the suspected natural landslide dam location (ND).

From the base rocks in the downstream from this suspected natural temporary dam location, it is interesting to note that lithilogy of Lom Sak Formation is mainly composed of high-resistant rocks of volcanic complex as shown in Figure 5-13. So the V-shape downstream with high sinuosity of Nam Ko Yai channel is generally controlled by these high-resistant volcanic rocks with some structural control of fracture lineaments as evidences by mainly channel straight change-directions and the topography.

Figure 5-12 Photographs illustrating a) the traces of erosional feature in the out curving-bank and b) huge logs or intertwined bamboo clumps after the 8/11 flow- flood event in Nam Ko Yai stream channel at location X in Figure 5-11.

Figure 5-13 Photograph showing general characteristics of the high-resistant volcanic rocks of Lom Sak Formation (Ls) in the downstream from the suspected natural temporary dam location.

Besides, newly deposited large boulders were found in the channel lying on the green weeds, where the gradient of stream bed changes from steep to flat (Figure 5-14). Eroded soil banks were also common.

From the field evidences and oblique aerial photograph (Figure 5-15) taken after the 8/11 flow-flood event, mainly the plant debris and soils that had been strongly eroded and transported from the upstream banks of Nam Ko Yai channel with high sinuosity characteristic in flat and hilly valleys were further spread out and deposited in the area of decreased confinement to form an alluvial fan at the toe of mountain front according to their high buoyancy and low viscosity. The descriptions and evidences of previous flow-flood activities in the alluvial fan will be mentioned and discussed in the following chapter.

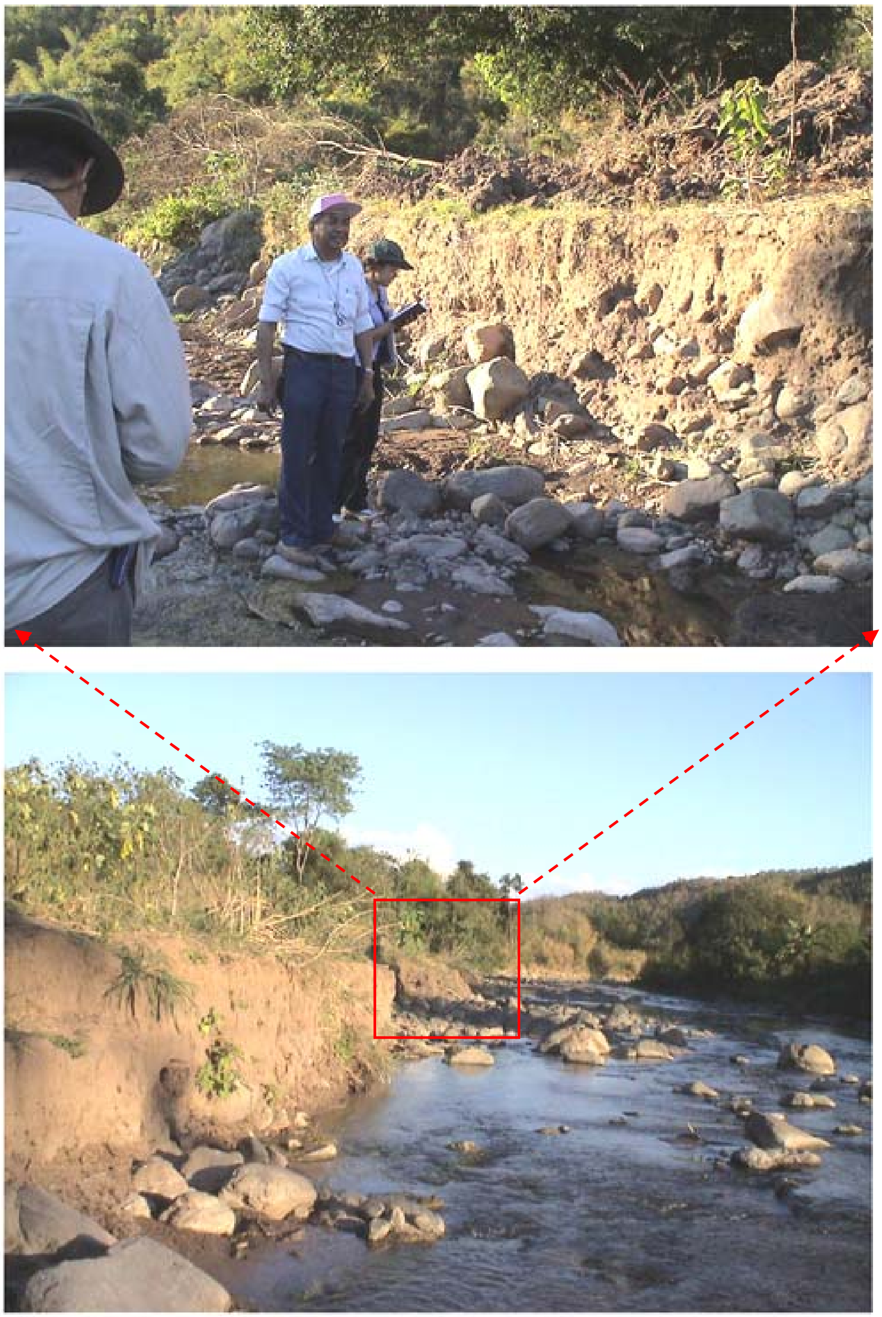

Figure 5-14 Photographs of the flat valley area with gentle slope in Nam Ko Yai stream channel at location Y in Figure 5-10 illustrating the rock boulder deposits along the bottom channel, as well as the erosional bank that prevailed the previous debris flow deposits with floating texture, unsorted, and unstratified characteristics of about 1.2 m thick.

Figure 5-15 Oblique aerial photographs along Nam Ko Yai stream channel. The photograph, at location Z in Figure 5-11, illustrates the flow-flood track along plant debris and soils had been strongly eroded and transported from its banks before reaching the outlet of the Nam Ko Yai sub-catchment.

(Data source: the photograph was taken on 22nd August 2001, 11 days after the 8/11 flow- flood event and provided by Provincial Police of Changwat Phetchabun)