11. Debris flow survey

3. 9 Debris Flow Survey

3. 9. 1 Debris flow site identification

（1）MS001 (STA.1+130)

Most of the large boulders deposited in the channel are basalt of 1 to 5m in diameter. In the area upward of the road is a basaltic cliff wall with an approximate elevation of 60m. Many of the large fallen rocks scattered at the bottom of the cliff are mainly caused by rock topples.

Water level was very low during the survey and the channel width measured about 2m, however, during the rainy season, it rises considerably which eventually become a waterfall. The channel bed gradient above the waterfall is about 2°. There is only a small amount of unstable sediment.

Shallow landslides are observed in tufficeous sandstone layers deposited at the base of the basaltic cliff wall due to erosion. Erosion under the basaltic layer also has resulted in overhanging. For this reason, there is a possibility that further erosion of the sandstone layers could lead to loss of stability for the entire cliff in the future.

A number of large basaltic rock s is also distributed in the channel downward of the road. The channel bed gradient is about 3.5° to 7.0°, and the channel becomes a waterfall again at a point about 80m downward from the road. One of the mass movement processes that can be expected in this area is Rockfall which causes damage to the road and the bridge (the bridge is approximately 12m in height and 14m in total length). Furthermore, Rockfalls could grow into debris flows when the stream discharge increases.

Photo 3. 9.1 Entire picture of MS001 (a waterfall exists in about 60m away from the bridge upstream from the road)

Photo 3. 9.2 Entire picture of MS001 (at downstream from the road)

Photo 3. 9.3 Water flow conditions in downpour time

（2）MS002(STA.1+760)

This channel flows from the basaltic cliff wall. Channel length is short and small amount of unstable sediment deposits are present on the channel bed.

This section is located in a Rockfall hazard area where sediment runoffs are observed in addition to Rockfalls. Unstable sediment consists mainly of fallen rocks that have been exfoliated and detached from the basaltic cliff walls. They are deposited near the road.

The channel bed gradient is approximately 30° and the channel width is 3 to 4m. Basaltic rocks are exposed under unstable sediment.

Water flow condition during heavy rainstorm was not clear or there was no water flow when this survey took place. Nonetheless, rock blocks deposited in the box culvert installed at the end of the channel, and sediment runoff was confirmed.

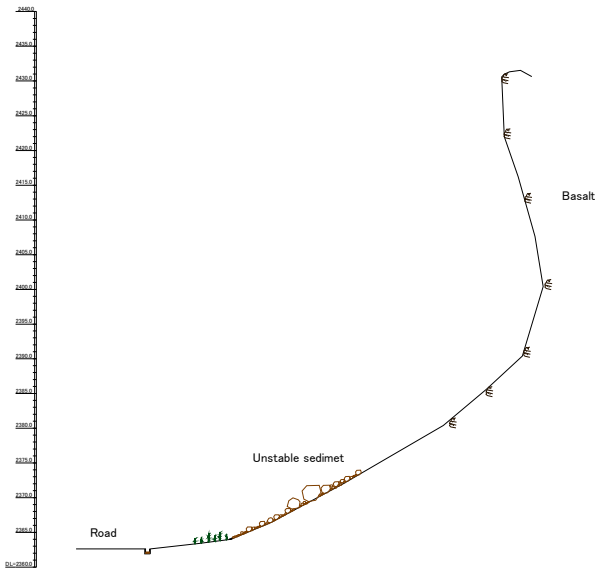

Figure 3. 9.1　Cross-sectional channel bed of MS002

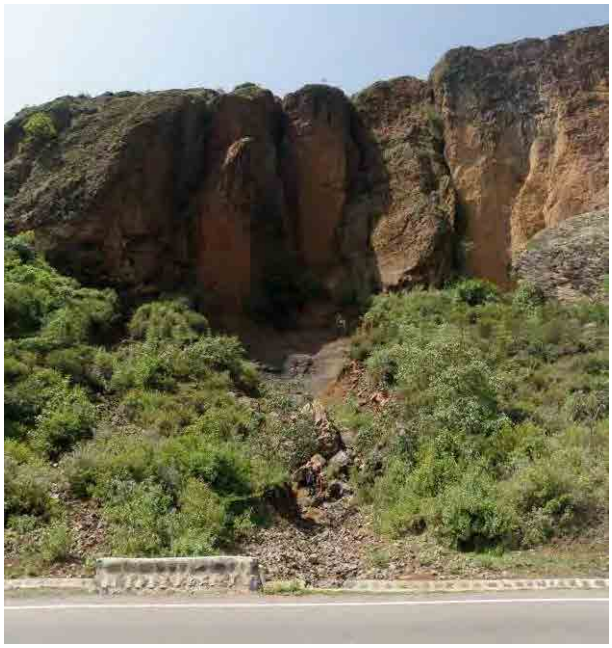

Photo 3. 9.4 Entire picture of MS002 (the upstream from the road)

Photo 3. 9.5　Entire picture of MS002 (the downstream from the road)

（3）MS003 (STA.8+220)

This small channel is located near the starting point side of the FILKLIK village.

The channel bed gradient is approximately 12° and the channel width is 1.0 to 3.0m. Top of the channel is at the drainage gutter and crossing drainage pipe, and surface water flows into this small channel. In fact, gullies have developed over time to form the channel. There are houses and fields on the side of the channel closest to the road and the side erosion is in progress.

Rock blocks are deposited in the box culvert installed under the road while sediment runoff is also taking place. As gullies develop, sediment runoff increases which eventually get transported down the river during heavy rainstorm and/or rainy seasons. Many rock blocks which are distributed in the channel are 10 to 50cm in diameter.

Photo 3. 9.6 Entire picture of MS003 (upstream from the road; fields and houses are scattered along the channel bank)

Photo 3. 9.7 Sediment which is deposited in the box culvert installed under the road (1.6m high and 2.0m wide)

Photo 3. 9.8 Channel upstream (located at the drainage of traversing drainage systems and road

（4）MS004 (STA.8+970)

This channel flows through the central area of the FILIKLIK village. Churches and houses are located along the road.

For the distance of 90m upstream of the road, the channel bed is 5° which corresponds to the deposition zone

of debris flow. In fact, rock blocks are observed in the channel bed. The channel width is from 4 to 15m widening toward the road. Further upstream of the 90m section is the zone of transportation and erosion with a channel bed gradient of 18°. This section is partially disturbed. The channel width is 2 to 8m, and large basaltic and limestone rocks with maximum diameter of about 3m are distributed.

The box culvert installed under the road is mostly blocked. The residents told us that sediment runoff sometimes gets deposited on the road during rainy seasons. Additionally, the gabions installed upstream from the box culvert have been damaged, which indicates significant sediment discharge.

No water flow was confirmed when this survey took place; however, the box culvert has been already blocked, and unstable rock blocks are distributed in the channel upstream. There is a basin with a channel bed gradient of 18°located upstream of the channel. (Debris flows occur in watershed basins with over 15° of channel bed gradient) posing a high risk of sediment runoff during rainy seasons.

Photo 3. 9.9 Entire picture of MS004 (upstream from the road; the channel bed is covered with rock blocks)

Photo 3. 9.10 Box culvert installed under the road (blocked by rock blocks)

Photo 3. 9.11 Upstream of MS004 (large rocks are scattered; basaltic cliff walls exist at the top of upstream)

Photo 3. 9.12 Conservation facilities located downstream from the channel (houses and churches are scattered)

（5）MS005 (STA.9+210)

This large channel flows along the Italian street, having a channel bed gradient of 3.6° and 4 to 100m in channel width. This channel is the longest channel in the FILIKLIK village. Boulders of varying sizes are distributed on the channel bed some of which are massive enough to reach few meters in diameter. Unstable sediment transported by debris flows is deposited in the entire segment of 1.4-km distance upstream from the road.

There is a damaged bridge in the upstream area, caused by a debris flow according to the interview with the local resident. A temporary road has been constructed further upstream of the bridge to be replaced. The total channel length is quite long, and branch channels have been also confirmed at a point approximately 850m upstream of the road. This indicates that stream discharge can increase immediately by rainfalls during rainy seasons.

The box culvert installed under the road (double barrel, 2.0m wide, and 7.0m high) has a larger inner space compared to those installed in other channels indicating its large drainage basin.

This box culvert is filled with sediments and rock blocks which were carried down from above during rainy seasons.

Photo 3. 9.13　Entire picture of MS005 (upstream from the road; large rocks are scattered)

Houses are scattered along the channel and bank erosion is also in progress. Thus, potential risk of houses to be affected by runoff water is high when the channel overflows.

Photo 3. 9.14 Channel upstream (covered with rock blocks)

Photo 3. 9.15　Damaged bridge

Photo 3. 9.16 Box culvert (with rock blocks deposited)

（6）MS006 (STA.10+250)

This channel does not resemble any form waterway nor have water flowing as it is usually used as a walking path for the local residents.. Nonetheless, trenches to direct flow into the gutter are installed along the channel upstream of the road for when water flows from upstream during rainstorm or rainy season. Gravels are scattered downstream from the road, which shows sediment ran off onto the road.

For a segment of approximately 50-m above the road, channel bed gradient is 23°, while it is 3° further upstream. The channel width is 5.0m or narrower with a short channel length. Settlements are scattered in the area upstream of the channel. The area where settlements are distributed has moderate channel gradient and a flat terrain.

Many rock blocks of 30cm or smaller are scattered in the channel. Because channel bed gradient near the road is steep, there is a high risk of sediment runoff during rainy seasons. There are rock blocks and sediment deposited in this trench, so that proper maintenance such as the removal of the sediment is required.

Photo 3. 9.17　Entire picture of MS006 (upstream from the road; water flow is drained from trenches to gutters on the road side)

Photo 3. 9.18　Entire picture of MS006 (downstream from the road; rock blocks are scattered)

（7）MS007 (STA.10+800)

This is a confluent channel formed by merging of three other channels (MS003, M004, and M005) and flows through the FILIKLIK village.

The channel width around the road is about 15m to 20m and it has a channel bed gradient of 10.4° (18%, read from the topographic map). Large rock blocks of about 2m are scattered on the channel bed. But most of them are mainly rock blocks with varying sizes from 10 to 50cm. Although stream discharge is small, flow is always present, providing drinking water for domestic animals.

The average elevation between the channel bed and the road is approximately 9m, and a big double-barreled box culvert with a large inner space is installed under the road. Rock blocks are deposited in the box culvert; however, the amount of deposits is much less when compared to the other three channels flowing through the FILIKLIK village.

A dam (2.0 high and 13.0m long) is installed downstream of the road, which has been mostly filled high with

debris and sediment. The basin area is rather large-sized with a relatively large sediment supplies, so that there is a risk of debris flow.

Photo 3. 9.19　Entire picture of MS007 (upstream from the road; slight water flow is seen)

Photo 3. 9.20　Entire picture of MS007 (downstream from the road; behind the dam is almost filled with sand)

（8）MS008 (STA.11+030)

This small channel where gullies have developed has a channel bed gradient of 4.8° (8%, read from the topographic map) and 1 to 3m in width. Rock blocks approximately from 30 to 50cm are distributed in the channel bed, but sediment composite is predominantly sand mixed with gravels. The channel bank is debris mound vegetated with shrubs. This channel is also short in length.

A number of smaller channels are located toward the end of the main road where gullies have developed. They tend to have moderate channel bed gradient and short channel length; in addition, they have a large amount of sediment runoff due to erosion.

This channel has thick layers of sand and gravels deposited in the box culvert (2.5m high and 2.5m wide) installed under the road. Such deposits are also transported downstream. The elevation from the channel bed to the road is approximately 6.5m, which lowers a risk of sediment runoff entering the road.

No water flow was confirmed when this survey took place; this channel presumably become a flow path in rainstorm and rainy seasons.

Photo 3. 9.21 Entire picture of MS008
(upstream from the road; no water flow confirmed)

Photo 3. 9.22 Entire picture of MS008
(downstream from the road; gullies develop)

Photo 3. 9.23 Box culvert installed under the road (rock blocks are distributed)

（9）MS009 (STA.11+390)

As is the case of channel MS008, MS009 is also a small channel where gullies have developed into a stream. Channel gradient is 8.7° (15%, read from the topographical map) and width is 2 to 3m. Similarly to the previous channel, the value of channel bed gradient is less than 10° which corresponds to “the depositional zone” of debris flow. Vegetation grows in the surrounding area and rock blocks approximately from 30 to 50cm are distributed on the channel bed.

The channel banks are consisted of debris mound which induced significant bank erosion. A topographic depression or scour depression with vertical walls has been formed in the area upstream. The cliff is approximately 5m high. Further upstream of the cliff is flat terrain where no flow path was observed.

Sediment and many rock blocks are deposited in the box culvert (2.5m high and 2.5 wide) installed under the road indicating that sediment runoff is generated during rainstorm and rainy seasons.

Elevation from the channel bed to the road is also approximately 6m, which shows a low risk of sediment runoffs onto the road.

Photo 3. 9.24 Entire picture of MS009 (upstream from the road)

Photo 3. 9.25 Box culvert installed under the road

Photo 3. 9.26 Channel upstream area (flat terrain and no flow path seen)

（10）MS0010 (STA.11+820)

This small channel where gullies have developed has a channel bed gradient of 7.1° (12%, read from the topographic map) and is 2 to 3m in channel width.

An alluvial fan with moderate slope is formed in the area upstream, which is covered with shrubs. This channel also corresponds to “the depositional zone” of debris flow. No failed slope is confirmed in the upstream area.

Little sediment deposit is observed in the box culvert (2.0m high and 2.0m wide) under the road, which shows that sediment runoff has not occurred recently. Rock blocks from 30 to 50cm in diameter are distributed in the channel bed, but main deposits are sand and silt.

Photo 3. 9.27 Box culvert installed under the road (no sediment deposits)

No water flow was observed when this survey took place; presumably this channel becomes a flow path during rainy season.

Photo 3. 9.28 Entire picture of MS010 (upstream from the road; no water flow)

Photo 3. 9.29　Entire picture of MS010 (at downstream from the road)

（11）MS011 (STA.12+080)

This small channel where gullies have developed into a stream has a slope gradient of 9.0° (16%, read from the topographic map) and 2 to 4m in channel width. Vegetation grows along the channel, and many rock blocks are deposited on the channel bed to a certain degree. The channel bed on the road side is steep. Large rock blocks about 1m in diameter are scattered in this side. Channel banks are debris mound which is mainly consisted of gravels.,

The box culvert (3.5m high and 3.0m wide) installed under the road is larger compared to that of the previous channel. Debris and rock blocks cover the entire floor of the box culvert indicating large amount of sediment supply.

No water flow was confirmed when this survey took place.

Photo 3. 9.30　Box culvert installed under the road (sediment deposits cover the entire inside)

Photo 3. 9.31 Entire picture of MS011 (upstream from the road; no water flow confirmed)

Photo 3. 9.32　Entire picture of MS011 (downstream from the road; a channel where gullies developed)

（12）MS012 (STA.12+320)

This small channel has a channel bed gradient of 11.3° (20%, read from the topographic map) and a width of 2 to 3m. The channel bed gradient becomes steeper above the quarry. The entire channel length is short, and the upstream area of this channel is used as cultivating fields.

A quarry of limestone and gypsum is located on the right bank. The channel bed is covered with sediment having run off from the quarry in addition to rock blocks from about 30cm to 1m in diameter. The quarry extends approximately 150m where; no vegetation grows on the bare surface.

Currently, there is little sediment deposit in the box culvert (2.5m high and 2.0m wide) under the road. However, there is a threat of sediment runoff being generated during rainstorm and rainy season. The average Elevation from the channel bed to road is approximately 9m, which shows a low risk of sediment running off onto the road.

Photo 3. 9.33　Quarry located on the right channel bank (sediment runs off into the channel from the quarry)

Photo 3. 9.34　Entire picture of MS012 (upstream from the road)

Photo 3. 9.35　Box culvert installed under the road

（13）MS013 (STA.12+550)

This small channel where gullies have developed into a stream has a channel bed gradient of 15.0° (27%, read from the topographic map) and is 1 to 1.5m in channel width. Geological layers of the channel banks are of limestone and gypsum. Shallow scour depressions have been made and formed gullies in the channel upstream. The channel bed gradient becomes steeper in the channel above the road. Rock blocks about 50cm in diameters are scattered on the channel bed. Very little vegetation grows near the banks; hence there is a possibility of surface water entering the channel immediately during rain fall.

The box culvert (1.8m high and 2.0m wide) installed under the road has a small inner space and very little sediment deposit. The channel bed gradient is slightly steep and the entire channel length is short. This shows that there is a low risk of sediment runoff generation.

Photo 3. 9.36　Entire picture of MS013 (upstream from the road; no water flow)

Photo 3. 9.37　Channel upstream (Limestone is exposed)

Photo 3. 9.38　Box culvert installed under the road

（14）MS014 (STA.12+750)

In this channel, the channel bed gradient is 14.6° (26%, read from the topographical map) and the channel width is 1m to 2m.

The flow path is short and steep where no water flow was confirmed during the survey. The quarry for limestone and gypsum is located on the left bank. The channel bed upstream from the road is covered with sediment that has run off from the quarry.

The box culvert under the road has been blocked half-way up by sediment debris from the quarry. As a result, ability of the culvert to flush down the stream gets significantly decreased. If the volume of sediment runoffs from the quarry increased, the box culvert would be completely blocked. It is desirable to remove sediment as soon as possible.

This channel joins together with subsequent channels of MS011 toward the end the road.

Photo 3. 9.39　Entire picture of MS014 (upstream from the road; the quarry is located on the left bank)

Photo 3. 9.40　Channel upstream (Limestone is exposed)

Photo 3. 9.41　Box culvert installed under the road

（15）MS015 (STA.13+380)

This small channel has a channel bed gradient of 14.0° (25%, read from the topographic map) and is 1.0m to 2.0m in channel width. Massive boulders of basalt and limestone are scattered on the channel bed. The channel banks are of debris mound and many large rock blocks are distributed in the area upstream.

This channel flows along a flank scarp and joins together with the channel MS016 at a point downstream from the road. The channel banks are covered with vegetation, and shrubs densely cover the upstream area. There is no evidence of failures in the area upstream. Sediment supply would be low.

Slight deposit is observed in the box culvert (4.0m high and 2.0m wide) installed under the road.

Photo 3. 9.42　Entire picture of MS015 (upstream from the road)

Photo 3. 9.43　Channel upstream (large rocks are scattered)

Photo 3. 9.44　Box culvert installed under the road

（16）MS016 (STA.13+430)

This small channel is located near the channel MS015, with a channel bed gradient of 11.3° (20%, read from the topographic map) while its width ranging between 1.0m to 1.5m. Gravels around 20 to 40cm in diameter are distributed in the channel bed. The surrounding of the channel is covered with shrubs.

This channel flows along the side of a landslide wall, whose channel conditions resemble those of MS015. A crossing drainage work with 1.0m in diameter is installed under the road.

Photo 3. 9.45　Entire picture of MS016 (upstream from the road)

Only a small amount of sediment deposit exists in the drainage work and its upstream indicating a comparatively small supply of sediment. As is the case with the previous channel, no water flow was confirmed when this survey took place.

Photo 3. 9.46　Channel upstream (large rocks are scattered)

Photo 3. 9.47　Drainage pipe installed under the road

（17）MS017 (STA.13+640)

This channel has a long channel length with a channel bed gradient of 14.0° (25%, read from the topographic map) and is between 4 and 6m in channel width. This channel is categorized as a medium-sized channel. Basaltic rocks from 1 to 3m in diameter and large limestone rocks are distributed in the channel bed upstream from the road. Both channel banks are steep to a certain degree, and bank erosions can be partly seen.

Upstream of the channel flows along basaltic cliff walls, and branching streams are seen approximately 300m upstream of the road. It can be speculated that there is a comparatively large amount of sediment supply.

The box culvert (4.0m high and 4.0m wide) installed under the road has a large inner space, representing a large basin area. Sediment and gravel deposits are not currently seen; however, the accumulated large rocks in the channel bed indicate a high potential of debris flow.

Photo 3. 9.48 Entire picture of MS017 and MS018

(left: MS017; right: MS018)

Photo 3. 9.49 Entire picture of MS017

(upstream from the road)

Photo 3. 9.50 Channel upstream (large rocks are scattered)

Photo 3. 9.51 Box culvert installed under the road

（18）MS018 (STA.13+670)

This small channel is located immediately after the end point of channel MS017, with a channel bed gradient of 18.0° (33%, read from the topographic map) and a width between 1 and 3m. This channel meets with channel MS017 downstream of the road, while it flows along a landslide wall upstream from the road.

Photo 3. 9.52 Entire picture of MS018 (upstream from the road)

A cliff wall with an elevation of approximately 12m stands at approximately 40m upstream from the road and the channel width further upstream is smaller than 1.0m. Although this channel is likely to have been developed

from gullies into a channel, bank erosion is also in progress.

A crossing drainage work of 1.0m in diameter is installed under the road and almost no sediment deposit is confirmed.

Photo 3. 9.53　Channel upstream

Photo 3. 9.54　Drainage pipe installed under the road

（19）MS019 (STA.14+110)

This small channel has a channel bed gradient of 26.1° and a width between 1 and 3m.

As the channel bed is steep, this section of the channel can be categorized into a potential debris flow source based on the gradient. Gravels between 10 and 30cm in diameter are distributed in the channel and both channel banks are also very steep. As bank erosions are partially in progress, stream disturbance is evident.

Almost no sediment deposit is seen in the box culvert (2.0m high and 1.5m wide) installed under the road. However, the steep channel bed gradient indicates great velocity of sediment runoff.

According to our references, this channel is recognized as a channel with a high potential of debris flow. Judging from the channel bed gradient, this channel is potential debris flow source.　Nonetheless, the basin area is small and the average height between the road and the channel bed is approximately 8m. Hence, we determined the possibility of sediment runoffs spilling onto the road is small.

Photo 3. 9.55　Entire picture of MS019 (upstream from the road)

Photo 3. 9.56　Channel upstream (channel bank erosion)

Photo 3. 9.57　Box culvert installed under the road

（20）MS020 (STA.14+720)

This small channel has a channel bed gradient of 18.3° (33%, read from the topographic map) and a width of 1 to 4m. A quarry of limestone and gypsum is located on the left bank.

The entire channel is less than 500m long and the right bank is within a landslide area.

Sediment and gravel discharged from the quarry are deposited in the channel bed. This accumulated sediment is blocking part of the crossing drainage work installed under the road.

Photo 3. 9.58　Entire picture of MS020 (upstream from the road)

Vegetation grows upstream of the channel; however, the progressive bank erosion is causing stream destabilization. No water flow was confirmed when this survey took place. However, amount of sediment runoff is presumably large during rainstorm or rainy season for the surface of the quarry is bare.

Photo 3. 9.59　Quarry on the left bank

Photo 3. 9.60　Drainage pipes installed under the road

Photo 3. 9.61　View of upstream

（21）MS021 (STA.15+860)

This small channel is located near the Kajima Corporation warehouse.　It has moderate slope throughout the stream.

Flow path is unclear upstream from the road which rather forms a irregular terrain (or channel) surface. Nonetheless, gravels are scattered around. On the other hand, the terrain downstream from the road is almost flat with very little relief.

No sediment deposit is observed in the crossing drainage work installed under the road, showing that sediment runoff is limited.

Photo 3. 9.62　Entire picture of MS021 (upstream from the road)

Photo 3. 9.63　Drainage pipe installed under the road

Photo 3. 9.64 Entire picture of MS021 (downstream from the road)

（22）MS022 (STA.16+680)

This channel has a channel bed gradient of 5.7° (10%, read from the topographic map) and a width of 1 to 2m. The flow path is less than 500m long which is relatively short for a stream, and the channel bed gradient is moderate. For this reason, there is a small possibility of debris flow occurrence. The line connecting this channel and the ABAY Bridge goes through the plateau edge which is consecutive cliffs of sandstone and siltstone.

Gravels are deposited in the box culvert (3.0m in height and 2.0m in width) installed under the road and large rocks are distributed upstream. However, at a point approximately 50m upstream from the box culvert, the gradient becomes moderate and sandstone is exposed in the channel bed.

We speculate that as surface water from the road enters into the channel, sediment is also discharged during heavy rain or rainy season.

Photo 3. 9.65 Large rocks near the box culvert

Photo 3. 9.66 Channel upstream (located on the road side)

Photo 3. 9.67 Box culvert installed under the road

Photo 3. 9.68 Large rocks in the box culvert

Photo 3. 9.69 Entire picture of MS022 (downstream from the road)

（23）MS023 (STA.20+580)

This channel has a channel bed gradient between 25° to 35° and is 5.0 to 10.0m in width. This is a long channel that runs through the Kurare or Endejen village close to Dejen eventually flows into the ABAY Valley. There is a waterfall with approximately 65m in height located upstream of the road, which is within a Rockfall hazard location. As there is abundant water in this waterfall, there is constant flow of water throughout the year.

An artificial pond is located near the waterfall. This pond is utilized for general water use. According to the interviews conducted, the water overflows in the rainy season.

A dam (discharge channel being approximately 2m in width and 0.6m in height) is installed near the road whose arm on the right bank has been scoured by Rockfall or debris flow.

Large rocks distributed in the channel bed are sandstone, basalt, and limestone. During rainy season, it is likely to be that sediment containing gravels are transported from upstream. The inner space of the box culvert installed under the road is smaller than the large sandstone rocks which are spread out upstream. This blocks the box culvert. If a debris flow occurs, there is the threat that the large rocks will totally block the box culvert and force sediment runs off onto the country road.

Photo 3. 9.70　Entire picture of MS023 (upstream from the road)

Photo 3. 9.71 Waterfall upstream from the road

Photo 3. 9.72　Dam built upstream from the road (picture taken from the upstream)

Photo 3. 9.73　Entire picture of MS023 (downstream from the road)

Photo 3. 9.74　Inside view of the box culvert

（24）MS024 (STA.20+970)

This small channel has a channel bed gradient of 32° and is 1.0 to 1.5m in width. This channel does not exhibit the characteristics of a general mountain stream.

The channel bed gradient indicates as potential debris flow source, hence there is a relatively higher possibility of debris flow occurrence. This channel is usually used for a pathway by local people, and no water flow was confirmed when this survey took place.

Sediment control structures have been installed near the road which indicates the previous experience of sediment run off in the past. Presumably, in a rainy season (or seasons), surface water flowed along gullies which also transported to sediment onto the road.

Although vegetation grows upstream, fallen stones from 30 to 50cm in diameter are distributed along the gullies. There is a possibility that these fallen stones may fall onto the road transported by sediment runoff.

Photo 3. 9.75　Entire picture of M024 (upstream from the road)

Photo 3. 9.76　Channel upstream

Photo 3. 9.77　Entire picture of M024 (channel view from upstream)

（25）MS025 (STA.21+280)

This small channel is located in a Rockfall hazard location, where water flow is confirmed. Although small amount of gravels are distributed in the channel bed, no signs of scouring or large rocks are present.

There is a great possibility that this channel experiences rising of water during the rainy season. However, as the distance from the road is sufficient, the potential risk of sediment runoff spilling onto the road is small.

Photo 3. 9.78　Channel bed

Photo 3. 9.79 Entire picture of M025 (upstream from the road)

（26）MS026 (STA.21+530)

This small channel has a channel bed gradient of approximately 15° and is 1.0 to 2.0m in channel width, where gullies have developed.

There is no water flow, and fallen stones from 30 to 50cm in diameter are distributed along the gullies. Surface of the area around the gullies are bare due to erosion, and large basaltic rocks are present in the channel upstream. As is the case of channel MS024, sediment control structures have also been installed indicating that there has been sediment run off in the past.

The steep channel bed poses a potential risk of overland flow of unstable sediment and gravels from the stream during rainy season.

Photo 3. 9.80　Entire picture of M026 (upstream from the road)

Photo 3. 9.81　Channel upstream

Photo 3. 9.82　Entire picture of M026 (upstream channel view)

（27）MS027 (STA.21+740)

This channel has a long channel length that reaches approximately 3.6km.

The channel bed gradient is 5.5° for the length of approximately 2.8km upstream from the road and the gradient becomes 10° further upstream. Compared to the channel length, its width is narrow which is between 1 and 4m wide. Both of the channel banks consist mainly of deposited sediment.

Gravels from 10cm to a few meters in diameter are distributed in the channel bed. Bank erosion is also significant. This channel goes under the road several times through the box culverts and drainage pipes, and then joins together with some branch flows that have developed gullies. The channel upstream is connected to the end of a water path, so that the surface water above the water path also flows into the channel.

Although the channel bed has a moderate gradient, the channel is long and bank erosion supplies a large amount of sediment. Hence, risk of debris flow is high.

Photo 3. 9.83　Entire picture of MS027 (upstream from the road)

Photo 3. 9.84　Box culvert under the road

Photo 3. 9.85　Drainage pipe installed in the channel upstream

Photo 3. 9.86　Water path drainage that reaches the channel flow

（28）MS028 (STA.30+420)

This small channel is located on the landslide, with a channel bed gradient of 14.0° (25%, read from the topographical map) and width of 1.0 to 2.0m. Vegetation is present around the channel, and upstream of the road is covered with shrubs. A dam is installed on the road side; however, this dam has been totally damaged to the point where it no longer retains its original form.

There is a large amount of sediment deposit in the box culvert installed under the road causing occasional overland flow of sediment onto the road in the rainy season according to the interviews conducted. Water flow was observed in the channel during the survey. Spring water occurring upstream is used for daily water consumption.

Similar to this channel, several channels located in the section ST.32+000 toward the end also have springs upstream. They all have steep channel bed, posing a high risk of sediment runoff.

Photo 3. 9.87　Entire picture of M028 (upstream from the road)

Photo 3. 9.88　Damaged dam (taken from the upstream of the road)

Photo 3. 9.89　Spring point in the channel upstream

Photo 3. 9.90　Box culvert installed under the road

（29）MS029 (STA.30+860)

This channel has a channel bed gradient of 16.7° (30%, read from the topographic map) and 3 to 5m in channel width. This is a small to medium-sized channel flowing along the side of the landslide wall. A water channel work is installed at the end of the channel beside which gabions are set along the stream to prevent surface erosion.

The flow path is used for a walkway leading to a water point, and large rocks over 1m in diameter are scattered in the channel bed. The entire channel bed of the upstream side is covered with gravels deposits.

Gravels deposited in the box culvert under the road (2.5m high and 2.5m wide) are presumably transported down during rainstorm or rainy seasons.

Photo 3. 9.91　Entire picture of MS029 (upstream from the road)

Photo 3. 9.92　Spring point in the upstream channel

Photo 3. 9.93　Crushed rock deposits conditions in the channel upstream

Photo 3. 9.94　Box culvert (upstream direction)

Photo 3. 9.95　Box culvert (downstream direction)

（30）MS030 (STA.31+210)

This small channel has a channel bed gradient of 13.2° (23%, read from the topographic map) and 1.0m in channel width, having developed gullies. The channel length is short, and this channel flows along the side of the landslide wall. Houses are scattered along the flow path downstream from the road.

Gravels 10 to 30cm in diameter are deposited in the box culvert installed under the road indicating all types of sediments and debris are transported down during rainy seasons.

Photo 3. 9.96 Entire picture of MS030 (upstream from the road)

Photo 3. 9.97 Entire picture of MS030 (at downstream from the road)

Photo 3. 9.98 Box culvert installed under the road (crushed rocks deposit)

（31）MS031 (STA.31+560)

This small to medium-sized channel has a channel bed gradient of 10.6° (19%, read from the topographic map) and 3 to 5m in channel width, flowing along the side of the landslide wall. A sediment control work is installed at the end of the flow on the road side. Damages observed on the structure are presumably done by large rocks.

Large rocks over 1m in diameter are distributed in the channel bed, and the bed is covered with gravels. Very little vegetation grows along the flow path, which is used as a walkway. As is the case of the previous channel, there is a spring occurring upstream which is used as a water point.

Gravels are deposited in the box culvert installed under the road indicating large amount of sediment runoff. In this channel, occasional sediment runoff has been reported in the past.

Photo 3. 9.99　Entire picture of MS031 (upstream from the road)

Photo 3. 9.100　Spring point in the channel upstream

Photo 3. 9.101　Box culvert (crushed rocks deposit)

（32）MS032 (STA.32+260)

In this channel, limestone cliff walls (about 7m high) continue on the road side and a crossing drainage work (1.5m of drainage pipe) is installed under the road. Natural slope begins further upstream of the limestone walls and a series of basaltic cliffs appears at the furthest upstream tributary or headwater.

No water flow was confirmed when this survey took place. Even when there is a flow, discharge is likely to be small judging from the size of the crossing drainage work. However, this drainage structure has become deformed whose ability is now limited. In addition, as there are no structures at the drainage for directing the flow, developing gullies are leading to significant surface erosion. Although the channel is relatively close to the road,the risk of sediment runoff is low as catchment basin is small.

Photo 3. 9.102　Entire picture of MS032 (upstream from the road)

Photo 3. 9.103　Entire picture of MS032 (at downstream from the road)

Photo 3. 9.104　Traversing drainage system (crushed rocks deposit)

Photo 3. 9.105　Traversing drainage pipe (drainage pipe shape has been altered)

（33）MS033 (STA.32+820)

This channel has a channel bed gradient of 16.2° and 17.0 to 36.0m in channel width, having a large basin area.

Upstream from the road, large basaltic rocks are seen, and some of them have 5m or larger in diameter. Basaltic cliff walls appear around 350m upstream from the road, and there is a waterfall in the channel. Large rocks are densely distributed around the waterfall presumably deposited there by Rockfalls or debris flows. Public facilities and other buildings in need of protection during disasters such as churches and houses are scattered in the area downstream near the road.

Large rocks about 2.0m are observed in the box culvert (7.0m high and 3.0m wide) installed under the road. In the past, the slope on the side close to the road failed, causing large rocks to fall. Large basaltic rocks are distributed in the area downstream from the road, which seems to have been transported and deposited by debris flow.

Judging from the size of the basin area, channel extension, and gradient, this channel has a high risk of debris flow.

Photo 3. 9.106　Entire picture of MS033 (upstream from the road)

Photo 3. 9.107　Larger rocks scattered around the waterfall

Photo 3. 9.108　Box culvert installed under the road

Photo 3. 9.109　Large rock in the box culvert

Photo 3. 9.110　Entire picture of MS033 (at downstream from the road)

（34）MS034 (STA.33+130)

This medium-sized channel is located approximately 400m away from the channel MS033 toward the end point, with a channel bed gradient of 9.1° and 3 to 10m in channel width.

Basaltic cliff walls stand along the channel upstream. Below the walls approximately 150m upstream from the road, there are branch flows joining the main tributary. This channel flows through the landslide area and gravels are distributed in the channel bed. Compared to the previous channel MS033, only a handful of large rocks are distributed and vegetation grows in the channel bed. The channel width near the road is approximately 10m; which becomes narrower as one goes upstream, about 2 to 3m. No water flow was confirmed when this survey took place. The surrounding area of the channel is used as corn fields.

No sediment is deposited in the box culvert under the road indicating small amount of sediment runoff during the last few years. However, depending on the precipitation level during the rainy season, there is a possibility of sediment runoff.

Photo 3. 9.111　Entire picture of MS034 (upstream from the road)

Photo 3. 9.112　Channel upstream (large rocks are scattered)

Photo 3. 9.113　Box culvert installed under the road

Photo 3. 9.114　Inside the box culvert

Stream in the Abay River Gorge (Alemgana)

Stream.No.	S01-1	S01-2	S02-1	S06-1	S07-1	S08-1
Photograph						
Stream.No	S08-2	S09-1	S10-1	S11-1	S11-2	S11-3
Photograph						
Stream.No	S12-1	S12-2	S12-3	S13-1	S13-2	S13-3
Photograph						
Stream.No	S13-4	S14-1	S14-2	S15-1	S16-1	
Photograph						

Stream in the Abay River Gorge (Debre Marco's)

Stream.No	S20-1	S20-2	S21-1	S21-2	S21-3	S21-4
Photograph						
Stream.No	S21-5	S30-1	S30-2	S30-3	S30-4	S31-1
Photograph						
Stream.No	S31-2	S31-3	S32-1	S32-2	S33-1	S33-2
Photograph						
Stream.No	S33-3					
Photograph