12.02.2018

Field work in Dolakha District

Assessment of landslide and slope stability at 11 schools.

FORUT

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Contents

Front picture: Gyalsung school. Photo by Thomas Ødegaard.

Summary

A team of engineers from Norway has assessed landslide and slope stability around 11 school plots in the Dolakha district. In general, the space available for schools including schoolyard is limited in terraced hill slopes. Some of the main observations for each schools are summarized in Table 0-1. Nine of the schools will need some kind of mitigation at the backwall. The schools seem to be planned and partly already built without stability assessments of back, or front wall. Two schools (Jana and Himali Devi) are directly influenced by road cut stability. Only Seditdevi has a rock fall risk, but the school security may be improved by a rockfall barrier. Six of the schools are situated on ridges, that general makes the schools dry from running water as long as roads do not drain water. Two schools are situated in depressions, where small streams occurs and channel/erosion protection should be carried out.

For each school, measures are divided into high, medium and low priority. High priority means that a new building is not regarded as safe without this measure. Therefore, a new building should not be constructed without these measures.

Table 0-1 Summary of most important measures for the schools, based on observations from fieldwork.

School	Backwall needs retaining wall	Other retaining walls	Rock fall	Erosion protection (drainage system)	Distance to access road	Sufficient space
1-Mahadesewori	6m height	4m height	No	Yes	100m downhill from school	No
2-Lingba	2m height	For landfill, 3-4m height	No	Yes, ditch along the road	4m above, footpath	No
3-Gyalsung	2m wall, against road	3-4 m behind temporary building	No	No	0m	Yes
4-Narayani	No	1.5m wall, improving walls due to new foundation	No	Yes, ditch along the road	10m	No
5-Kaleiswori	2-3m	In front, 6 m height	No	No	Possible to drive around, direct path 100m down	No
6-Setidevi	No	Rock fall barrier	Yes	No	0 m	Yes
7-Chirkun Than	Both behind the existing building and the new one	In front of new building, slope need reinforcement	No	No	Road above, more than 100m footpath	No
8-Deadhunga	6m height against road	Improvement of front wall	No	Yes	Road 6m above schoolyard, possible to make steep construction road	Yes
9-Jana	5m height	At least 6 m wall at road cut in order to secure a new building	No	Local spill water drainage from neighbours and awareness of possible drainage from parking lot	Road ~30 m above, and below, steep stairs	No
10-Himali Devi	Road cut below building, 6m height	Downside road stabilization, 10-15m	No	No	At end of buildings	No, possible space on the SE plateau
11-Himkhande Bhuwaneswori	Backwall terrace lowered	Front wall of lower terraces, 5m	No	No	0 m	Yes

Introduction

In April 2015, Nepal was hit by an earthquake with moment magnitude of 7.8 with epicentre in Gorkha. A series of aftershocks (M>6) followed the event, including an earthquake with M7.3 with epicentre in the district of Dolakha in May. Almost 90 % of the buildings were severely damaged in the district. Today, temporary sheds are still dominating in the district. New standards are applied for new constructions with improved strength against earthquakes. FORUT (Norwegian foundation) and CWIN (Nepalese NGO) have received a contract from the Norwegian Embassy to rebuild schools in Dolakha.

Through Engineers Without Borders (EWB) Norway (IUG), Åse Marit Wist Amdal and Øyvind Armand Høydal (both NGI) have been engaged to assess landslide and slope stability around 11 school plots in the Dolakha district. Thomas Ødegaard, a Master student from University of Stavanger participated in the fieldwork, meetings and this report. He will do his master thesis through IUG on the topic of a new building at Kanti hospital in Kathmandu and its strength and risk assessment for earthquake events. The team visited Kathmandu, including Kanti Hospital and Dolakha district from January 22 to February 2 2018. CWIN organized the logistics and gave local information and contacts during the trip.

This report should not be considered as a design report, but the purpose is to give advice and a rough estimate of required measures. The suggested measures are general, and therefore each measure needs to be designed separately.

For each school, measures are divided into high, medium and low priority. High priority means that a new building is not regarded as safe without this measure. Therefore, a new building should not be constructed without these measures.

Slope stability and landslide assessment

For each location a general assessment of local geometry and stability, and risk of landslides for the school plots is given. The basis for this evaluation is topographic and geological characteristics, such as:

- Landforms tells about the areas properties to concentrate surface water: ridge, depression, ravine, concave/convex.
- River- drainage pattern:
    - Distance and height difference from nearby rivers regarding river erosion.
    - Distance and location of drainage pattern/ravine, stream and possible drainage following road ditches. The question is if running water and debris may enter the plot
- Land cover: arable land, forest, rural, both upside, at the sides and downside of the site.
- Soil types, characteristic, depth to "bedrock".
- Seeping of groundwater, soil water content.
- Topography/geometry, terrain profiles locally through the school plots and along the hill side: length, inclination upside and downside.
- Description of nearby landslides: type, shallow/deep. Triggering effects: rainfall/earthquake?
    - What is the difference in topographic characteristics at the school plot and at the landslides?
- Description of access roads to the school.
- Road cut stability, soil/rock characteristics in road cut.

Landslides – natural hazards

- In general the focus of landslide or processes is:
  - Flood and debris flow that may be initiated in streams and/or caused by lateral water displacement due to road construction.
  - Earthslide: Larger slide of weathered soil often with rock content released in areas steeper than 30°, triggered by rainfall or earthquake. Long run-out distance. Road cut and fills may increase landslide activity.
  - Rockfall: Direct outfall of rock from cliff. Rockfall activity is assessed based on stability of rocks up in the cliff, age of stones in the talus and number of blocks downside the talus.

Local stability

In this assessment, we typical talk about local stability of terraces. Local stability covers the slopes that may have a short runout distance or movements causing small deformations that influence the school buildings or its plot.

The main principles of local stability problem are illustrated in Figure 0-1. Both the front- and backslope is steep and the terraces give the school plot limited space. The building is placed close to the backwall that reduce the light through the windows.

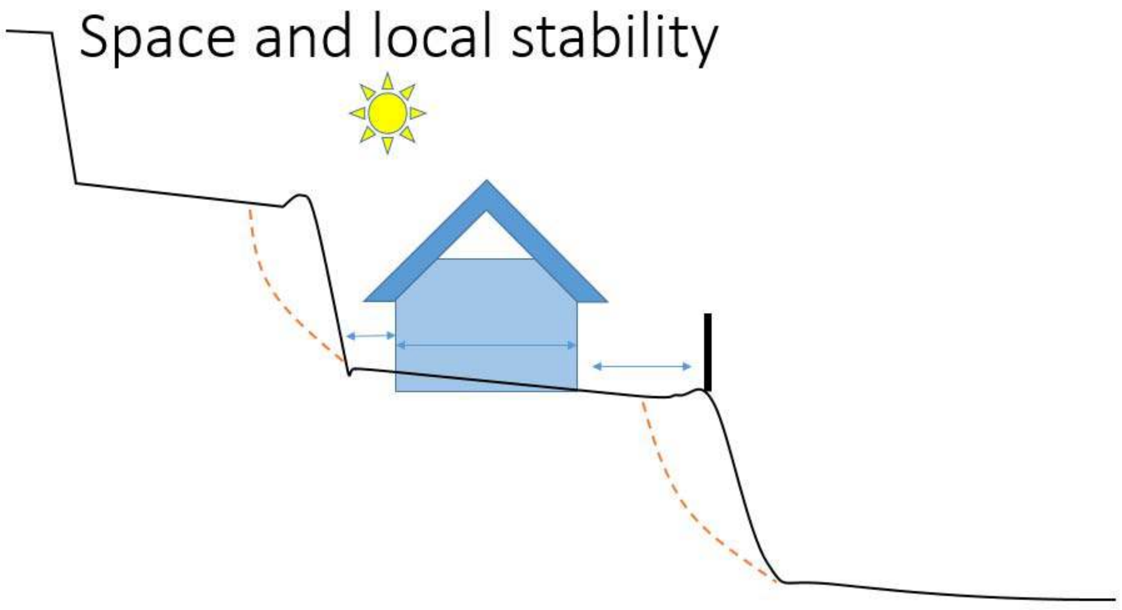

Figure 0-1 School located on a narrow terrace. Distance to backslope and its stability must be considered. A short distance to backslope reduces light through windows. The distance to front slope and its stability must also be considered. A short distance reduces the space for the schoolyard and load from the foundation may deform the slope.

Figure 0-2 illustrates the case where the backside terraces have been excavated in order to increase the space. An old terrace slope is vegetated and, if available, stones are placed as a reinforcement. The new backslope will contain unfertile soil and its effective height for stability assessment increase. Gabion walls will therefore be necessary to maintain stability.

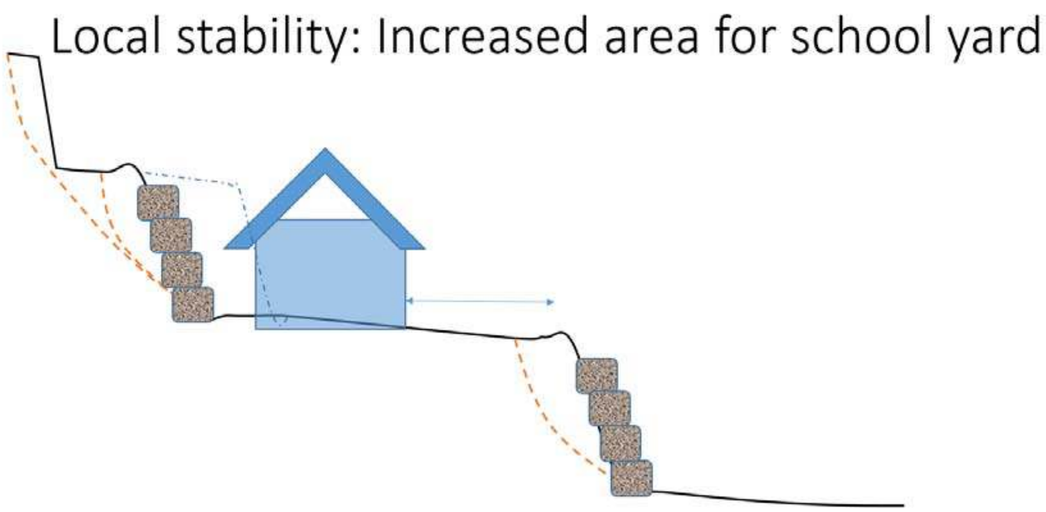

Figure 0-2 Backslope excavated backwards to increase space for schoolyard.

School plot reports

In the following chapters, a short report from each visited school is presented. The reports include a plan view sketch of each school plot, with field observations, conclusions and recommendations. Photographs are shown to illustrate the main observations. Figure 0-3 presents the school locations and the travel route between the schools logged by a GPS. Both local stability and natural hazard at each location are emphasized, but also other topics are discussed, such as sanitary conditions and other safety measures. For all schools, they plan to build 3-room toilets (girls, boys and disabled people).

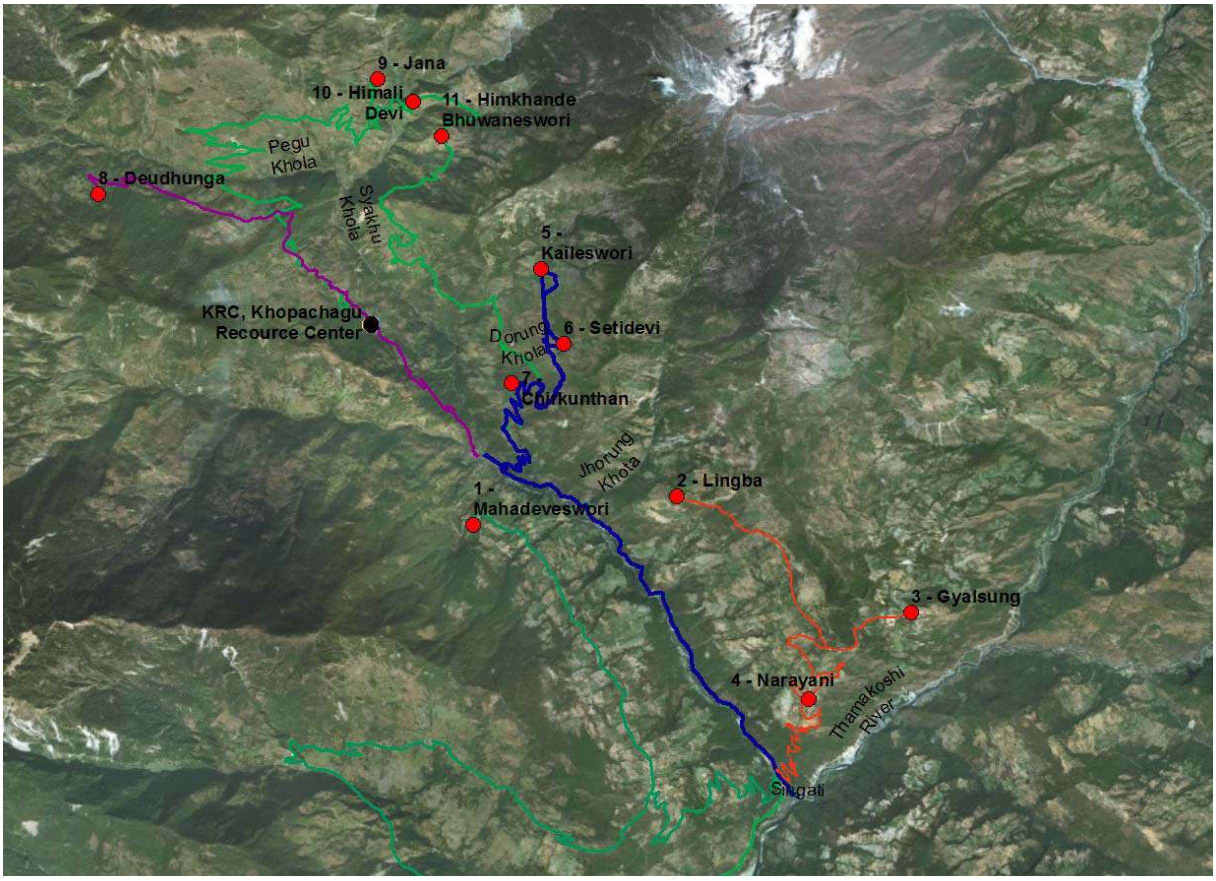

Figure 0-3 School locations and travelling day by day. We stayed in Singati and at the KRC, Kopachagu Resource Centre

1 Mahadeveswori (Babare)

1.1 Key information

Visit date: 24-01-2018
Participiping during visit: Åse Marit, Øyvind, Thomas, Sujan Subedi (Civil Engineer, CWIN), Bishnue Subedi (Educational Officer, CWIN)
Number of students (staff): 89 (10)

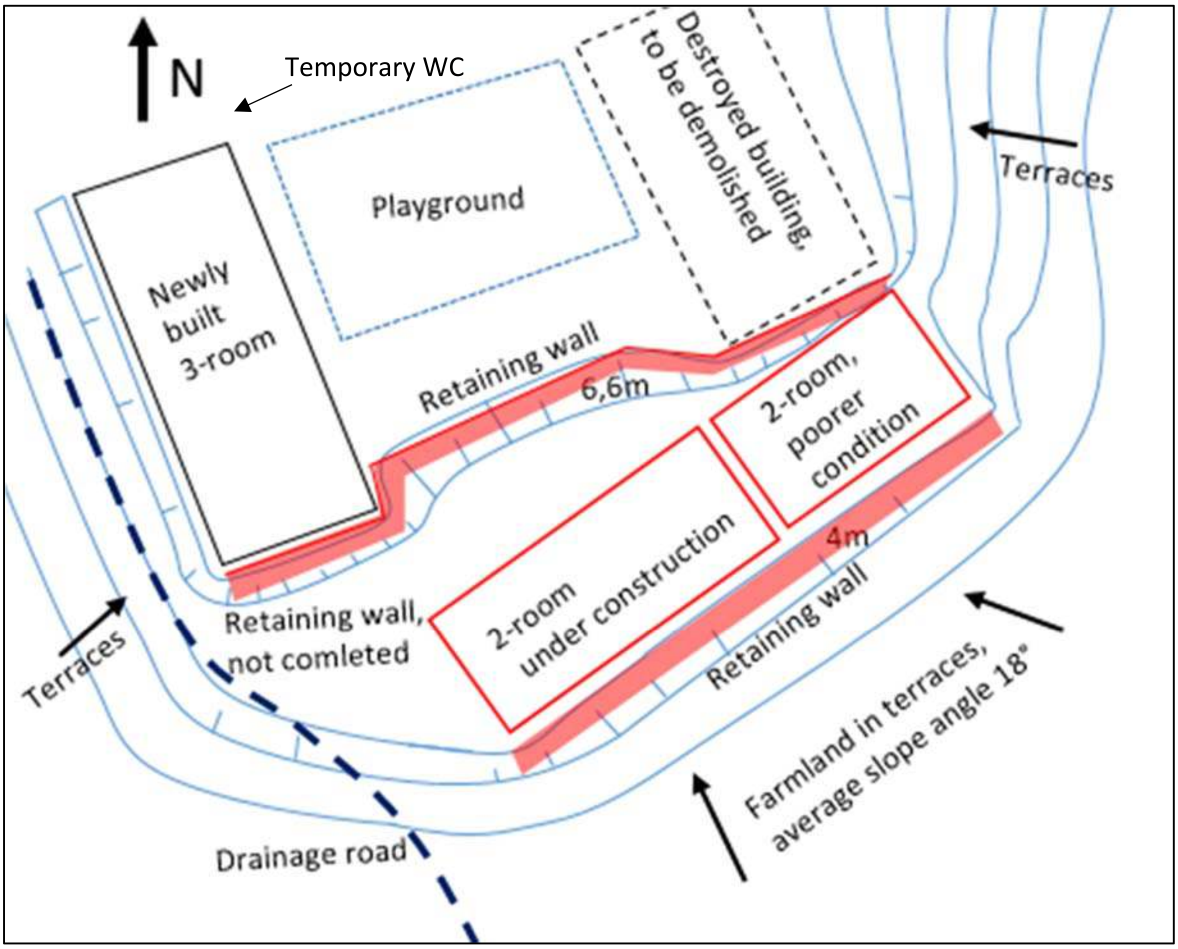

Figure 1-1 Plan view – Mahadesewori school. There is a height difference of 6,6 meters between the upper (southern) and the lower (northern) plateau. A retaining wall between the two plateaus should be constructed, also a railing for safety. The retaining wall close to the newly constructed 3-room building should be completed. Note: The drawing cannot be considered correct in terms of scale, it is based mainly on field observations.

1.2 Field observations

<u>School buildings</u>
A newly built 4-room building (as presented in [1]), a temporary shelter, an old building that was destroyed from the EQ, two buildings (planned with 2 rooms) on top of the plateau; one of these is under construction, the other one is also under construction, but has less progress.
<u>Landform</u>
The school plot is placed in a relatively flat area (among all the very steep and high hills). The terrain is formed as a bowl. Locally, the plot is divided into two plateaus. The lower one has the school yard with a volleyball-field, and three buildings; one temporary, one completed, and one building destroyed by earthquake that will be demolished. There is a steep slope (almost vertical) up to the upper plateau, (6-7 meter above), where two buildings are located. There is no stairs between the two plateaus.

Rivers – drainage pattern
The school is situated in a depression below a local hill and a small stream flow around the school partly in a manmade drainage-path. The drainage area on the upper side of the school is restricted (about 6,5 ha). This stream is possible dry from March to May (at least). We assume that this is the source for tap water. There are no rivers nearby affecting the school plot.
Topography/geometry
The average slope angle is approximately 18° from the road (a bit further down from the school) up to the forest (170 meter in horizontal plane). The slope angle in the forest and further uphill is about 37°.
Type of area
Farmland and agricultural terraces surround the schools.
Soil types
Weathered soil, brown fine sand. Possible shallow depth to bedrock.
Landslides in the area
No landslides nearby. The terrain at, and around, the school plot is more gentle than terrain where landslides have occurred.
Access road
No roads upstream (as far as we know). The access road is about 100 meters below the school, and does not affect the plot regarding soil stability or drainage of water.
Retaining walls
The list below highlight this topic. Generally, some walls are almost completed, but the steel rebar is not finished and points out of the concrete. At other slopes, there are no reinforced walls where this is essential. See Figure 1-1 for description.
Water supply
Probably about 9 of 12 months.
Other comments
The schoolyard is small, approximately measured to 150m^2 including the area for the temporary shed. There is little room for kids playing on the plot. The volleyball field takes up almost all the space, but shows clearly positive activity where boys and girls play together.

The location of the sanitary system is not decided yet. At the time being, there are temporary toilets below and outside the school plot. One of the toilets will be designed for disabled people.

The two new buildings not completed (with 2 rooms each) have a simpler construction than the drawings received from CWIN. The building to the west is planned to be completed in April 2018. The vertical concrete columns are lacking around windows and doors. The footing is 3 feet wide, and the wall thickness is 40cm.

There is no entrance for disabled people to the school (compared to Norwegian practice).

1.3 Conclusions and recommendations

1.3.1 High priority measures

Retaining walls
Construct a retaining wall between the two plateaus, and complete the retaining wall close to the newly constructed 3-room building (Figure 1-7). Construct a retaining wall between the upper schools and the farmland (Figure 1-4). A stair between the plateaus should be included in the retaining wall.
Drainage system
The drainage system behind the upper buildings should be connected to the existing drainage and stream (Figure 1-6).

1.3.2 Medium priority measures

Stairs

Stairs are missing from the bottom plateau to the upper buildings. This should be included. The path to the upper buildings is slippery, especially when wet.

Unfinished concrete work

Newly constructed concreted retaining wall behind new school building is not finished. Exposed rebar provides a significant safety hazard.

1.3.3 Low priority measures

Railing

At the plateau, railing is needed (Figure 1-5).

Figure 1-2 Path to Mahadeswori school. The road is approximately 100 m below the school plot.

Figure 1-3 Schoolyard. The temporary shed will be removed. The building under construction is about 6 m above the schoolyard. The slope must be completed with a dry wall and stairs.

Figure 1-4 Movement of masses in the backslope. The slope should be secured by a reinforced wall.

Figure 1-5 Schoolyard. View towards the damaged building. Railing should be constructed at the edge of the plateau.

Figure 1-6 A small stream enter the school plot and is led around the new building. Drainage from the upper building should be linked to this drainage pattern. The flow path should be secured around the plot.

Figure 1-7 Concrete wall (reinforced wall) is not completed.

2 Lingba (Laduk)

2.1 Key information

Visit date: 25-01-2018
Participing during visit: Thomas, Øyvind, Åse Marit, Bishnue, Sujan
No. of students/staff: 30/unknown

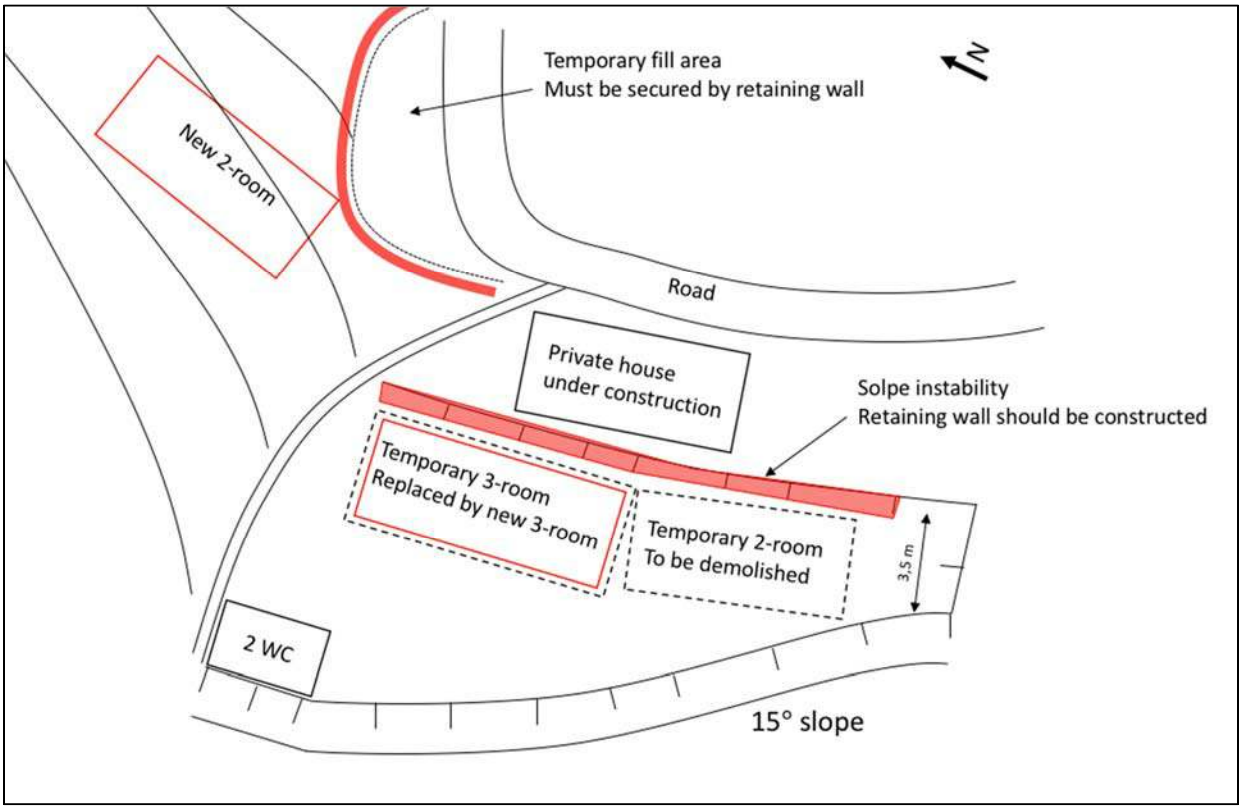

Figure 2-1 Plan view – Lingba school. Two retaining walls must be constructed; in front of the fill area and at the backwall.

2.2 Field observations

<u>School buildings</u>

The plot consists of several buildings: Two temporary buildings, a private house under construction between the road and the school. The plan is to build two new buildings with 2 and 3 rooms. The locations of the 3-room is at the same position at the temporary one (the northernmost), and the 2-room building is planned to be further north. The present position of the south temporary building seems to be a bit narrow for a new building. This place can be a schoolyard.

<u>Landform</u>

The school plot is on a sharp ridge.

<u>Rivers – drainage pattern</u>

The sharp ridge results in topographic self-draining. There is no ditch at the road; drainage water may follow the wheel track along the road. There should be a drainage system along the road.

<u>Topography/geometry</u>

The average downslope angle is approximately 15° over 100 meters in the horizontal direction, then steeper.

<u>Type of area</u>

Farmland.

Soil types
Weathered rock and weathered soil. Phyletic shale bedrock.
Landslides in the area
Several soil- and rockslides at the valley bottom and in the tributary valley vest of Lingba. The terrain is steeper at these locations.
Roads to the school
The road to the school is above the plot.
Retaining walls
Retaining walls needed against the road for the new building in the north.
Water supply
They have water supply all year round.
Other comments
The site is quite narrow, and we don't recommend to place a building close to the wall, due to reduced light. Therefore, only one building should be placed at the existing school plot. Additional area north of the building is planned to be used for the 2-room building. This area is currently terraces with farmland. The 2-room building should be placed close to the road, see Figure 2-6.

The fill close to the road needs to be steepened by a reinforced gabion wall. Land use of road and school plots must be clarified.

The location of the sanitary system is not decided yet.

2.3 Conclusions and recommendations

2.3.1 High priority measures

Retaining walls
The fill from the road construction needs to be steepened by a gabion wall.
Drainage system
There should be a drainage system along the road, preventing water from the road to access the school plot.

2.3.2 Medium priority measures

Retaining walls
There should be constructed a retaining wall behind the existing school building before the construction of a new building in its place. Both to secure good light conditions, and for the local stability of the above terrace with a building.

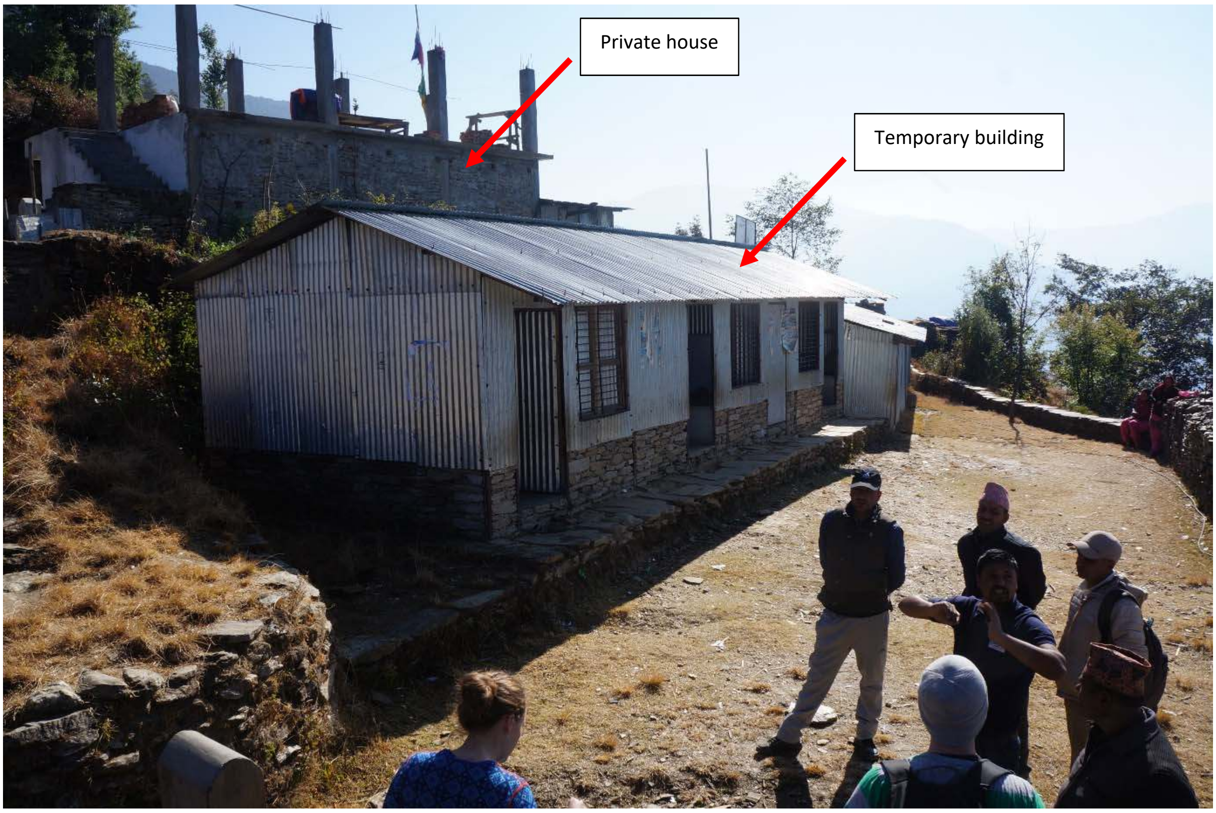

Figure 2-2 Lingba school, private house on a terrace close behind the school, two temporary buildings. A new building will be placed at the same location as the nearest one. Reinforcement of back-slope is necessary.

Figure 2-3 The plot is narrow at the eastern side. The stone wall at left side (downside) must be rebuilt in order to build the foundation.

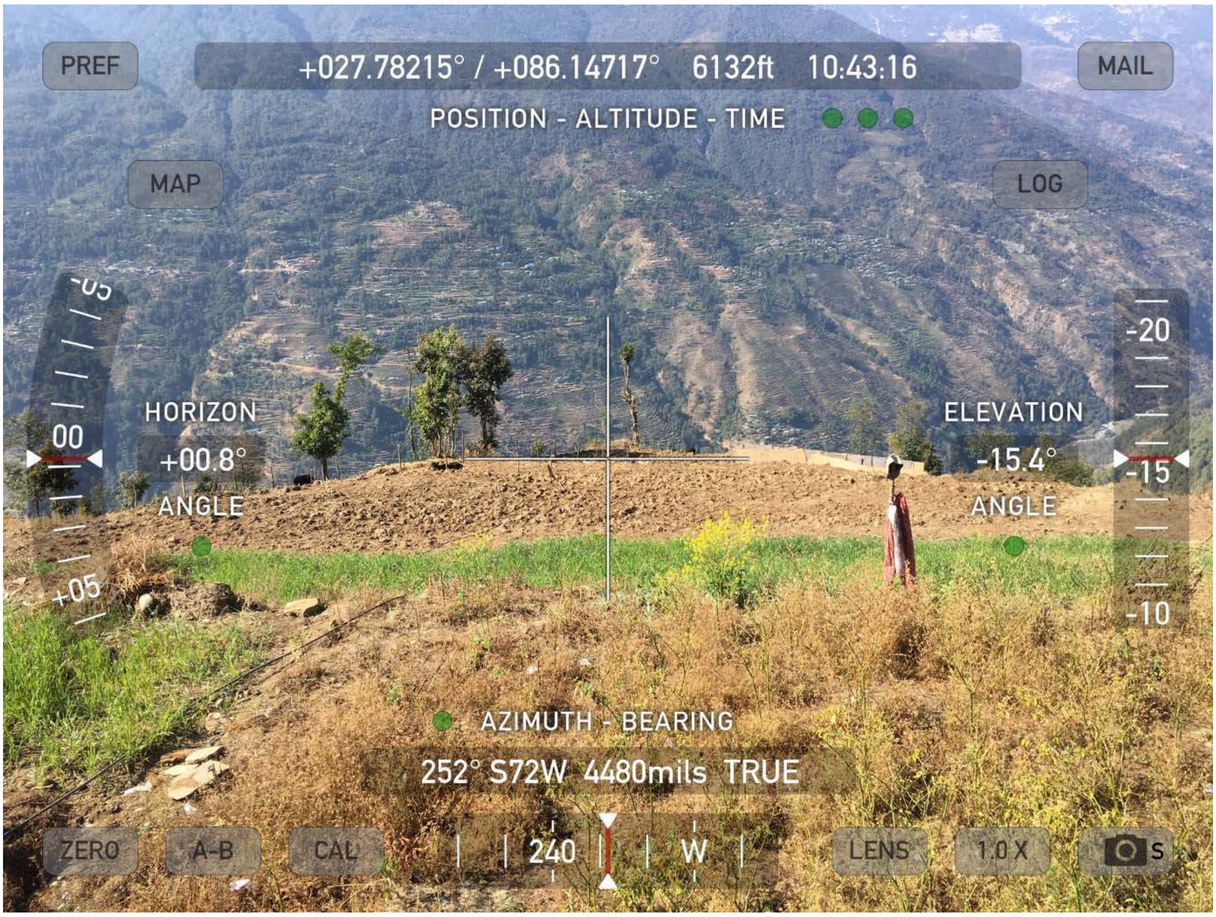

Figure 2-4 The average slope directly downside existing plot is about 15 degrees. The slop increases to the right side.

Figure 2-5 Slope behind the school and private house. The road has a sharp bend to the right.

Figure 2-6 Alternative plot for the second building. It is close to the landfill and at present arable land. It is not advisable to move the new building against the slope. Land use planning and restriction of fill is needed in order to use this plot.

3 Gyalsung (Laduk)

3.1 Key information

Visit date: 25-01-2018

Participants during the visit: Åse Marit, Øyvind, Thomas, Sujan, Bishnue

Number of students (staff): 52 (?)

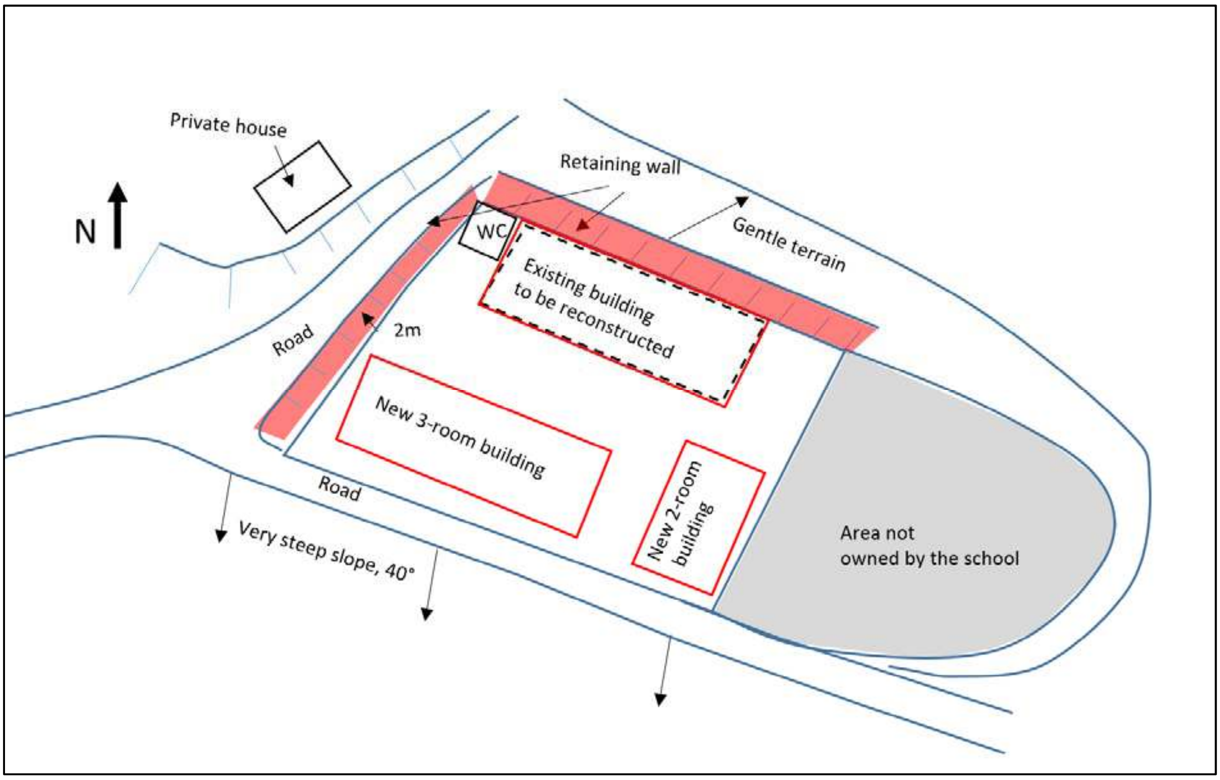

Figure 3-1 Plan view - Gyalsung school. Big flat plot. Retaining walls should be constructed in north-west to stabilize the road, and in north to stabilize existing building. The position of the 2-room is proposed either in east, as in the figure, or in west of the plot.

<u>School buildings</u>

One damaged 3-room building is being reconstructed north on the plot. Two new buildings are proposed (3-room and 2-room).

<u>Landform</u>

The school plot is big and flat, and is situated on a wide ridge with a great view of the Himalayas.

<u>Rivers – drainage pattern</u>

The ridge results in topographical self-drainage.

<u>Topography/geometry</u>

The southern slope is 40° and locally steeper. The north slope is gentle. The school plot is inside the road at the southern side.

Type of area

Farmland.

<u>Soil types</u>

Weathered rock and soil. Phyllitic shale bedrock.

<u>Landslides in the area</u>

Many rock- and soil slides, but in steeper terrain.

Access road

The road to the school is above the plot. Direct access into the schoolyard.

Retaining walls

There is a damaged retaining wall north of the plot, which has resulted in settlement in the damaged building. This should be repaired upon reconstruction. If the 2-room building is constructed close to the road, a retaining wall should be constructed to stabilize the slope and ensure good light conditions.

Water supply

Two alternatives: From the same source as the northwest village, or from a small stream against southeast (900m away).

3.2 Conclusions and recommendations

High priority measures

Retaining walls

The retaining wall in the north part of the plot is damaged, causing settlements in existing building. This should be repaired upon reconstruction of the existing school to prevent further settlement damage.

Medium priority measure

Retaining walls

If the 2-room building is built close to the road, a gabion wall should be constructed to stabilize slope and to ensure good light conditions.

Figure 3-2 Gyalsung school plot. Looking north-east.

Figure 3-3 Rest of existing building. The roof will be reused, but the foundation has to be new.

Figure 3-4 The stone wall or gabion wall has to be rebuilt together with the foundation of a new building.

Figure 3-5 A new road is built or enlarged south of the plot. The second building will be placed left of this road, the third probably in the front between the buildings. There will be some room for a schoolyard between the buildings.

Figure 3-6 Northern side of the "building".

Figure 3-7 Slope angle below the new road (or newly enlarged road) ~40°.

4 Narayani (Laduk)

4.1 Key information

Visit date: 25-01-2018

Participants during the visit: Øyvind, Åse Marit, Thomas, Sujan, Bishnue, Ramesh Oli (Social Mobilizer Laduk)

Number of students (staff): 65 (6)

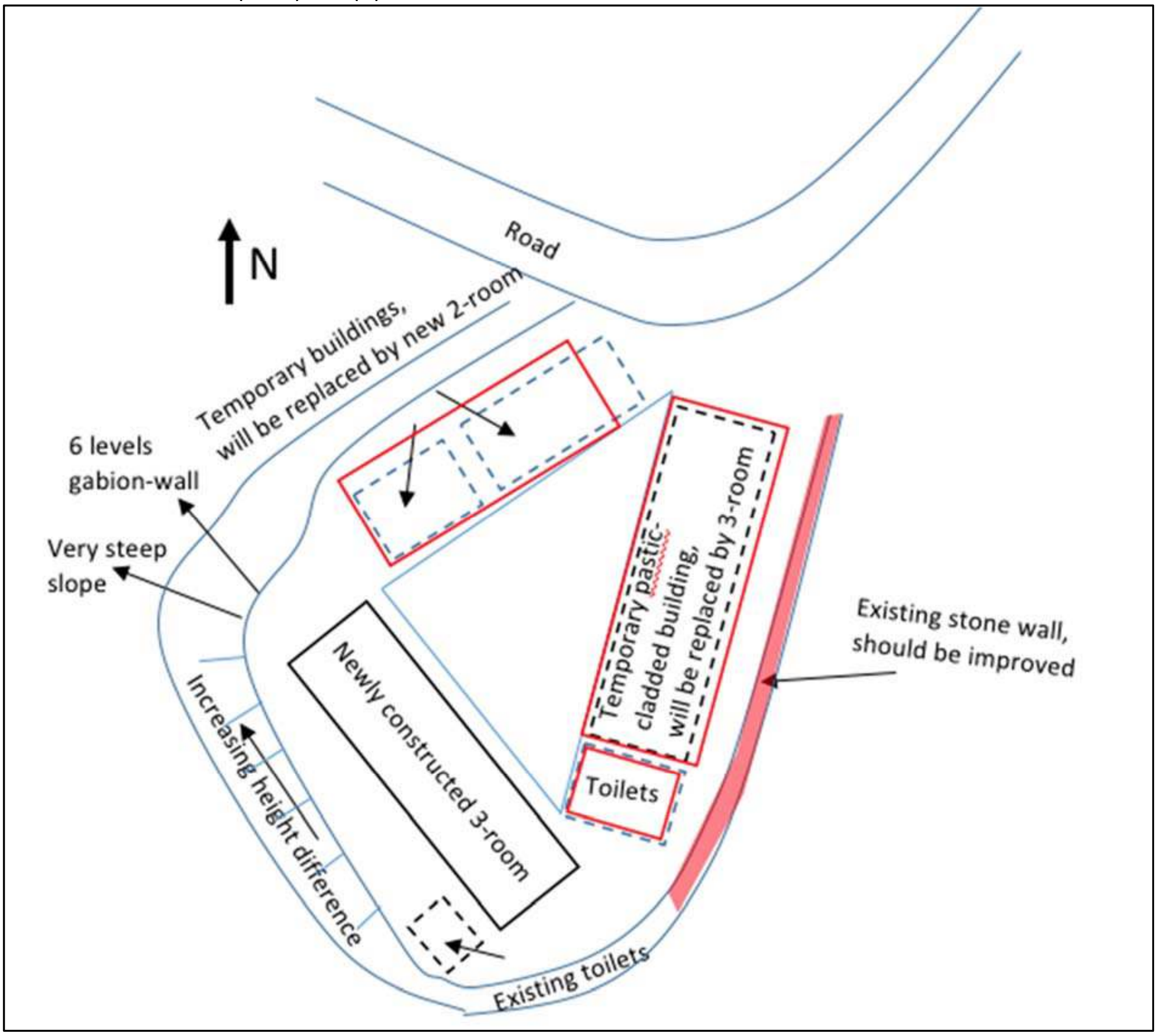

Figure 4-1 Plan view – Narayani. A retaining wall should be constructed on the east side of the plot. The foundation of the new 2- room building may require a dry stone wall at the border of the school plot.

4.2 Field observations

School buildings
The school consists of four buildings; one newly constructed 3-room, and three temporary buildings (one large, two small). To new buildings are planned (2- and 3-room) in the same place as the temporary buildings.
Landform
The school plot is situated on a ridge.
Rivers – drainage pattern
The ridge results in topographical self-draining.
Topography/geometry
The terrain is very steep (40°) at the southwest corner of the newly constructed building. In the other directions, the terrain is more gentle.
Type of area
Farmland.
Soil types
Weathered rock and weathered soil. Phyllitic shale bedrock.
Landslides in the area
Close by Naryani, there is no larger landslides. There is landslides in road cuts in the bottom of the valley, and smaller landslides/rockfall (from ground) along the local road.
Access road
The road is north of the school. The road has no constructed ditch and the wheel tracks may drain water. A low wall may be constructed along the outer edge of the road against the school.
Retaining walls
There are retaining walls around the perimeter of the plot. The retaining wall on the east side should be improved upon construction of the new 3-room. Retaining wall on the west side is high (4-5m) and steep (40°) and railings should be considered.
Water supply
All year round.
Other comments
The site is narrow, a triangular shaped area. Little space for a schoolyard.

4.3 Conclusions and recommendations

4.3.1 High priority measures

Retaining walls
A retaining wall should be constructed on the east side of the plot. This should be in place before the foundation work of the new 3-room is started, to prevent damaging settlements.

4.3.2 Medium priority measures

Dry stone wall
The foundation of the new 2-room building may require a dry stone wall at the boundary of the school plot.

4.3.3 Low priority measures

Railing
Railing should be considered at the west side of the plot.
Remove excess soil masses
Excavated masses in front of the new 3-room building and the schoolyard should be removed (Figure 4-2).

Figure 4-2 Narayani school. New 3-room to the left. The excavated masses in front of the new 3-room building and the schoolyard should be removed.

Figure 4-3 Narayni school. Entrance to the school between the buildings.

Figure 4-4 New 3-room building to be constructed in the place of the building centre. The triangular schoolyard to the right of the temporary sheds.

Figure 4-5 East side of the plot.

Figure 4-6 South side (downside) of newly constructed 3-room building.

Figure 4-7 Four-five gabion-levels in new wall at SW corner of the new building. Railing should be considered.

5 Kaileswori (Chilankha)

5.1 Key information

Visit date: 26-01-2018
Participants during visit: Åse Marit, Øyvind, Thomas, Sujan, Bishnue
Number of students (staff): 35 (3)

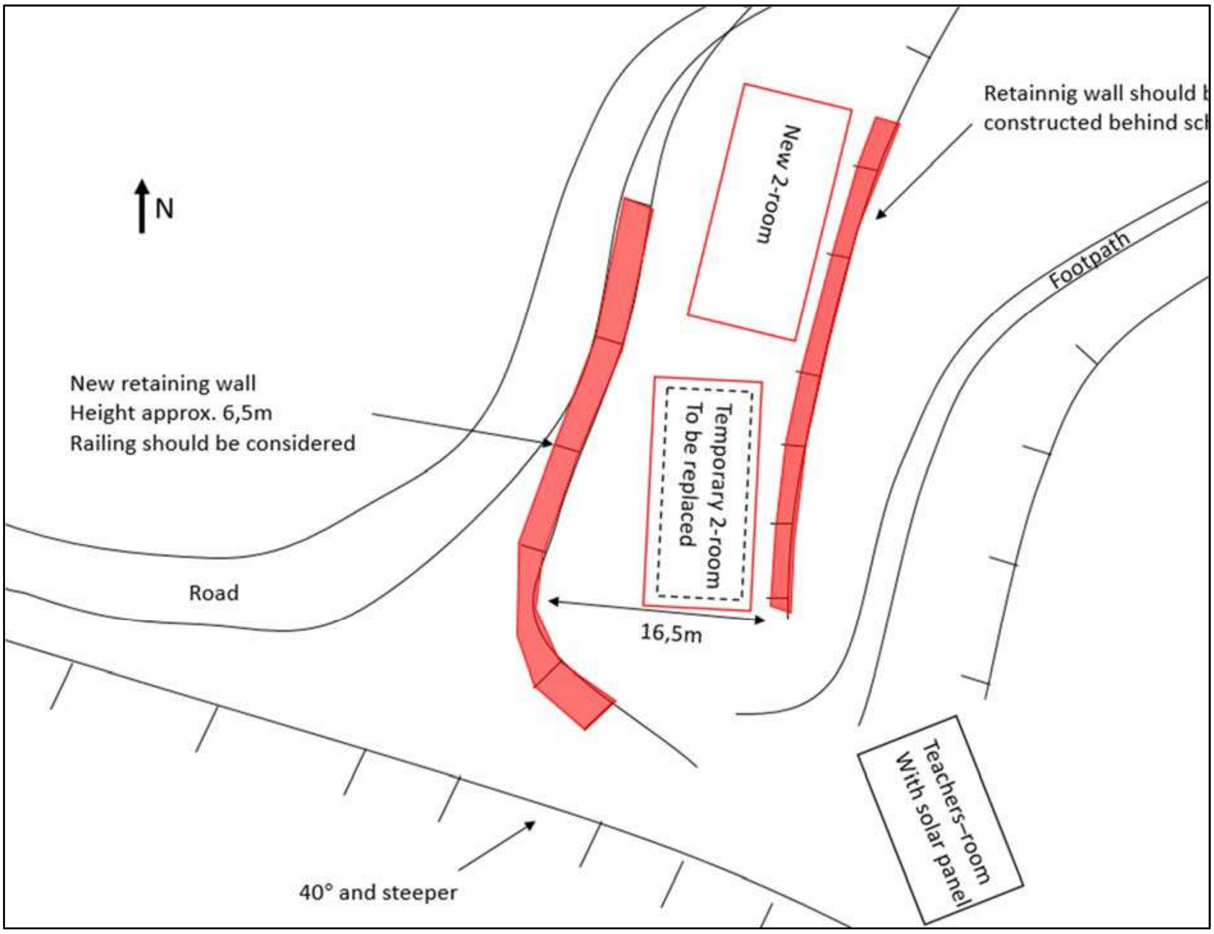

Figure 5-1 Plan view - Kaileswori. The new buildings should not be placed any further south than the existing temporary building because of the very steep slope. A retaining wall should be constructed between the road and school plot (west). A retaining wall should be constructed on the east side of the new school buildings, to improve local stability and ensure good light conditions.

5.2 Field observations

School buildings

The plot consist of one permanent building used as a teachers room (with solar panels), and one temporary 2-room. They plan to build two new 2-room; one at the same place as the temporary one, and in north of the temporary building.

Landform

The school plot is on a wide ridge, a steep slope at south.

Rivers – drainage pattern

The ridge results in topographic self-draining. No rivers nearby.

Topography/geometry

Uphill, east of the plot the average slope angle is 27°. South of the plot there is a very steep slope (40°). West of the plot there is a 6,5m drop to a plateau with cows, further west the terrain is gentle about hundred meters.

<u>Type of area</u>
Farmland.
<u>Soil types</u>
Weathered soil, not any visible rocks or bedrock.
<u>Landslides in the area</u>
Some rock- and soil slides, but not in the same areas as arable land. The terrain in slide areas seem to be steeper, and has more shallow bedrock.
<u>Access road</u>
Road is situated on the west (above) and NE side of the school plot.
<u>Retaining walls</u>
No existing retaining walls. The lower plateau has some stones in the slope below.
A retaining wall should be constructed at the western side of the plot, and on the east side of the new school buildings.
<u>Water supply</u>
Water supply will be solved.
<u>Other comments</u>
For the new building, the top soil should be removed and the ground compacted. The ground is inclined and must be lowered at a level below the temporary building (the two buildings will have different ground levels).

5.3 Conclusions and recommendations

The new buildings should not be placed any further south than the existing temporary building because of the very steep slope.

For the new building, the top soil should be removed and the ground compacted. The ground is inclined and must be lowered at a level below the temporary building.

5.3.1 High priority measures

A retaining wall should be constructed in west between the road and school plot.

5.3.2 Medium priority measures

A retaining wall should be constructed on the east side of the new school buildings, to improve local stability and ensure good light conditions

5.3.3 Low priority measures

Railing should be considered in west side of the plot.

Figure 5-1 Kaileswori is situated on a ridge with a steep slope south of the plot. The white house is the staff building; the new school will be placed at the position of the grey building below. The entrance is from the road above the school.

Figure 5-2 Steep slope at left side. The farmland to the right will be used for the second building.

Figure 5-3 The new building should not be placed any closer to the slope. Staff building behind.

Figure 5-4 The second building will be placed on this farm land. The top soil must be removed and the ground levelled. The slope behind the building should be secured with a gabion wall in order to give safety and better light.

6 Setidevi (Chilankha)

6.1 Key information

Visit date: 26-01-2018
Participants during visit: Åse Marit, Øyvind, Thomas, Sujan, Bishnue
Number of students (staff): 46 (3)

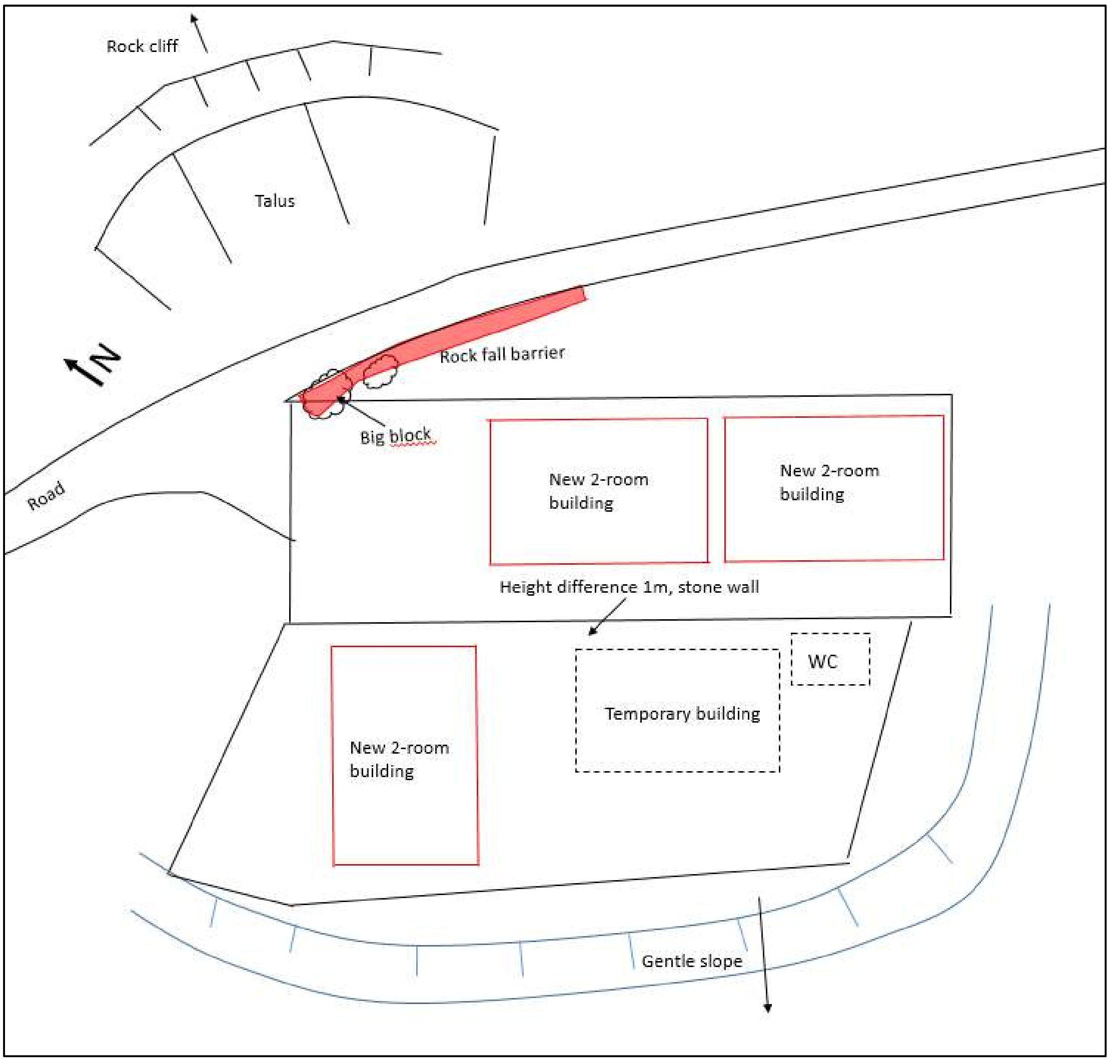

Figure 6-1 Plan view - Setidevi. There is an existing barrier between the road and the school site. This should be supplied with blocks from the upper side of the road in order to function as a rock fall barrier.

6.2 Field observations

<u>School buildings</u>
The plot consists of one temporary building. They plan to build three 2-room buildings, see the sketch for information.
<u>Rivers – drainage pattern</u>
No rivers nearby.
<u>Topography/geometry</u>
No typical ridge. There is a rock cliff north of the site causing rockfall that must be considered.
<u>Type of area</u>
Farmland below, and forest above the plot.
<u>Soil types</u>
Rock (also with some quarts-content) and weathered soil.

<u>Landslides in the area</u>
Rock fall from the cliff behind the school. A talus is formed below the cliff. The blocks are generally sharp edged and elongated. This is a form that restrict runout distance compared with rounded blocks for single blocks outfall. We were informed that there has not been any rockslides since the great earthquake in 1945, but the lack of any trees below the cliff indicate more recent rock fall. There is some smaller rocks in that area with sharp edges and light colour indicating recent rock fall.
<u>Access road</u>
The road to the school is next to the plot (Figure 6-2).
<u>Retaining walls</u>
There are some small stonewalls between the upper and lower parts of the site.
<u>Water supply</u>
Water supply will be solved.
<u>Other comments</u>
Based on statistical study of rockfall in Norway, a smaller fraction of the blocks has longer runout distance than to the foot of the talus. Using this experience, the zero pint in the profile figure (wall between the two schoolyard levels), correspond approximately to a 400-years runout (annual probability 1/400). 100 years runout is just on the upper side of the road. A rockfall barrier will not stop all blocks, but typical statistical stop more than half of the blocks (some jump higher). We recommend improving the safety against rockfall as it can be done quite simple with local blocks.

There is an existing barrier of rocks between the road and the school site. This should be supplied with blocks from the upper side of the road in order to function as a rock fall barrier. Generally, the barrier should have a cross section not less than 2 by 2 metres. The stones should have contact with each other like a brick or stone wall, so that the stones act as one unit.

The two new upper buildings should be placed as far east as possible. Safety increase in eastern direction due to a depression upside the road, and some longer distance from the cliff.

6.3 Conclusions and recommendations

6.3.1 High priority measures

There is an existing barrier between the road and the school site. This should be supplied with blocks from upside side of the road in order to function as a rock fall barrier. Generally, the barrier should have a cross section not less than 2 by 2 metres. The stones should have contact with each other like a brick or stone wall, so that the stones act as one unit. A gabion barrier will also be an alternative.

The two new upper buildings should be placed as far east as possible. The safety increase in eastern direction due to a depression upside the road, and some longer distance from the cliff.

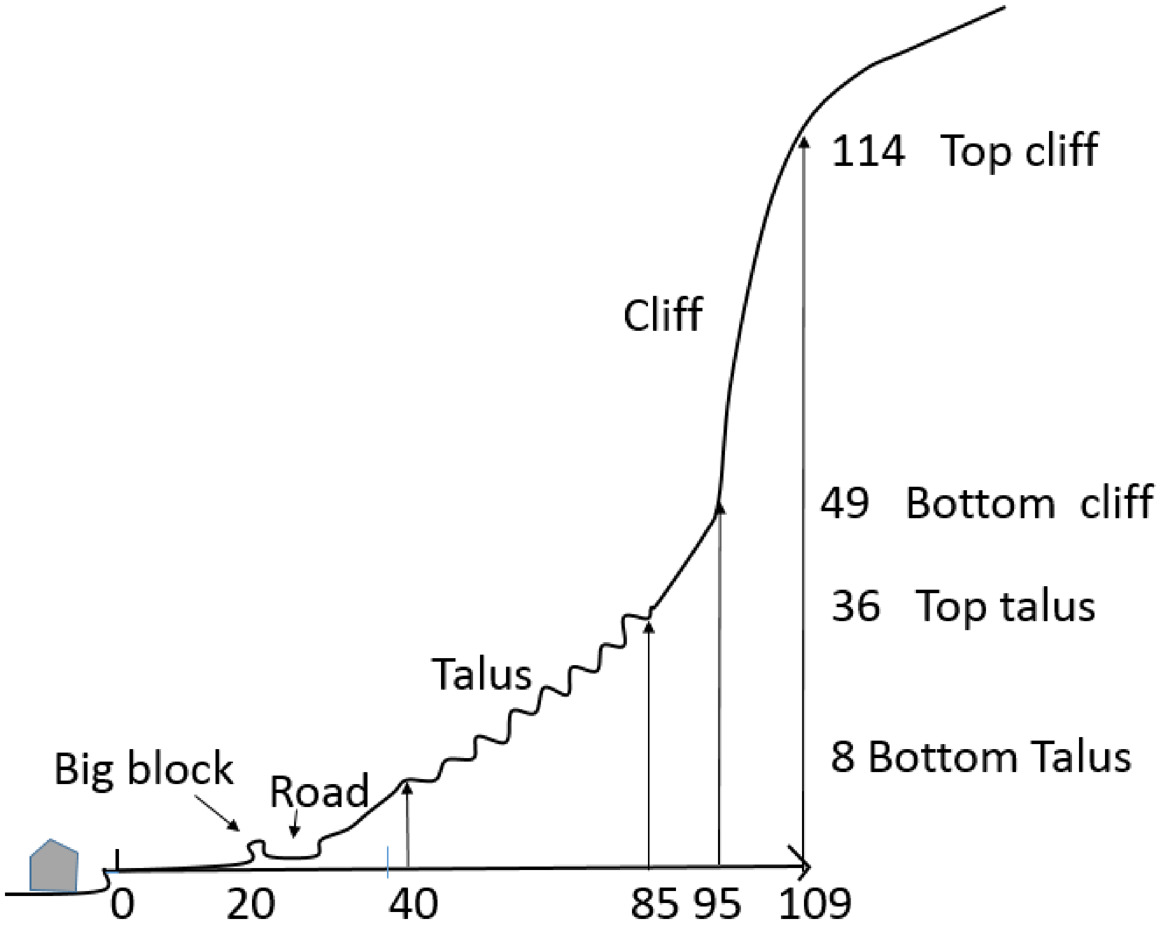

Figure 6-2 Profile from schoolyard up to the top of the cliff. The profile corresponds to the section through the big block in the next figure. Unit is meters horizontal and vertical

Figure 6-3 The cliff behind Setidevi. The road goes behind the blocks in the front. The talus stops before the road, but scattered blocks from rockfall exist downside the talus. Light areas on the cliff show the more recent outfall areas. "Younger" blocks are found inside the talus. The profile shown in the next figure, cross the big block to the left in the front. An improved rockfall barrier can be made by constructing an embankment/dam from the blocks upside the road.

Figure 6-4 The lower level with the temporary building. Two buildings will be placed at the higher level, preferably in the inner part of the excavated area.

Figure 6-5 Road. The rockfill embankment should be placed from the first big and blockwards, until the road bends to the right.

7 Chirkun Than (Chilankha)

7.1 Key information

Visit date: 24-01-2018
Participants during visit: Åse Marit, Øyvind, Thomas, Sujan, Bishnue
Number of students (staff): 64 (1)

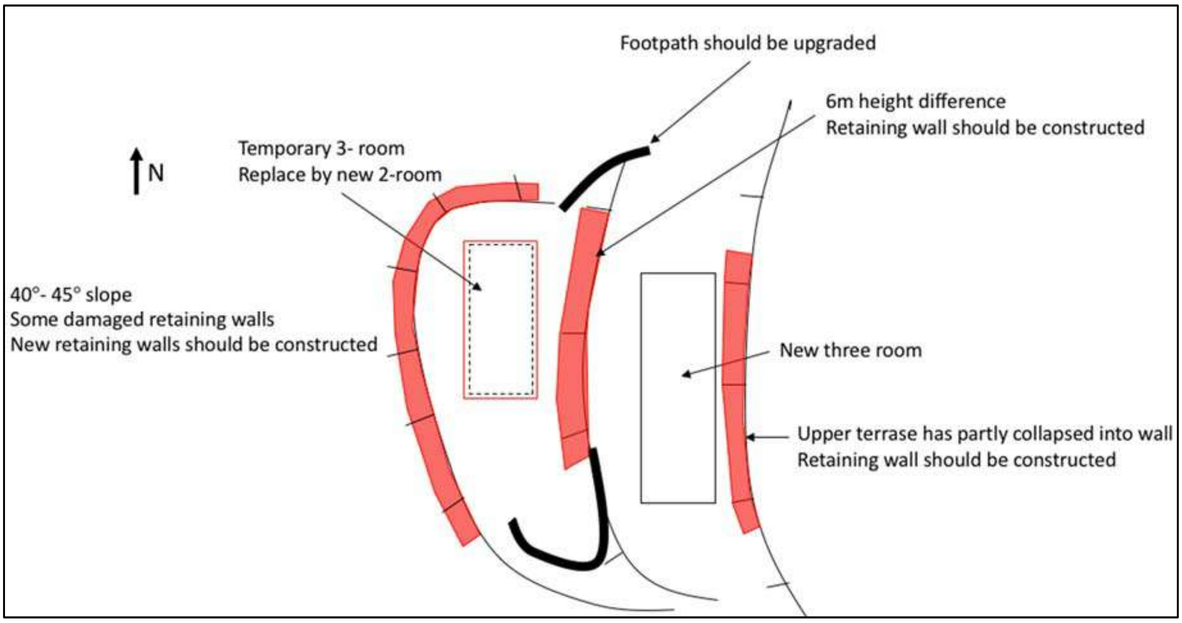

Figure 7-1 Plan view - Chirkun Than. The height difference between newly built- and temporary school building is 6m. There should be carried out extensive work with retaining walls at the site. There is need for a gabion wall both behind the newly built house, between the two houses and in front of the planned building.

7.2 Field observations

<u>School buildings</u>
The plot consists of a newly constructed 3-room (large rooms) and one temporary building. The plan is to build a 2-room in the same location as the temporary building.
<u>Landform</u>
A sharp ridge. Very step and narrow area.
Rivers – drainage pattern
No rivers nearby
<u>Topography/geometry</u>
Very steep in all directions, especially in front of the temporary building (40-45 degrees).
<u>Type of area</u>
Forest / Farmland.
<u>Soil types</u>
Weathered soil.
<u>Landslides in the area</u>
No rock fall from behind. There has been a small rotation behind the new building, a retaining wall is necessary.
<u>Roads to the school</u>
There are no access by road to the plot, only available by a foot path.
<u>Retaining walls</u>
There is a stone wall behind the new building halfway, and the rest is not supported. There are some old temporary gabions behind the temporary building, but they have collapsed.
<u>Water supply</u>
Water supply will be solved.

<u>Other comments</u>
The site is very narrow and the terrain is generally very steep. There is a small area south of the temporary building that act as a schoolyard and steep slopes around.

7.3 Conclusions and recommendations

7.3.1 High priority measures

<u>Retaining walls</u>
There should be carried out extensive work with retaining walls at the site. There is need for a gabion wall both behind the newly built house, between the two houses and in front of the planned building.

7.3.2 Medium priority measures

7.3.3 Low priority measures

<u>Railing</u>
Footpath should be updated.

<u>Railing</u>
At several places, there should be put up railings/fences because of the steep terrain.

Figure 7-1 A small open place (schoolyard) south of the temporary building.

Figure 7-2 Slope, incomplete dry stone wall, between the new and temporary building.

Figure 7-3 Lower plateau. Slope between the upper (new building not completed), and lower plateau must be stabilized.

Figure 7-4 The tree stabilize the corner of the wall, movements below the tree and behind the tree, se next picture.

Figure 7-5 Slope failed outside temporary building, north of tree.

Figure 7-6 Slip failure in the slope cut behind the new school. Gabions wall are required, preferably in steps.

Figure 7-7 Upper part of the slip failure. The slope has been cut into an existing terrace.

8 Deadhunga (Bigu)

8.1 Key information

Visit date: 27-01-2018
Participiing during visit: Aang Nima Sherpa (Chairman of school Management Committee of Deudhunga), Sony Khadka (Social Mobilizer for Khopachagu), Sujan, Bishnue.
Number of students (staff): 50 (4)

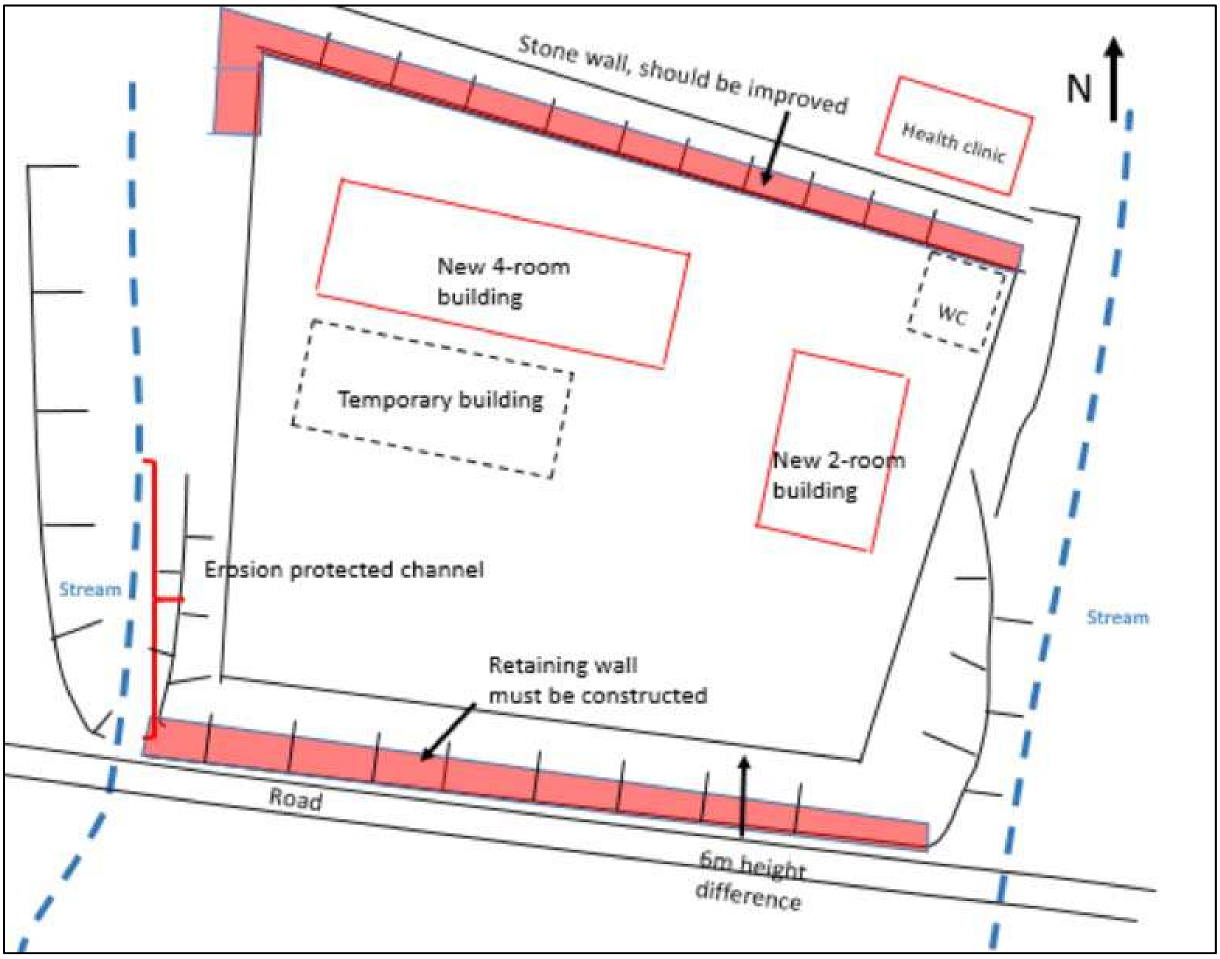

Figure 8-1 Plan view – Deadhunga. A retaining wall south of the plot should be constructed. The western stream should be secured by building an erosion-protected channel to avoid water into the school plot during critical rainfall. The masonry wall north of the site should be improved slightly.

8.2 Field observations

School buildings

The school plot consists of one temporary building. The plan is to build one 2-room building and one 4-room building (see the sketch for information).

Landform

Concave, depression with two smaller streams.

Rivers – drainage pattern

There is one stream on each side of the school plot. The western stream should be secured by an erosion-protected channel to avoid water into the school plot during critical rainfall.

Topography/geometry

The average terrain slope above the school plot (above the private buildings) is around 25°. There are low risk for rock- or landslides at the school plot.

Type of area

We assume that the plot previously is used for farming. Further south, uphill, the slope is covered with forest.

Soil types
Different soil type than at the other locations. Bedrock is probably partly visible in the area, at least along the road. The visible rocks and blocks are of better quality than earlier observed.
Landslides in the area
No visible active land- or rockslides close to the school. This northern faced hillside is more gentle here than down at the river, and at the southern side of the hill, where landslides are visible.
Access road
The road to the school is above the school plot, but it does not affect the stability of the school plot.
Retaining walls
There is a masonry wall north of the plot. The wall is generally in good condition, but some of the upper stones are loose, and should be fixed. There should also be a retaining wall upside the slope against the access road. The height of the slope is here about 6m.
Water supply
All year round.

8.3 Conclusions and recommendations

8.3.1 Medium priority measures

Erosion-protection
The western stream should be secured by building an erosion-protected channel to avoid floodwater into the school plot during critical rainfall.

Retaining wall - south
There should be retaining wall south of the site (6m high and 40m long).

8.3.2 Low priority measures

Masonry wall – north
The masonry wall north of the site should be improved slightly.

Figure 8-2 The southern slope should be secured with a gabion wall. The boundary of the plot should be well defined so that no masses are deposited in the slope.

Figure 8-3 The stream at the western side need to be led in a channel and erosion protected rip-rap at the top of the plot. The stream at eastern side is controlled by the depression (a low pass) in the road.

9 Jana (Alampu)

9.1 Key information

Visit date: 28-01-2018
Participing during visit: Thomas, Øyvind, Åse Marit, Bishnue, Sujan
Number of students (staff): 53 (4)

Figure 9-1 Photo from the ridge at Himali Devi towards Jana school and the access road from south. The new climbing road left of Jana is visible. Following drainage patters from the hillside above, we see that the road cross these patterns, but the school is outside.

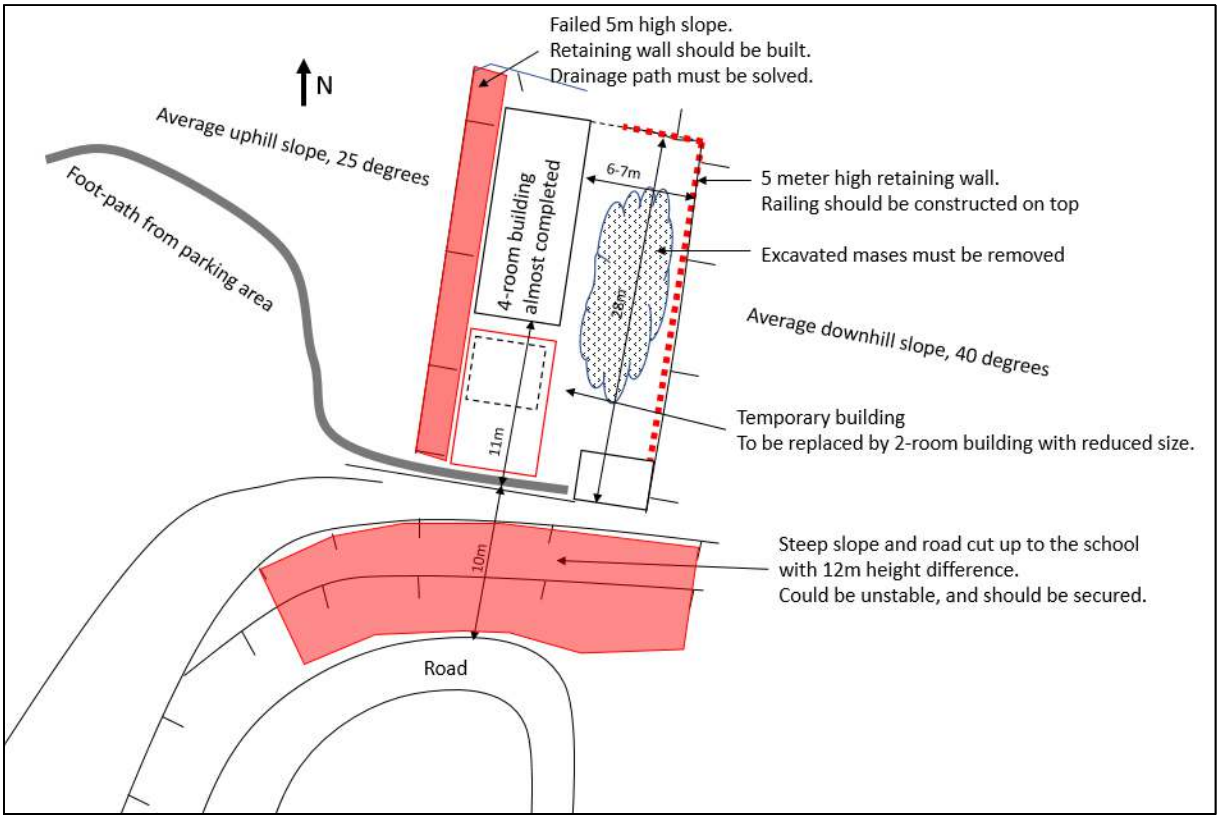

Figure 9-2 Plan view – Jana school. A gabion wall should be constructed, both at the backslope failure already has occurred (west) and at the slope towards the road (south) where the height difference is 14m. Water from the terraces should not be permitted to flow down the backslope. For safety, we recommend to railings in front of the school where the wall height is about 5m and the slope continues steep downwards.

9.2 Field observations

School buildings

The plot consists of one newly constructed building (4 rooms of smaller size), and one temporary building. They plan to build one 2-room building (or 1-room if not sufficient space at the plot) at the same location as the temporary one. See the sketch for information).

Landform

The village is laying on a steep terraced cone, where the school plot lies in the upper part. The road cuts terrain south of the school plot.

Rivers – drainage pattern

There are no streams in the area.

Topography/geometry

The upper slope is around 25°, and the terraces have visible larger natural stones in the slopes. Low risk for global rock- or landslide events from behind. Drainage patterns/ravines upside the school do not enter the school plot. The wall behind (west) the building is about 5m high, and this wall is not sufficiently supported (only a gabion wall in one level). There is a local slip failure all the way behind the building. The terrain south of the plot against the road cut is very steep (18m vertical/10 m horizontal distance). The terrain in front of the schoolyard is also very steep – starts with a ~5-6 m gabion wall and a slope angle of 40° to a vertical distance of 15m.

Type of area

We assume that the plot previously is used for farming. The area north of the school is farming area.

Soil types
Weathered soil with some larger blocks. Bedrock not visible at the village. Bedrock is visible along the access road south of the village.
Landslides in the area
A lot of landslides mainly caused by the road, undercut of slope and outside slope steeper than natural due to filling of excavated masses.
Access road
The road climbs south of the school with the parking lot upside the school (west). Low risk for water drainage from road to school plot, but water running in the bend of the road bay destabilize the steep road cut against the school. Drainage of the parking lot above the school should be avoided.
Retaining walls
There is a gabion (4-5 levels) wall in front of the area (east). Generally, the wall is in good condition. The backwall of the school building (west) is 5m high, and this wall is not sufficiently supported (only a one level gabion wall behind half of the building).
Water supply
We are informed that water supply will be solved.
Other comments
The school is only reachable by foot, as the access to the school is from either stone stairs below, or stairs from the parking lot above the plot.

The plot is generally very tight, there is no space for a schoolyard.

9.3 Conclusions and recommendations

9.3.1 High priority measures

Space for the new 2-room building
A 2-room building according to the drawings [1] is of ~11m length. Our measurements made in the field show that the space between the 4-room building and the stonewall is around 11m. They should not construct the building outside of the wall/stairs. The distance to the stone walls east and south of the building, should not be less than 6m and 3m, respectively. This means that there is not sufficient area for a 2-room building. The building should not be constructed unless the road cut is secured.
Retaining wall west
Construct a new gabion wall behind the school (west).
Retaining wall south
Construct a supporting structure at the road cut (south) towards the school (around 6m height). This is mandatory if a new building is constructed.
Drainage system
Lead water from the terraces around the school plot. Water from the terraces should not be permitted to flow down the backslope.
Remove excess masses
Remove the excavation masses in front of the school, as these masses stress the front wall.

9.3.2 Medium priority measures

Railings
Support the low stonewall restricting the schoolyard east of the plot (with height difference 5m) with a railing.

Figure 9-3 Excavated masses adds load on the retaining wall behind. These masses should be removed before further construction starts.

Figure 9-4 The slope behind the building is about 5 m high. Along the northern part there is a gabion in one level at the bottom, and two levels in the northern corner. The slope has failed in northern part and should be secured by a retaining wall.

Figure 9-5 Water is flowing from the neighbour's kitchen, close to the northern end of the excavated slope. Water should not flow from the terraces down the slope behind the building.

Figure 9-6 Retaining wall is 5-6 m high downside Jana. The wall consist of gabions, partly stonewall and interlocked big stones. The top of the wall is levelled about 0.5m above the school yard. The slope angle is ~40° in 15 meters vertical distance.

Figure 9-7 The road is maximum 16m lower than the stone stairs that marks the border of the school plot. The road cut needs a gabion wall with at least the height of the road cut. The geometry restrict the use of the southern area of the plot. We do not recommend a 2-room building, rather a 1-room building. There is about 12m between the new building and the stone stairs.

10 Himali Devi (Alampu)

10.1 Key information

Visit date: 28-01-2018
Participing during visit: Thomas, Øyvind, Åse Marit, Bishnue, Sujan
Number of students (staff): 75 (5)
The school is from the "Phase 1"-project.

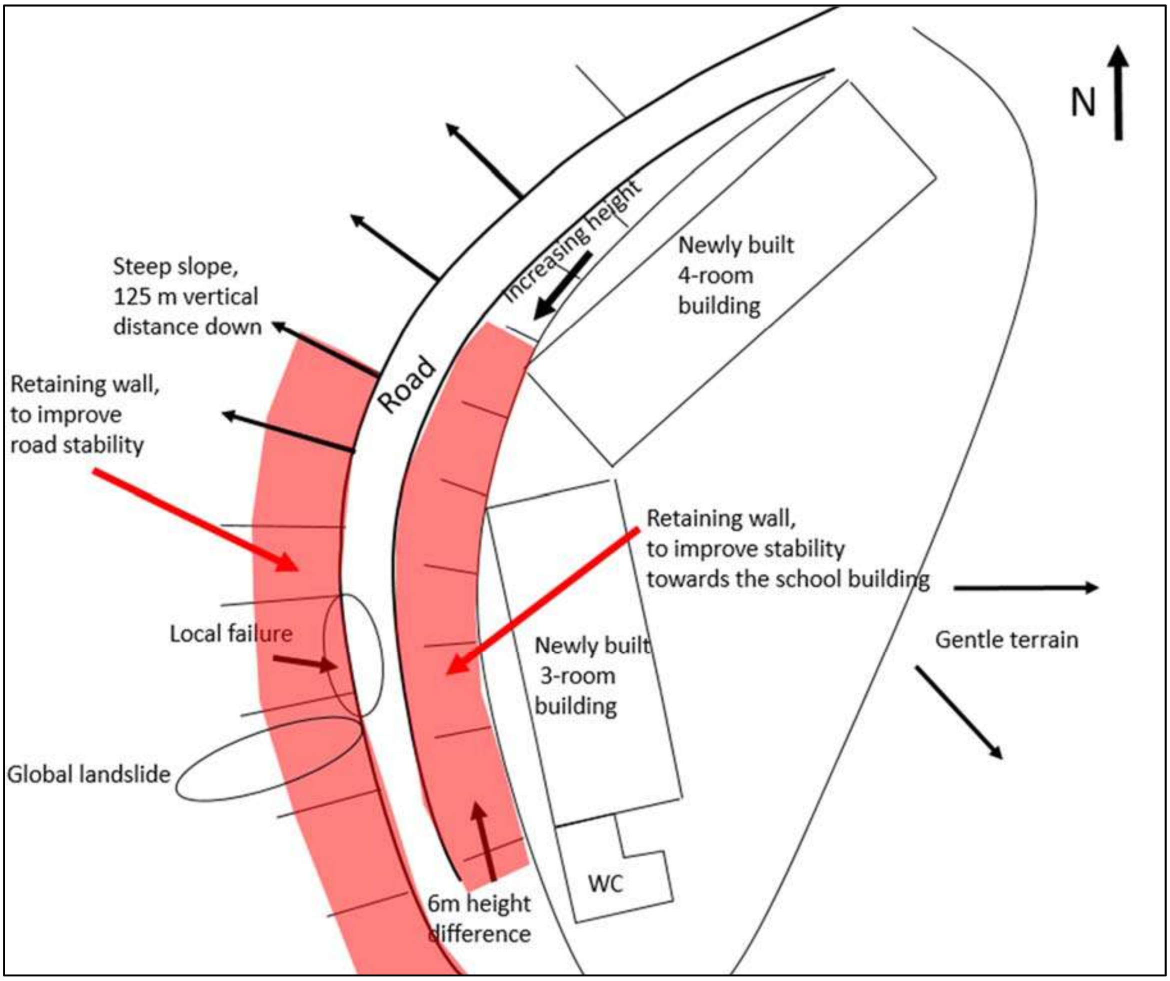

Figure 10-1 Plan view - Himali Devi. Two retaining wall west of the plot should be constructed; one to improve the road stability and one to improve the stability towards the school building.

10.2 Field observations

<u>School buildings</u>
The plot consists of two newly constructed buildings (one 4-rom and on 3-room). The area is very limited.
<u>Landform</u>
Very sharp ridge and steep slope in NV direction against the river.
<u>Rivers – drainage pattern</u>
There are no streams in the area that influence the local stability or may induce larger slides.
<u>Topography/geometry</u>
The NW slope is very steep and continues down to the river with a vertical distance of 125 meter. There has been a landslide (also NW) caused by the construction of the road and a local slip failure of more recently date into the road. This side of the school plot is therefore of most concern. The stability of the road is related to the stability of the southern building. The terrain in the southern and eastern part is gentler.

<u>Type of area</u>
The area north of the school is farming area.
<u>Soil types</u>
Weathered soil with some rocks. Weathered bedrock is visible north of the plot (light colour). Most likely visible bedrock 5m below the road. The bedrock in the landslide area is darker, and weathered. Even though the rock structure is partly visible in the road cut, there is a reason to believe that the strength of the road cut is comparable with the strength of sandy silt due to strong weathering.
<u>Landslides in the area</u>
There is a landslides west of the school plot. The instability is caused by the road construction, induced by rainfall.
<u>Access road</u>
The road is west of the school. The school and the road is on a local hill on the ridge, and only local rainfall affects the road.
<u>Retaining walls</u>
There are no retaining walls.
<u>Water supply</u>
Water supply is solved.
<u>Other comments</u>
The plot is generally limited; there is no space for a schoolyard.

10.3 Conclusions and recommendations

10.3.1 High priority measures

<u>Retaining wall below the road</u>
The road below the school should be secured by a retaining wall (e.g. gabion wall) that is sliced into a shelf in the bedrock, or bolted
<u>Retaining wall at the southern building</u>
After securing the road, the NW part of the southern building should be secured by a retaining wall.

Figure 10-2 Himali Devi Primary school situated on the top of a slope, east of Syakhu River.

Figure 10-3 Looking south-east. Front of school, mainly in eastern direction.

Figure 10-4 Looking north. The southern and eastern land (not visible) are arable land, the road visible at left side.

Figure 10-5 Road, west of the school plot. The critical point is where the man is standing. The southern building needs a gabion wall, after the road is secured.

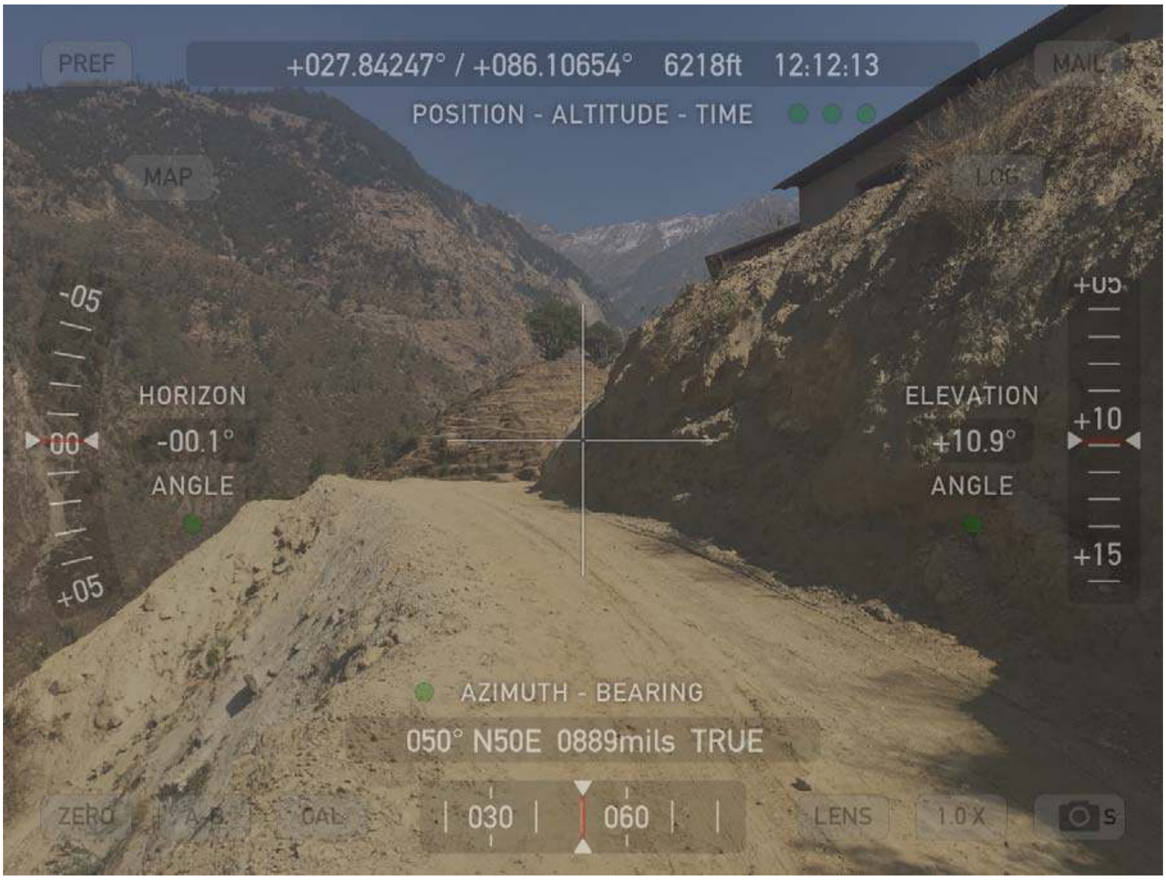

Figure 10-6 Road cut below the school, looking north.

Figure 10-7 The average slope is about 47°. Bedrock is visible about five meters below the road and further north. In the southern direction, the new slide (shown in next figure) most likely covers bedrock.

Figure 10-8 Slide at the edge of the road. Around 10-15 m below, the inclination decrease for some meters, maybe due to bedrock.

11 Himkhande Bhuwaneswori (Chilankha)

11.1 Key information

Visit date: 28-01-2018
Participing during visit: Thomas, Øyvind, Åse Marit, Bishnue, Sujan
Number of students (staff): 60 (4)

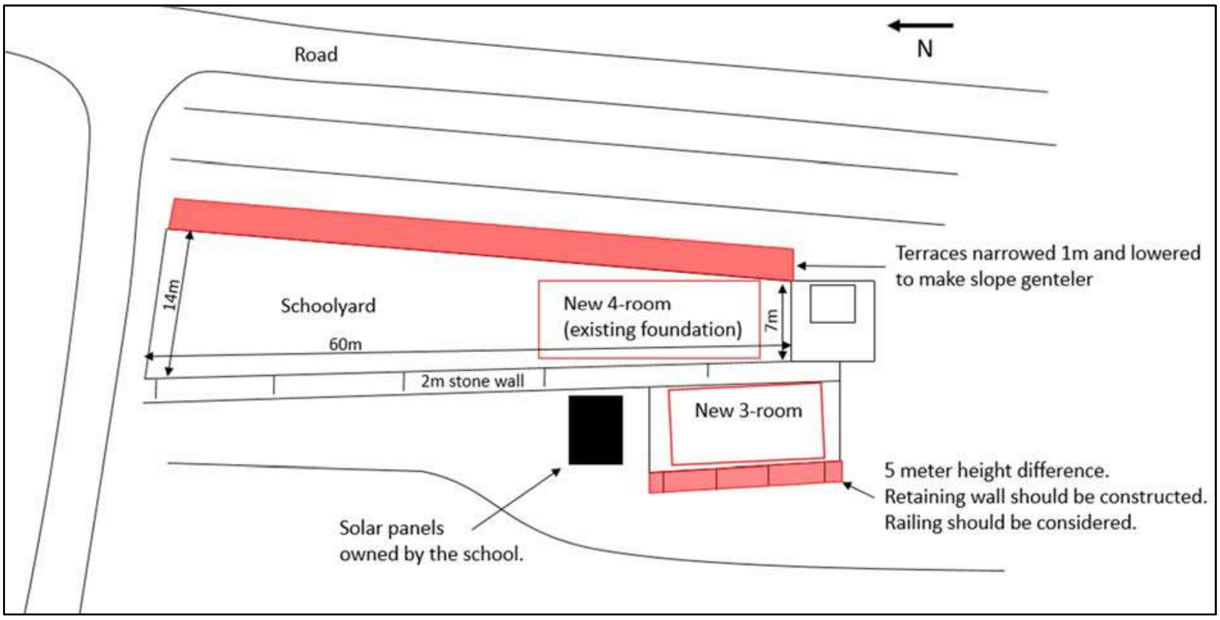

Figure 11-1 Plan view – Himkhande Bhuwaneswori. The slope west (below) of the plot should be secured by a retaining wall..

11.2 Field observations

<u>School buildings</u>
The plot consist of no buildings, but two remaining foundations in two different levels.
<u>Landform</u>
Gentle terrain.
<u>Rivers – drainage pattern</u>
There are no streams in the area.
<u>Topography/geometry</u>
Generally, the terrain is gentle. East of the plot, the lower terrace will be reduced by 1m. The plot for the 4-room building is 2m higher than for the 3-room building. Below the lower plot there is a 5m height difference.
<u>Type of area</u>
Farming area.
<u>Soil types</u>
Weathered soil.
<u>Landslides in the area</u>
No landslides.
<u>Access road</u>
The road is east (above) of the area. There is access road into the school plot from north.
<u>Retaining walls</u>
There are no retaining walls.
<u>Water supply</u>
We are informed that water supply will be solved.

11.3 Conclusions and recommendations

11.3.1 Medium priority measures

Gabion wall west

The slope west (downside) of the area should be secured by a retaining wall. The foundation of the lowermost building will be close to the steep part.

The front of the terrace upside the plot will be lowered.

11.3.2 Low priority measures

11.3.3 Recommendations

Is it possible to use the remaining foundation for the construction of the new building? (Place the plint on top the existing.)

Figure 11-2 Looking south-west. The northern area will be the schoolyard and the two buildings will be placed on the southern area. The terrace above the plot will be narrowed 1 m and lowered.

Figure 11-3 The lower part of the plot are fairly narrow compared to the width of the new 3-room building. The slope below (see next figure) must be secured by a reinforced structure.

Figure 11-4 The stones are temporary placed at the edge of the plot. The foundation of a new building will need a supporting structure in the slope.

12 References

[1] MRB & Associates (2016) Construction of new classrooms in Solukhumbu district. (Received by CWIN)