

Skhalta Community Briefing Report

Engineering Geological and Geotechnical Assessments for Landslides

August 2013

Adjaristsqali Georgia LLC

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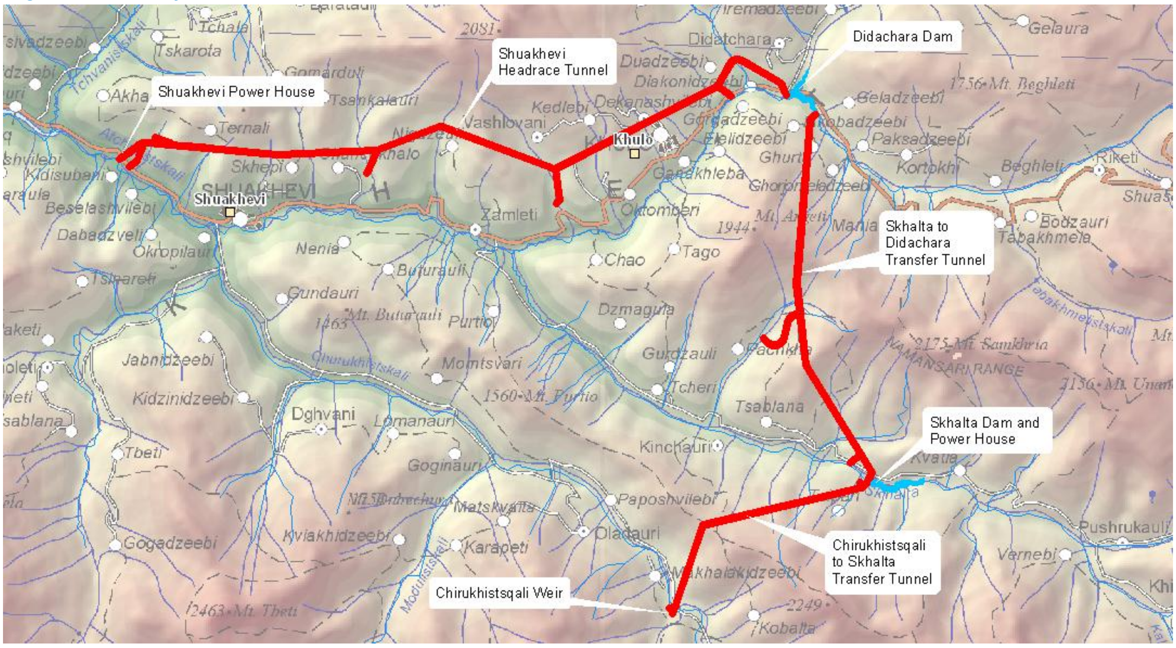
1 Introduction

The Shuakhevi Hydropower Project is to be constructed on the Adjaristsqali River in southwest Georgia. A main dam will be constructed at Didachara with water transferred via a tunnel to the hydropower plant at Shuakhevi. The scheme will also collect waters from the Chirukhistsqali and Skhalta Rivers through the construction of a weir (Chirukhistsqali) and a secondary dam (Skhalta). The water from Chirukhistsqali will be transferred to Skhalta through a tunnel and a further tunnel will transfer the water from Skhalta to Didachara. The layout of the scheme is shown in Figure 1.1.

This document provides an overview of the engineering geological and geotechnical considerations that have been addressed in selecting the most appropriate location for the secondary dam at Skhalta. The main focus is on works that have been carried out to understand and mitigate landslide hazards which are of great concern to the local population.

Over the past 3 years an ever more detailed understanding of the ground conditions in the Skhalta region has been developed through extensive field, laboratory and desk based studies. Starting in 2010 with the pre-feasibility stage and carrying through to the detailed preconstruction investigations, currently on-going, improving knowledge of the ground conditions and understanding the impacts that construction and operation will have on the surrounding area has been a priority of the design team. A combination of Georgian and internationally recognised experts have been utilised throughout project development and design, to ensure that the most appropriate path is followed.

Figure 1.1: Layout of the Shuakhevi HPP Scheme



2 Project Development Phases

To bring the project to its current status it has passed through three main phases; pre-feasibility, feasibility and design. There has been a sequential increase in the length of time taken, level of detail, and extent of the works carried out during each phase. The additional works undertaken in each phase have continually improved the understanding of the ground conditions allowing refinement of the dam layout, planning for construction works and an appraisal of the effects on the area surrounding the reservoir during operation.

The works undertaken during each phase are briefly outlined below and detailed discussion then follow on how the works have linked together to arrive at the final layout at Skhalta

2.1 Pre-feasibility

The project began with the pre-feasibility and inception phase investigations. During this phase Georgian engineering experience combined with international experience was utilised to develop a preliminary plan of what the scheme would look like. The respective experts visited the region to gain an early, yet important, basic understanding of the region. In the Skhalta area as well as a number of other locations within the project, the potential for landslides was identified as a significant risk for the project and plans were put in place to conduct detailed assessments to understand the hazard.

2.2 Feasibility

During the feasibility phase the key requirements were; understanding the landslide hazard and understanding ground conditions for the proposed dam site. The preliminary works focused on broad scale desk based geomorphological assessments followed by ground truthing and mapping, which allowed preliminary landslide hazard assessments to be undertaken. These preliminary assessments resulted in refinements and definition of the most suitable area for the dam structure. Further, more detailed, geomorphological studies then continued in numerous areas around the reservoir where a greater understanding of the prevailing ground conditions and processes were deemed necessary to understand the possible effects of the operation of the reservoir on the stability of the slopes. The geomorphological studies were supplemented by geological and rockmass mapping within the region to further understand the geological materials and the on-going processes. Intrusive investigations were also undertaken in a select number of locations to understand and confirm the subsurface ground conditions and interpretations from geomorphological and geological mapping.

The findings of these studies were instrumental in defining the upstream extent of the reservoir which was limited to its current location to ensure that there was no risk of a large existing landslide, upon which residential dwellings are located, being reactivated by associated changes in groundwater levels.

The location of the dam was also moved upstream during the feasibility stage due to some uncertainty in the ground conditions on the left bank at a downstream location. The geomorphology suggested the potential for rock that may not be insitu and it was considered that intrusive investigations may not give conclusive evidence that conditions were suitable. To remove the risk the decision was taken to move the dam upstream to a more appropriate location.

A number of features, and areas, where small to moderate volume failures may be expected during the reservoirs operational life were also identified. However, the anticipated areas of influence do not extend to existing populated areas.

The studies also considered the occurrence of the devastating Tsablana landslide that occurred in April 1989 and attempted to assess whether similar failures were possible within this stretch of river in the future. The investigations of the failed form of Tsablana indicate that it initiated in a tributary catchment on the left bank at considerable elevation above the valley floor. The failure probably resulted from failure of highly to completely weathered rock and erosion products in the upper catchment that had been over steepened by erosion of the tributary, and was likely triggered by extreme climatic conditions occurring immediately prior to the time of failure. Observations downstream of Tsablana also indicate that similar large landslides have occurred in the upper parts of tributaries, high above river level, on the left bank resulting in the formation of large debris fans at the slope toes that have been partially eroded away by the Skhalta river. Smaller debris fans noted at the base of some tributaries also indicate that a more gradual erosion process may dominate in some catchments rather than the catastrophic failure that occurred at Tsablana.

Upstream of Tsablana the area, identified as unit 124 in Figure 4.3 was investigated in detail in the feasibility mapping. The unit is located in the upper catchment of a left bank tributary, of similar orientation to Tsablana, the unit is in excess of 200m above the valley floor. The on-going weathering and erosion by the streams within the catchment may be considered similar to the processes that were occurring in the tributary in which the Tsablana landslide originated. However, at the time of the studies, only localised areas of shallow instability were observed in the catchment with no signs of large scale instability indicating no immediate threat. A small colluvial fan is currently present at the base of the tributary at river level suggesting that small volumes of eroded material are being transported down the tributary.

A residual risk of another large scale landslide at some time in the future, perhaps well beyond the lifetime of the scheme, exists at the location of unit 124. However, the occurrence of this landslide would result from the effects of natural processes of erosion and denudation on the slopes of the upper catchment, with no effect from the proposed dam and reservoir located upstream in the valley bottom. Currently there are no houses located on or below this area or within the potential run out zone for any failed material, and hence the risk to people is considered low. However, if such a failure did occur, depending upon the size of the failure, the proposed dam may be affected by the run out zone.

2.3 Design

After the feasibility stage was completed and the project determined viable, works for the design of the scheme began. Although a detailed understanding of the ground had been developed during the feasibility phase, design required much more detailed, and location specific, information to ensure a comprehensive understanding of the ground conditions at and around the precise dam location and within the reservoir. To obtain this information, additional, phased intrusive investigations were undertaken at key locations by a Georgian drilling contractor under the full time supervision of Mott MacDonald engineering geologists. This phased approach allowed further minor refinements to optimise the dam location and construction with regard to engineering geological and geotechnical considerations.

Further geomorphological assessments have, and are continuing to be, carried out for the areas around the reservoir rim. These assessments have focused on features of concern where moderate volumes of material may be expected to fail during the reservoirs operational lifetime due to both natural processes of denudation and also as influenced by altered water levels within the ground and fluctuating water levels within the reservoir. The occurrence of such failures would not impact the populated areas but could have temporary implications for infrastructure surrounding the reservoir or for the reservoir itself which need to be checked. If necessary, mitigation measures will be put in place as part of the construction to manage such occurrences. The areas where small volume failures are anticipated are not being individually assessed as they are akin to small events that would occur naturally, and on an annual basis, at the boundary of a natural watercourse; they are likely to affect only the thin top layer of soil.

3 Engineering Geological and Geotechnical Investigations

Throughout the phases of the project, as noted in Section 2.2 and 2.3 above, a large number of investigations have been carried out at the Skhalta site to develop the understanding of the ground conditions with particular emphasis on the landslide hazard. The investigations undertaken can be classified under three different categories of; geomorphological studies, surface geological studies and intrusive geological studies. The works undertaken under each category in the Skhalta area are summarised in Table 3.1 below.

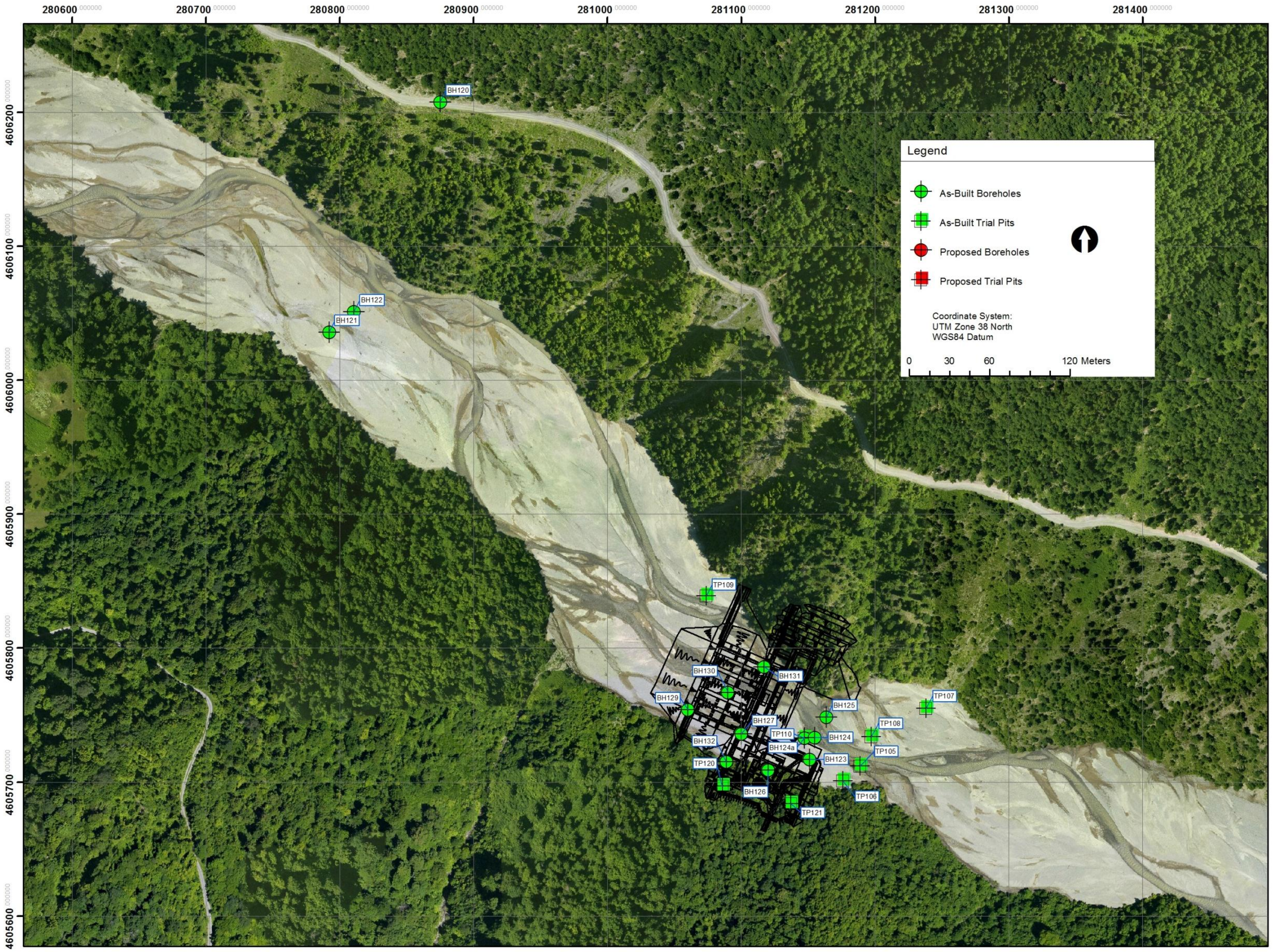
Table 3.1: Engineering Geological and Geotechnical Studies carried out at Skhalta

Category	Investigations/Studies
Geomorphological Studies	Aerial Photograph Interpretation at 1:50,000, and 1:25,000 Field mapping at 1:10,000
Surface Geological studies	Geological mapping at 1:2,500; 1:5,000; 1:10,000 Rockmass assessments - 20 specific locations Scan lines - 25 Specific locations
Intrusive Geological Studies	8 Trial Pits 13 Boreholes Geophysical investigation – seismic refraction – 11 Profiles

Although these investigations were generally undertaken separately they are interlinked and together allow a greater appreciation of the prevailing conditions. Throughout the implementation of these investigations the findings have been reviewed together to develop and guide the subsequent investigations. The locations of the boreholes and trial pits in the Skhalta area are presented in Figure 3.1.

In the following sections, the specific works that have been carried out for assessments at Skhalta are discussed in more detail. The logic behind these assessments, that have determined that the proposed works will not increase the landslide hazard to the locally populated areas, is explained for specific areas around the reservoir.

Figure 3.1: Plan of Skhalta Ground investigation locations



4 The Assessment Process at Skhalta

Starting in pre-feasibility, the initial site appraisals and visits identified the area of Skhalta as a potentially suitable location for positioning of a dam. The works undertaken in this phase were at a high level and encompassed limited detail. The brief assessments undertaken during site visits identified the presence of near surface rock at a number of areas within the reservoir and within a broad area that was considered suitable for location of a dam. These initial assessments also noted the on-going slope processes within the region and identified a number of larger landslide features; the risk that these features posed to the project and the potential impacts on the surrounding population were recognised at this early stage. The need for a detailed understanding of the geological materials and the slope processes was identified and a detailed assessment process was devised to approach the problem.

At the start of the feasibility phase, works commenced with a detailed assessment of site slope conditions from aerial imagery. An initial broad review was made at a scale of 1:50, 000 and then a more detailed assessment at a scale of 1:25,000. The best available digital elevation model (DEM) was acquired and the imagery draped over this surface to assist in interpretation. However, the data resolution was insufficient for detailed delineation of landslide features or identification of small scale slope movements. The imagery used was dated from 2005 and appeared to have been captured in spring / summer. The approximate extents of possible historical and current landslides were traced onto the photographs using ESRI ArcGIS software, Figure 4.1. Due to the vegetation cover in the area, the extents of landsliding and likely failure mechanisms were principally based on the shapes and landforms that typically demonstrate historical and active landslides at various scales. In addition to the aerial imagery, the historical landslides identified on a Geological Engineering map, produced by a Georgian consultant, at 1:50,000 scale were considered in the assessment.

The areas of instability identified were split into different types of landsliding with four main categories:

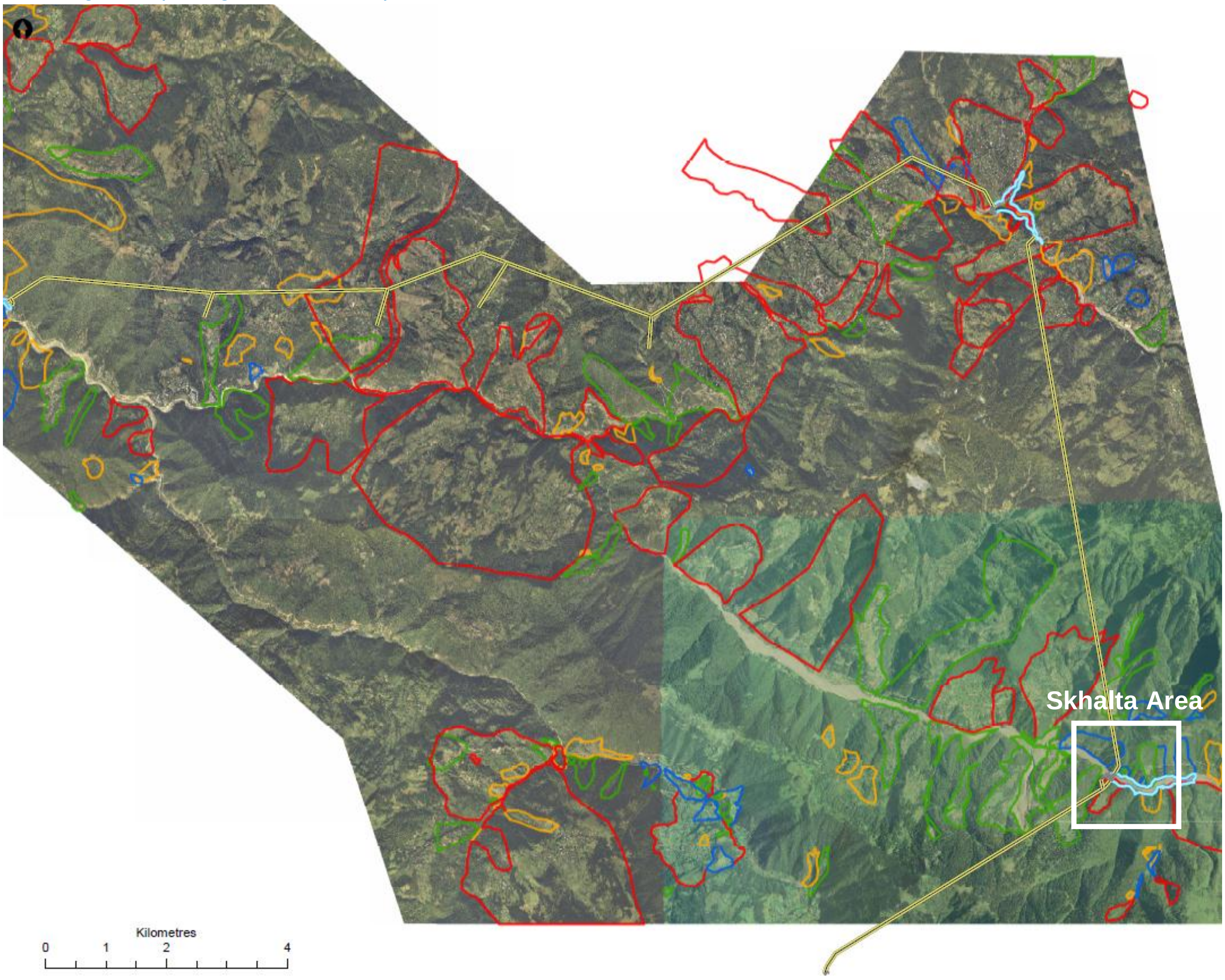
1. Mudslide / debris slide;
2. deep seated / rotational;
3. shallow / planar; and
4. rockfall / talus.

The resulting interpretation identified a number of potential landslide features within the general area of the proposed dam and reservoir location that warranted further detailed investigation. The generally uniform steep slopes observed within the area indicated structural control and shallow depths to underlying bedrock, with anticipated hazards of shallow planar and translational failures.

The interpretation from the aerial imagery was then taken into the field for verification/ground truthing studies. Where possible the local population were consulted to gain knowledge of historical slope movements. The mapping team comprised one UK specialist and a Georgian geomorphologist to help facilitate these consultations.

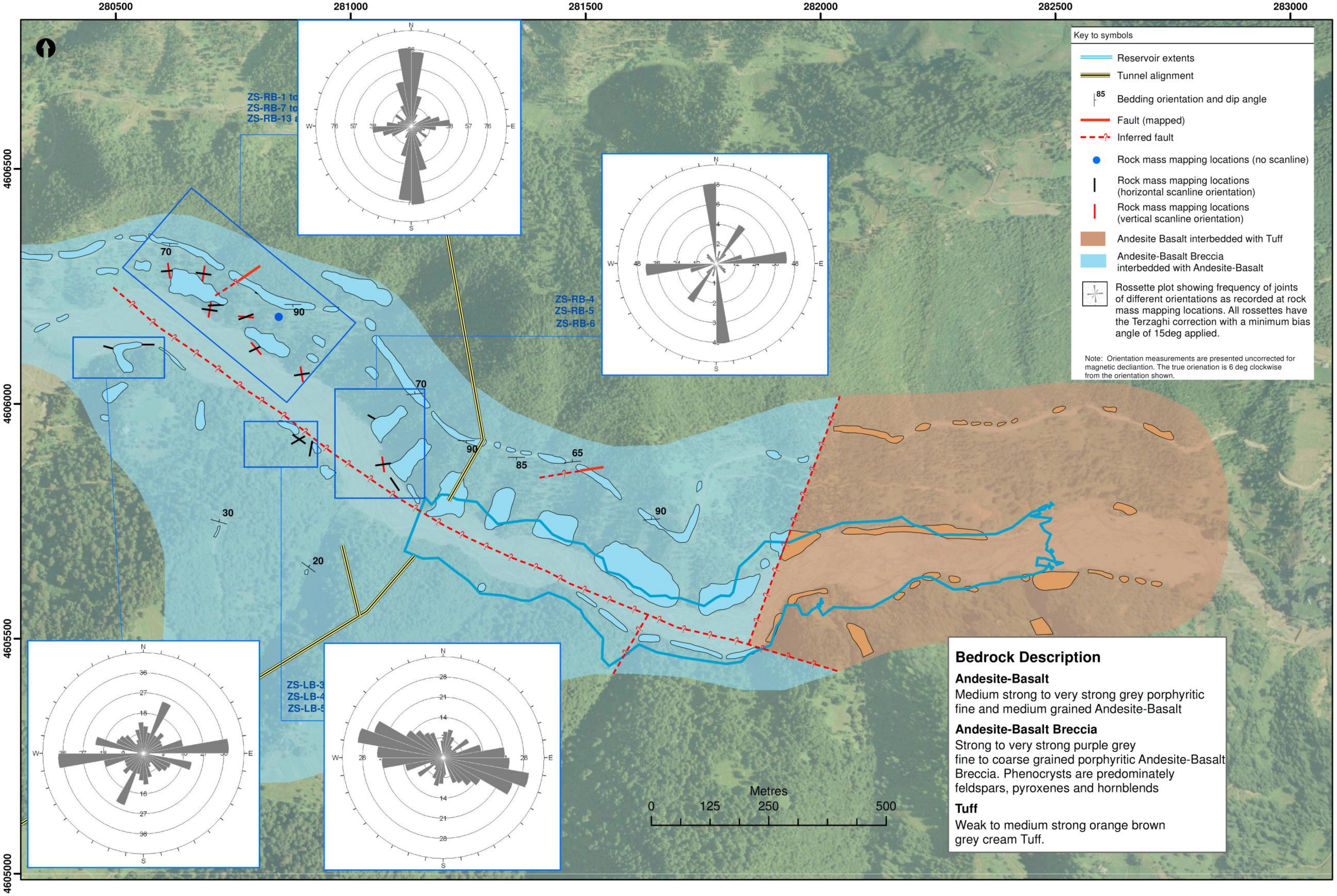
The verification is undertaken to establish that interpretations made from aerial photography i.e. landslide type and failure mechanism, are valid when certain features are viewed in the field and to improve delineation of the features. Verification studies at Skhalta comprised geomorphological mapping assessments, at scales of 1:10,000 and 1:25,000, in the areas surrounding the proposed dam site and in a number of locations around the reservoir extent. During this stage the combined site and aerial photo findings were independently checked by another senior geomorphologist to confirm the interpretations made were appropriate.

Figure 4.1: Preliminary Aerial Imagery Interpretation for the Shuakhevi HPP area – Now superseded by ground truthed geomorphological hazard maps



At the same time as the geomorphological field studies, surface geological studies were also progressing in the area and were used to supplement the geomorphological works. The location of rock outcrops, information on rock condition, recorded joint patterns and faults (Figure 4.2) gave confidence in the presence of in-situ bedrock and contributed to a better understanding of the landslide extents and potential mechanisms.

Figure 4.2: The Geological Mapping of the Skhalta area. Outcrops and regionally identified structural trends are displayed



Intrusive investigations were progressing in proximity to the proposed dam location and were focused on understanding the dam foundation conditions and groundwater levels. Initially 3 boreholes were undertaken at a downstream location for the dam, 2 in the river bed and 1 on the right bank. However, as the geomorphological studies continued some uncertainty over this location became apparent with the possibility for a large block of rock that was not insitu at the left bank. The decision was taken to move the dam location upstream to more appropriate location. Four additional boreholes were drilled in the river bed at the upstream location during the feasibility stage. As noted earlier in Section 2.2 and 2.3, the intrusive investigations were undertaken in phases and further investigations have been undertaken continually improving the understanding of conditions in the area surrounding the dam site (Figure 3.1) where the increases in water level due to the reservoir will be greatest.

Following the completion of the geomorphological studies, all of the available information was considered together to carry out a landslide hazard assessment for the Skhalta area and the results presented on a landslide hazard map, Figure 4.3. It must be emphasised here that the landslide hazard map does not only indicate hazards that may result, in part, due to the effects of the proposed reservoir. The fieldwork also considered the hazards that are actively occurring, with no direct influence from the proposed reservoir. However, the risk rating assigned is based on the likelihood of the scheme construction causing a landslide.

The assumptions made in the assessment have been continually checked against the findings of subsequent intrusive investigations and site observations to ensure that they continue to be valid.

4.1 The Assessment

The qualitative assessment considered two aspects for each of the defined landslide units in the final landslide hazard map, Figure 4.3:

1. The impact (magnitude, extent, duration, reversibility) that the occurrence of the landslide would have upon the local population and the dam structures.
2. The likelihood of the project construction and operation causing the landslide to occur.

The resulting hazard matrix is shown in Table 4.1 and is reflected in the landslide hazard map by the colour of the landslide extents, Figure 4.3. The definitions of the two aspects considered for the ratings are given below:

Hazard Impact definitions:

- Low impact: Event having little effect on the local population or the dam structures, low spatial extent (<500m3) and with small volumes of material in one instant or larger volumes at a slower rate. For example, localised rockfall or shallow creep movement on soil slopes.
- Medium Impact: Event where the dam structure / farmland / local population may be directly impacted by slope movement. Spatial extent of the hazard is restricted to affecting only local areas and a single scheme structure. For example where the fluctuating water levels in a reservoir may increase the porewater pressure in the side slopes and cause a slope failure which destroys a roadway.

- High Impact: Event having a catastrophic impact on the regional community or the project. Large scale movement with a high spatial extent, with little ability or likelihood for reversibility. For example: a large debris flow which has potential to cause dam overtopping and severe disruption to the project and to communities including death.

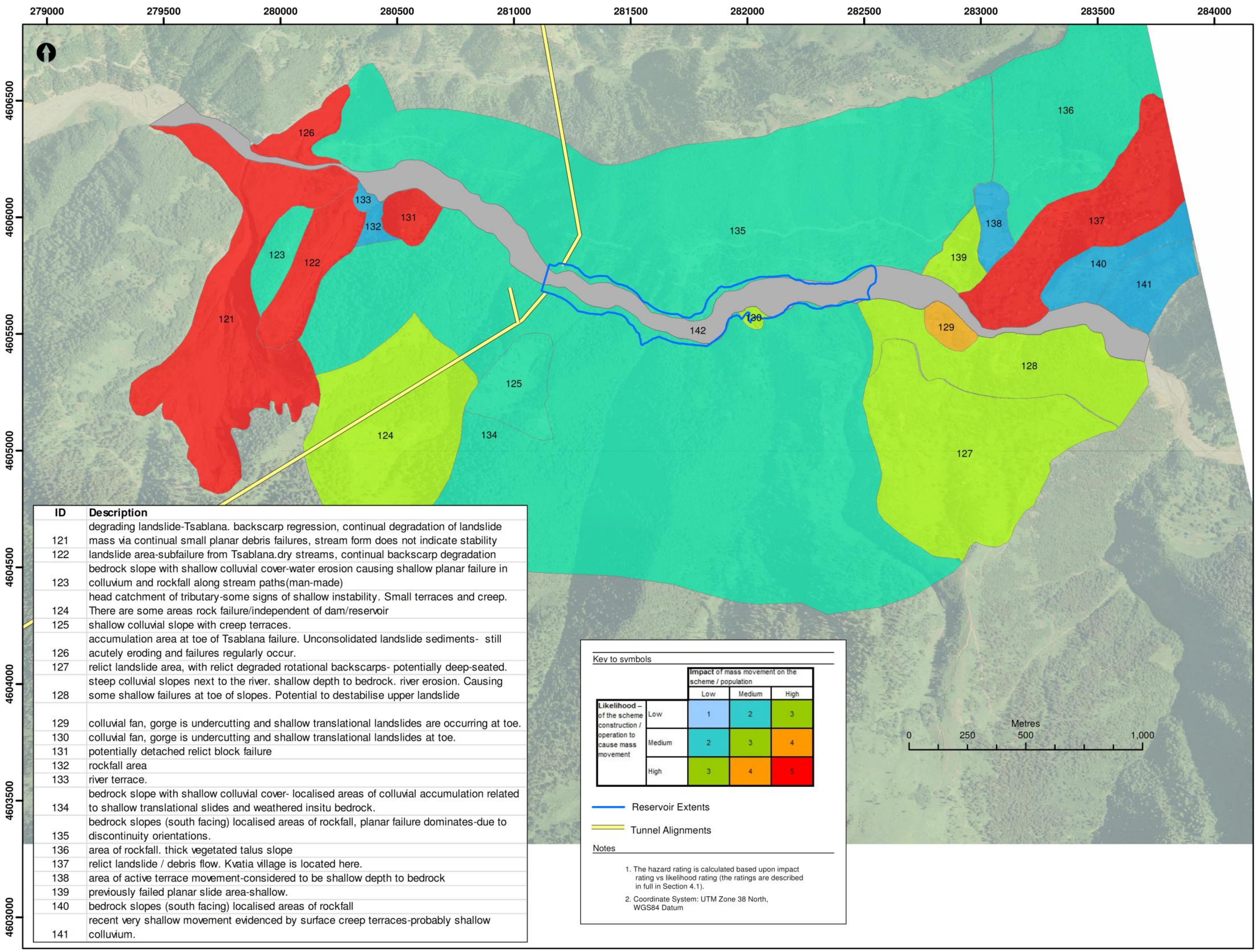
Hazard likelihood definitions:
- Low Likelihood: Landslide hazard is not likely to occur within the lifetime of the project.
- Medium Likelihood: Landslide hazard may occur within the lifetime of the project.
- High Likelihood: Landslide hazard is actively occurring or is likely to occur in the near future, almost certain to occur within the lifetime of the project

Table 4.1: Landslide Hazard Matrix

	Low Impact / Magnitude	Medium Impact / Magnitude	High Impact / Magnitude
Low Likelihood	1 (Negligible)	2 (Minor)	3 (Moderate)
Medium Likelihood	2 (Minor)	3 (Moderate)	4 (Major)
High Likelihood	3 (Moderate)	4 (Major)	5 (Critical)

The strategy adopted following the landslide hazard assessment was as follows:
- Major and Critical features - Avoid (i.e. move structures and reservoirs or limit their extents if required)
- Moderate features – Subject to further assessment and potentially engineered solutions
- Negligible and Minor features – No action

Figure 4.3: Landslide Hazard Map for Skhalta



ID	Description
121	degrading landslide-Tsablana. backscarp regression, continual degradation of landslide mass via continual small planar debris failures, stream form does not indicate stability
122	landslide area-subfailure from Tsablana.dry streams, continual backscarp degradation
123	bedrock slope with shallow colluvial cover-water erosion causing shallow planar failure in colluvium and rockfall along stream paths(man-made)
124	head catchment of tributary-some signs of shallow instability. Small terraces and creep. There are some areas rock failure/independent of dam/reservoir
125	shallow colluvial slope with creep terraces.
126	accumulation area at toe of Tsablana failure. Unconsolidated landslide sediments- still acutely eroding and failures regularly occur.
127	relict landslide area, with relict degraded rotational backscarps- potentially deep-seated.
128	steep colluvial slopes next to the river. shallow depth to bedrock. river erosion. Causing some shallow failures at toe of slopes. Potential to destabilise upper landslide
129	colluvial fan, gorge is undercutting and shallow translational landslides are occurring at toe.
130	colluvial fan, gorge is undercutting and shallow translational landslides at toe.
131	potentially detached relict block failure
132	rockfall area
133	river terrace.
134	bedrock slope with shallow colluvial cover- localised areas of colluvial accumulation related to shallow translational slides and weathered insitu bedrock.
135	bedrock slopes (south facing) localised areas of rockfall, planar failure dominates-due to discontinuity orientations.
136	area of rockfall. thick vegetated talus slope
137	relict landslide / debris flow. Kvatia village is located here.
138	area of active terrace movement-considered to be shallow depth to bedrock
139	previously failed planar slide area-shallow.
140	bedrock slopes (south facing) localised areas of rockfall
141	recent very shallow movement evidenced by surface creep terraces-probably shallow colluvium.

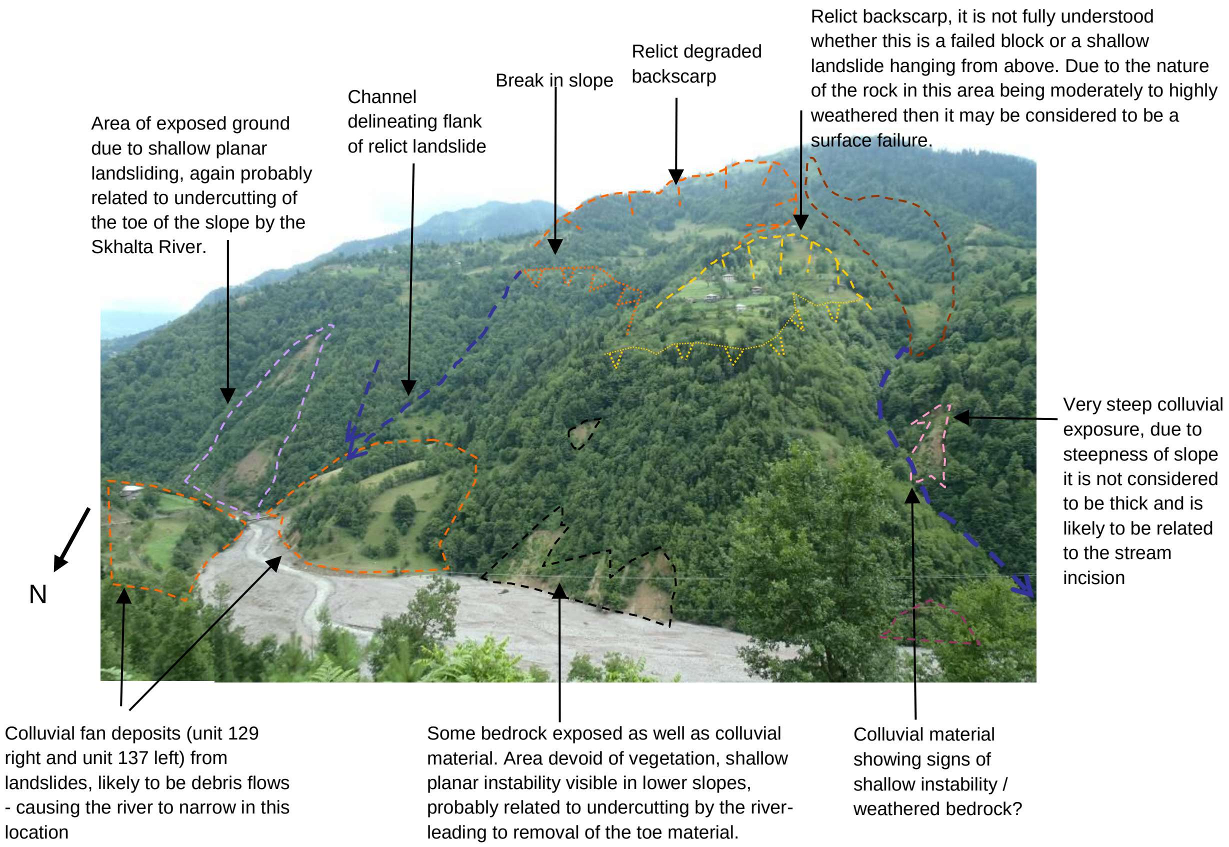
4.2 Landslide units with the potential to directly impact local residential properties

The assessment indicated that all identified local dwellings, farmland and infrastructure were located on landslide units identified as numbers 125, 127 and 137, Figure 4.3.

Unit 125 is located some 200 to 250m above the current river level at the location of the proposed dam and is in excess of 180m above the top level of the proposed reservoir. The unit is located above a break in slope where 40° slopes, forming part of unit 134, rise from river level and reduce to 20°. Geomorphological observations indicate that the existing residential dwellings are located on a shallow colluvial slope where down slope creep movements are actively on-going. Observations of rock exposures and intrusive investigations on the steeper slopes of unit 134 below have revealed that a limited thickness of colluvial materials is present over rock at river level and is expected to thin out upslope. Based on these observations the left bank at this location is considered to be relatively stable rockmass with limited localised coverings of colluvium/rockfall talus and thin soils. Due to the presence of rock and the limited covering of colluvium, the lower slopes of unit 134 are not considered to be connected with unit 125 and hence there is no mechanism for the proposed reservoir to result in reactivation and further movement of unit 125, although creep of the surface soils will continue to occur naturally.

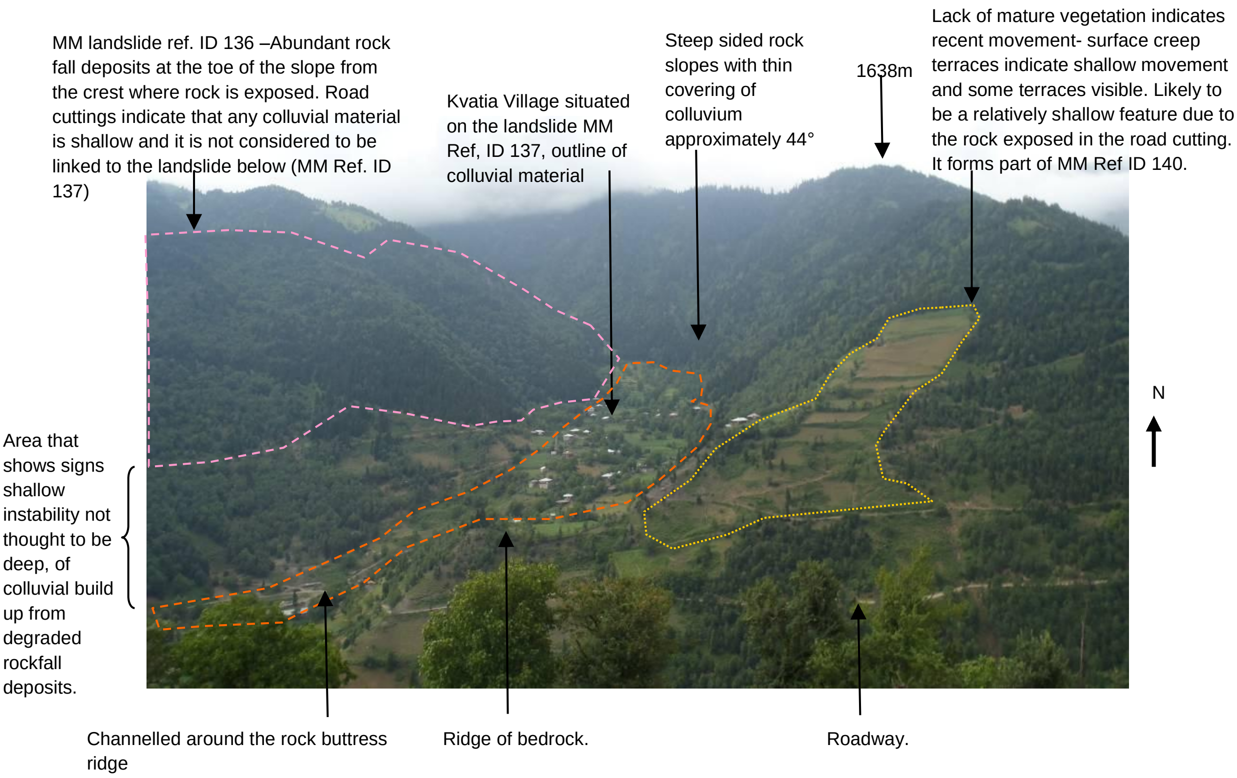
The geomorphology of unit 127 indicates that the residential properties present are located on a relict landslide, the base of which daylights approximately 70m above the current river level. At the identified base of the landslide there is a break in slope where slopes increase from the gentle 5-10° above to steep 50° slopes descending to river level Figure 4.4 . The steep 50° slopes are classified as unit 128 in Figure 4.3. Mapping observations on the 50° slopes noted rock exposures showing through a colluvial drape, in certain locations where undercut by the current river. These observations indicate that the current valley side is rock below a limited cover of colluvium and that it is unlikely to be connected to the slopes of the relict landslide, unit 127, above. It is considered that the river has cut down since the formation of landslide unit 127 leaving a rock outcrop at the river level that has been covered by a limited build-up of colluvium; resulting from weathering and accumulation of erosion products and rock fall from above. Based on these observations there is no mechanism for the proposed reservoir to result in reactivation and further movement of unit 127. The exception to the conditions noted above was at the location of landslide unit 129 (Figure 4.3) where a much greater thickness of colluvial material is present at the base of the slope. At this location, there is more uncertainty in understanding whether the slopes at river level are connected with the slopes of landslide unit 127 above. Due to this uncertainty the decision was taken to limit the reservoir extent to a location downstream of landslide unit 129 thereby eliminating the risk.

Figure 4.4: View of the left bank of the Skhalta river – Corresponding to landslide hazard unit 127 in Figure 4.3



The village of Kvatia is located on a relict debris flow identified as landslide unit 137 in Figure 4.3. The observations indicate that the debris flow has considerable thickness (in excess of 10m) and extends all the way down to river level (Figure 4.5) where the toe is currently being eroded by the river resulting in small scale slumps of material. To the west of unit 137, unit 139 also extends down to river level where similar small scale slumps of colluvial material are on-going. Unit 139 is considered to have thin colluvial cover over rock based on exposures observed in road cuttings. Due to the structure and composition of these landslide materials, it is unlikely that they would remain stable if subjected to large increases in groundwater levels or fluctuations in water level associated with an operational reservoir. However, due to the location of the landslide at the upper end of the reservoir, during the assessment it was considered that the lower parts of these slopes could be protected to allow the shallow end of the reservoir (1-2m water depth) to extend to the slope bases without causing further instability. The considerations for landslide unit 127 noted above, however, resulted in the reservoir extent being limited such that it will not impact these slopes.

Figure 4.5: View of the right bank of the Skhalta river – Corresponding to landslide hazard unit 137 in Figure 4.3



4.3 Other geomorphological units

The discussion above has focused specifically on landslide units upon which residential dwellings, farmland and infrastructure are located. However, there are additional units that will be impacted by the reservoir that are not occupied by residential dwellings. These units are identified as units 135, 134 and 130.

Unit 135 is located on the right bank of the Skhalta River. In this area the 30˚ to 45˚ slopes are vegetated and show regularly spaced, angular spurs that define drainage trends and likely follow geological structure. This morphology indicates generally stable rock slopes where erosive processes are dominating; forming drainage trends and depositing a build-up of erosive deposits at the slope bases. At a height of 100 to 120m above the valley bottom, rock is exposed along the valley in a road cut that leads to Kvatia village. The presence of rock is also noted sporadically below the road level and at river level where vegetation is thin and/or patchy. Between the proposed dam site and the kink in the river (noted just downstream of unit 130 in Figure 4.3) observations indicate that the slopes have a thin talus mantle that has accumulated from rock fall and is being eroded by the river (Figure 4.6). Upstream of the kink in the river observations indicate thicker deposits of talus and colluvium at the toe of the slope (Figure 4.7). These talus and colluvial accumulations show signs of shallow instability resulting from undercutting by the river.

Figure 4.6: View of the right bank of the Skhalta river – Corresponding to unit 135, downstream of kink, in river in Figure 4.3

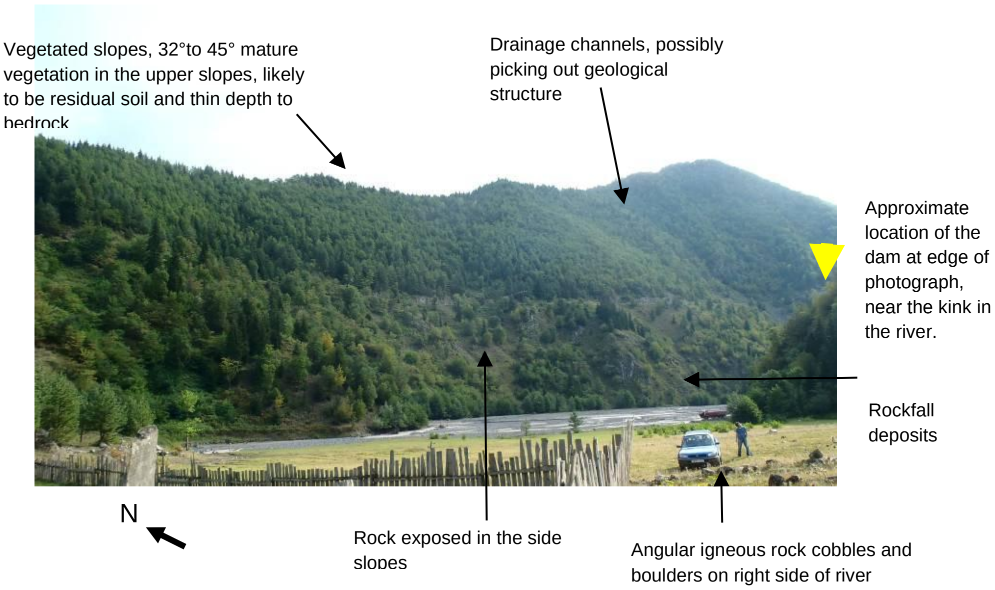
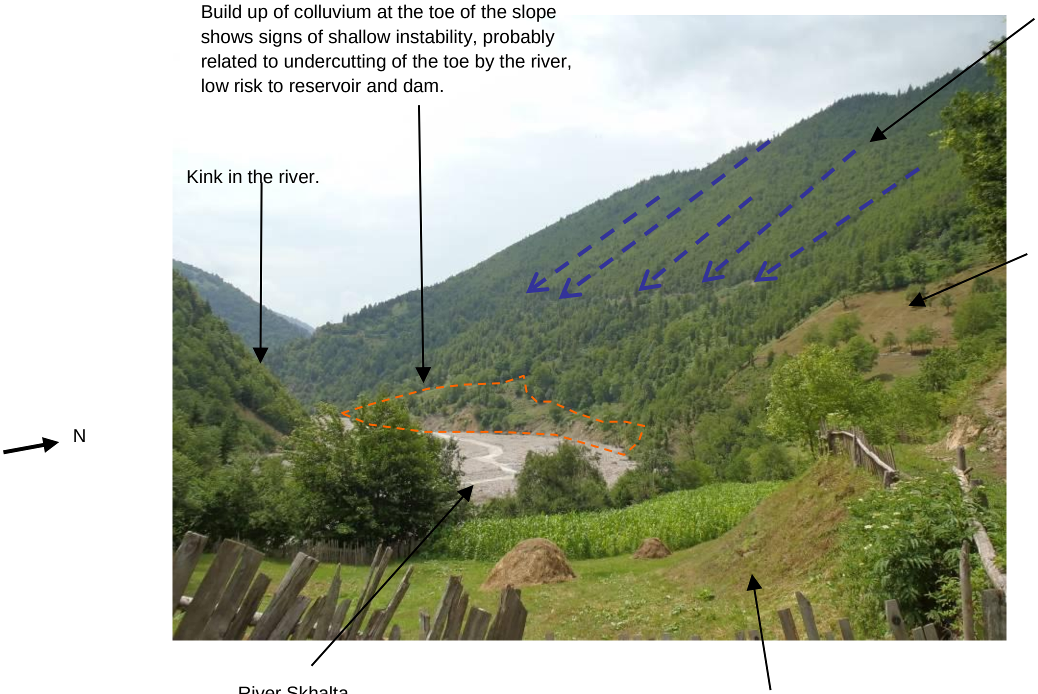


Figure 4.7: View of the right bank of the Skhalta river – Corresponding to unit 135, upstream of kink in river, in Figure 4.3



Unit 134 is located on the left bank of the Skhalta River (Figure 4.3) and has been discussed in connection with unit 125 in section 4.2 above. The slopes of this unit are heavily vegetated and vary between approximately 35˚ to 45˚. Tributary drainage patterns on the slopes (towards the northeast) are nearly perpendicular to the Skhalta Valley indicating strong structural control of the underlying bedrock. The presence of shallow bedrock in this unit is inferred from observations of bedrock in the base of tributaries and exposed in paths and roads cut into the hillside. As noted above in section 4.2, observations of rock exposures and intrusive investigations have revealed that a limited thickness of colluvial materials is present over rock at river level and is expected to thin out upslope. Based on these observations, the left bank in the vicinity of unit 134 is considered to comprise a relatively stable rockmass with thin coverings of colluvium, rockfall talus and thin soils which are locally thicker at the slope bases.

The main hazards posed by units 134 and 135 are deemed to be naturally occurring small scale and localised rockfalls and shallow translational movements of thin soils covering rock at levels above the reservoir. The effects on slope stability of the proposed reservoir are considered to be limited to the colluvial accumulations at and below reservoir level; these slopes may experience small scale slumps into the reservoir during filling and water fluctuations during operation.

Unit 130 is a localised colluvial fan deposit that has built up at the base of a tributary draining the slopes of unit 134 above. The toe of the fan is undercut by the river and localised shallow instability is noted. The slopes of unit 130 are likely to experience small scale slumps into the reservoir during filling and water fluctuations during operation but these movements are considered low impact events.

5 Summary

It was recognised in the early phases of the Shuakhevi Hydropower Project that landslides posed a hazard in the area of Skhalta where a secondary dam and associated reservoir were proposed. Through a phased approach incorporating geomorphological, and both surface and intrusive geological studies, a detailed understanding of the ground conditions and prevailing landslide hazard has been developed.

A landslide hazard assessment was carried out considering both the likelihood of a landslide occurrence within the lifetime of the project and the impact of the landslides upon the local population and project structures. The assessment focused on the likely effect that the construction activities and operational reservoir will have on existing landslides.

For the majority of slopes around the reservoir observations and considerations from intrusive works largely indicate the presence of shallow rock with limited thickness colluvial drapes which thin out upslope. The mechanism for formation is the natural denudation of the slopes and build-up of erosive products at the base of the slopes over time. The main hazards associated with these slopes are considered to be localised rockfalls and shallow slumps of thin soils covering rock at levels above the reservoir.

An area of concern was identified at the upper end of the proposed reservoir (left bank) where residential properties are located on a relict landslide that daylights approximately 70m above the existing river level. Although the majority of the underlying slopes were as above i.e. shallow rock with limited thickness colluvial drapes which thin out upslope, in one area with an increased thickness of colluvium there remained some uncertainty over the lower slopes being connected to the relict landslide above. To ensure stability the extent of the reservoir was limited to ensure that colluvial slopes at river level are not affected by the reservoir.

The limit on the reservoir extent, noted above, also means that the landslide body upon which Kvatia village is located will not be impacted by the proposed reservoir.

It was also recognised that the occurrence of events such as the devastating Tsablana landslide (April 1989), which is located downstream of the proposed reservoir, were of significant concern to the local population. As part of the studies the potential for a similar event to occur was considered. A residual risk of such an event was identified in a location downstream of the proposed dam and reservoir. However, this area will not be influenced by the proposed works and currently shows no signs of large scale failure, indicating no immediate threat. There are no houses located on or below this area and the potential run out zone is below the location of the proposed dam location, so in the current setting there is minimal risk to people should this landslide occur in the future.

It is also noteworthy that several examples of similar tributary valleys further downstream have colluvial fan deposits at their base indicative of a gradual erosion process rather than catastrophic failure which occurred at Tsablana.