



Analysis of man-caused alterations of the water balance in montaneous catchments resulting from the development of ski areas (Les Arcs winter sport resort, Savoie, France)

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The winter sport resort development results in alterations of mountain sites. For many years, ski areas structures have received increasing numbers of tourists. The need of recreational facilities requires more and more numerous road and building works.

Earth works are necessary to create access roads to the resorts, buildings, car parks, ways for chairlifts, long and wide ski slopes as well as sports facilities such as tennis courts.

Also, many forested areas and superficial vegetal covers disappear. In raining conditions, the natural vegetal cover and in particular the leaves of the trees intercept a part of water. They act in two ways: interception of a part of rainfall, and absorption of a part of the erosive energy due to the water drops on soils. As possible, previous natural vegetation on ski slopes is replaced by meadows or a scarce vegetal cover. But in high mountain areas, above 2000 meters, the vegetation growing is limited by extreme climatic conditions. At this level, the destruction of the vegetal cover is almost irreversible. These transformations affect the subsurface water flow and increase the erosive events occurrence. Quantitative assessments of the role of a natural vegetal cover on run off and soil erosion are available.

Another man-caused alteration is linked with the leveling of ski slopes. Modifications of the topography are required to create ski slopes. For example, in les Arcs winter sport resort, 70 000 m³ of soil have been moved for the laying out of a 2 km long

and 13 meters wide ski slope. Such alteration has a main impact on the drainage water rerouting and concentrating.

In addition, the working equipment comings and goings affect the natural surface structure. Some of these equipments are more and more efficient and heavy. Their continuous work has a compacting action on the bare soils.

Field conditions have been simulated in the laboratory firstly by Proctor compaction tests. Then, oedometer compression tests were implemented to determine the soil hydraulic conductivity variations. Various values of hydraulic conductivity coefficients of were obtained as a function of the initial water contents and void ratios. The influence of earth works and ski slope maintenance on soil compaction, ski slope erodibility and catchment water balance is illustrated.

In conclusion, the addition of factors as deforestation, topography leveling and action of the work equipments in high mountain areas has direct consequences on:

- the erosive action of rainfalls on soils,
- the water flow (rerouting and concentrating),
- the run off production.

Depending on the size of the ski area, these three factors associated with exceptional raining conditions are able to play a significant role on the modification of torrential activities and especially the triggering of debris flows.