Giornale di Geologia Applicata 1 (2005) 131 –138, doi: 10.1474/GGA.2005-01.0-13.0013

Research on Urbanized Areas Damaged by Natural Processes in Piedmont (NW Italy)

F. Luino

Consiglio Nazionale delle Ricerche (CNR)
Istituto di Ricerca per la Protezione Idrogeologica (IRPI) – Sezione di Torino - ITALY

ABSTRACT. This paper presents a research carried out on 41 villages of Piedmont Region (northwestern Italy) affected by natural processes over the last two centuries. These urbanized areas are entitled to benefit from an old act for the relocation or local reinforcement at State expense. All historical information found concerning old processes which involved these areas was considered, beginning with archives. Old documents, maps and technical reports were looked up in each municipality and in the archives of various Authorities working in land management. Books and newspaper were also consulted. For each phenomenon, aerial photographs were analyzed and compared with old photographs where available. Information was added by geomorphological surveys. Causes and effect were examined, in particular defining typology in relation to evolutive dynamics and kinematic features in prone areas. Data were assembled in chronological and technical files: these highlight recurrences, useful in defining hazard rating of the area.

Key terms: Urbanized Areas, Natural Processes, Damage, Piedmont, Italy.

Introduction

In 1970 the Italian Ministry of Public Works issued a list of the urbanized areas that were subject to natural instability processes and therefore needed either to be relocated or locally reinforced at the State's expense in accordance with the provisions of an Act of July 1908 and later amendments. Of the total 1804 urbanized areas identified, 1500 required reinforcement work and the rest required relocation. Usually the Ministry of Public Works continued to add towns, which had to be examined by decision-panels, to these two lists upon specific request from the various municipalities.

In 1984, the Ministry of Scientific Research, together with the Ministries of Public Works and Civil Defense, founded the Gruppo Nazionale per la Difesa dalle Catastrofi Idrogeologiche (GNDCI) of the National Research Council (CNR). The GNDCI was appointed the task to study, research and advise on matters in the field of geological-hydraulic risk and to establish a methodology to prevent effectively catastrophic floods and landslides. For this purpose, specific Research Groups were constituted and organized into Operative Units (universities, research institutes, regional geological surveys).

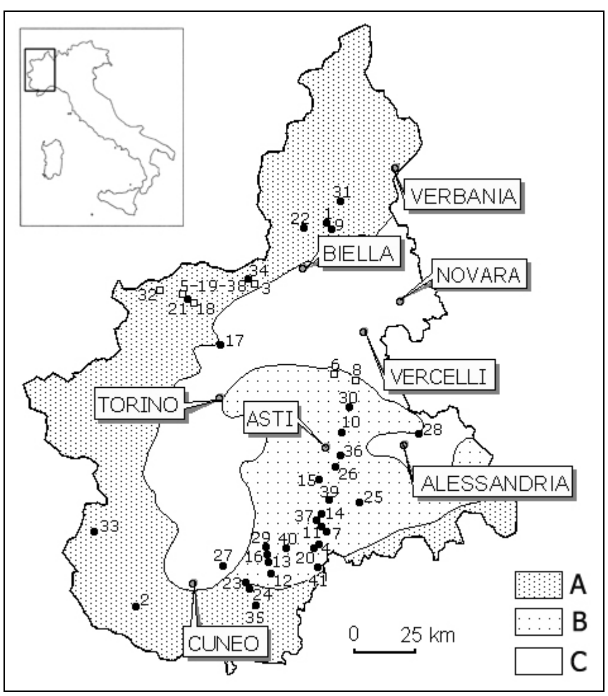

Figure 1 – The region of Piedmont, its chief towns and morphological environments: A) mountainous areas, B) Monferrato and Langhe Hills, C) Po River plain. The 41 small towns studied in the project are numerically indicated. Relocation (squares): 5. Bertodasco; 6. Brusaschetto; 8. C.na dei Frati; 18. Gascheria; 19. Grumel; 32. Piandellera; 38. Rosone. Reinforcement (dots): 1. Agnona; 2. Aisone; 3. Baio Dora; 4. Bergamaschi; 7. C.na Bormiotti; 9. C.ne Agnona; 10. Castagnole M.to; 11. Chiappa; 12. Cigliè; 13. Clavesana; 14. Cossano Belbo; 15. Costigliole d'Asti; 16. Farigliano; 17. Front C.; 20. Levice; 21. Locana; 22. Masseranga; 23. Mondovì G.; 24. Mondovì Piazza; 25. Montatone; 26. Montaldo Scarampi; 27. Montanara; 28. Montecastello; 29. Navigante; 30. Ottiglio; 31. Peracino-Civiasco; 33. Pleyne; 34. Quassolo; 35. Roà Marenca; 36. Rocca d'Arazzo; 37. Rocchetta Belbo; 39. S. Stefano Belbo; 40. Somano; 41. Valle.

One of the first projects to be proposed was the SCAI ("Studio Centri Abitati Instabili" i.e. Study of Unstable Towns"), whose goal was to carry out site-specific investigation, aimed to map and describe instability conditions associated with different types of natural processes affecting small towns. In particular this project focused on safety conditions of buildings and inhabitants.

Urbanized Areas of Piedmont Entitled to Benefit from the ACT

The study area

Piedmont (25,399 km²) is located in Northwest Italy and can be subdivided into three large sectors: a vast mountainous area (48.7%) along the outer rim (Western Alps), a fertile alluvial plain (25.4%) in the center drained by the Po River and its tributaries and the Monferrato and Langhe Hills areas to the southeast (25.9%) (FIG. 1).

The Alps consist mainly of metamorphic rocks, of which calcschists are the most prone to instability. These cover in surface up to 16% (25% in the Susa Valley) of the whole distribution area of calcschists. In the Monferrato and Langhe Hills, charcaterized by Cenozoic deposits of the Tertiary Piedmontese Basin, the flysch formation is much more prone to slope instability, and covers up to 29% of the whole surface where flysch formations are distributed (GOVI, 1990).

Past instability processes in Piedmont

The Istituto di Ricerca per la Protezione Idrogeologica of Turin (IRPI, i.e. Research Institute for the Hydrogeological Protection) began research on land instability from the time when it was founded in 1970. The key research activities of the IRPI were focused on four main themes: 1) to obtain as much data as possible on landslides, mud-debris flows and floods that had struck urbanized areas, road and railway networks in the past, to gain a general view of the location, recurrence, size and magnitude of natural processes and the extent of damage; 2) to study the distribution and typology of the phenomena by identifying and delimiting unstable areas for a better interpretation of previous data; 3) to generate a classification of the areas by indicating different degrees of hydrogeological risk; 4) to survey the influence of predisposing and triggering causes and to consider the effects produced by these processes.

Archive research carried out on hydrogeological events over the period 1830-1980, revealed that out of the 6000 urbanized areas, 1250 had been damaged by instability processes. Of these, 758 locations had been struck at least once by floods or mud-debris flows and 492 by landslides. The picture highlighted an unsuspected level of land vulnerability. A successive special program, the AVI Project (1994), was promoted in the 1990s by the National Department of Civil Defense to gather general information on all sites affected by landslides or floods in Italy since the First World War. This research highlighted the critical situation of the Piedmont Region compared with other Italian regions. In total, 3027 reports of landslide events and 4921 accounts of flood events were recorded. These events were responsible for damaging 2210 and 2590 villages, respectively, (FIG. 2). Despite these findings, the SCAI project listed only 41 urbanized areas in the Piedmont Region at potential risk.

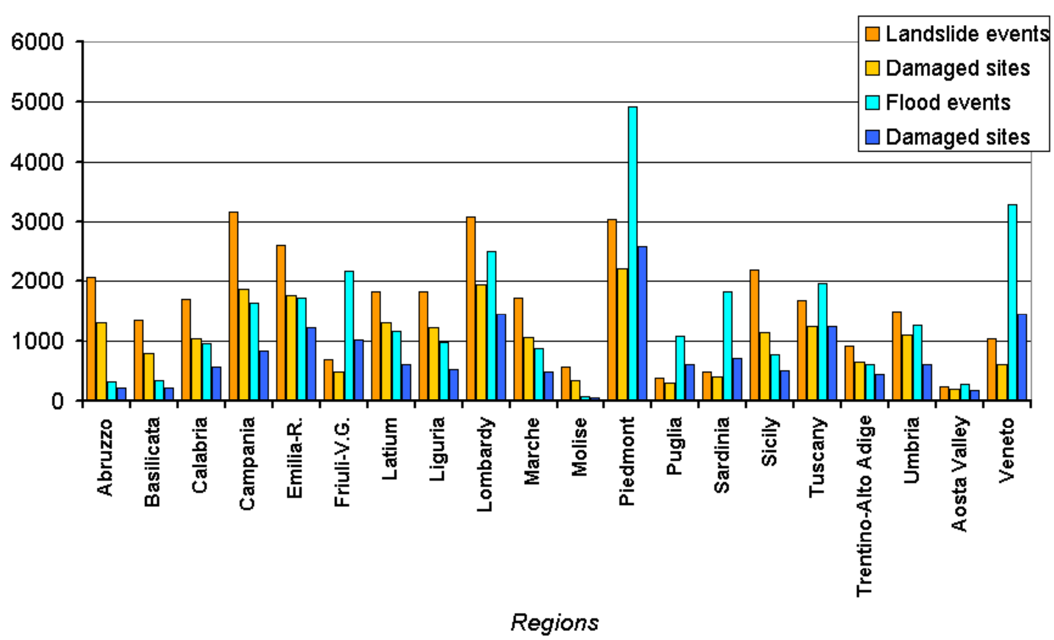

Figure 2 – Landslide and flood processes in Italy: number of events and damaged sites divided by region (GUZZETTI et al., 1994).

Metodology

CNR-IRPI of Turin and the Regional Geological Survey carried out a joint study on the listed urbanized areas. The work was tackled in two phases: firstly, past documents, maps and technical reports were investigated in the municipal archives and the archives of various institutes (Ministry of Public Works, Hydrographic Offices of the Po River, Civil Engineers, Records Office, etc.). Books on the local history of each small town and many other sources were analyzed; the main national and local newspapers were also consulted. All historical information about past natural processes involving urbanized areas was collected, selected and validated in order to map the damaged sites. While the period of investigation covered the last two centuries, prior events were also taken into consideration, if relevant. Data were collected in a historical database, so that useful information about recurrence, size and magnitude of processes could be assessed as important parameters for assessing the risk potential of a specific area.

A geomorphological analysis was also performed using multi-temporal aerial photographs combined with field surveys in order to verify the reliability of the historical data and changes of landform. Causes and effects of landslides were examined to define typology in relation to their geomorphic evolution, kinematic characteristics and morphological features of the affected areas. Preceding studies and previous remedial works were also considered. Each piece of information was entered into a structured data base which stores key information (geological features, local morphological features, type of process, see Table III). Together with historical accounts, these data were used to establish and assess the degree of risk associated with a specific urbanized area with the goal to suggest and prioritize interventions on the territory.

Results

Forty-one urbanized areas of Piedmont are entitled to benefit from the Act, of which 34 require reinforcement of existing structures, and seven relocation of the inhabitants. The SCAI project highlighted the fact that some of these decisions and choices were not always based on scientific studies, nor on a general technical assessment of the problem. In fact, some of them were justified on the basis of political reasons.

The analysis of the urban areas in relation to the type of process, damage incurred and remedial work showed two “styles” of classification. The first group concerns small towns listed at short notice as the result of a specific severe event that had caused serious damage in the past. These urbanized areas have decrees issued in different years. There are two prevalent clusters with several cases in the same year, such as the decrees of 1916 and 1956. In this group, remedial work carried out in the urbanized area was often not sufficient to eliminate the instability causes so that additional work was necessary over the following years. The second “style” is represented by reinforcement decrees issued on July 28, 1952 (17 cases out of 41). This list groups the 17 villages heavily damaged by instability processes during the exceptional hydrological event of November 1951. Except for two cases, these villages were affected by soil slips, mud-debris flows and bank erosion along the rivers. Most cases, where hazard conditions were surveyed, no longer exist today as such, since either the phenomena exhausted their action during the event or because the remedial works were effective. This consideration is true in particular for the urbanized areas affected by shallow landslides, even though the problem could arise at a different point on the same slope during an extreme future hydrological event.

The analysis emphasized that the instability of an area depends on a combination of several factors such as poor lithological and structural characteristics of the bedrock and soil (TABLE I).

Table I - Predisposing and triggering factors surveyed in the 41 villages analyzed.

PREDISPOSING FACTORS	%
Poor lithological and structural characteristics of the bedrock and soil: presence of shear surfaces, glaciopressure, frost wedging, superficial water infiltration, rapid change of water pressure, pressure variation in the bedrock, strata inclined toward free face, schistosity, gradual chemical weathering of the rock and soil, springs or water-bearing strata, thick layer of top soil, etc.	45.1
Morphological conditions: high steep slope, river bed insufficiently deepened in the apex of alluvial fan, large amount of fine and coarse debris in unstable equilibrium, progressive erosion at the foot of the slope, insufficient elevation above highest flood levels, etc.	35.4
Misguided man-made intervention: excavation and cutting away of foothills, mining activity, overload, reduction of the river bed section, bridges with inadequate span, inefficient interventions for flood protection works, water dispersion, deforestation, agricultural activity, etc.	19.5
TRIGGERING FACTORS	
Prolonged rainfall	77.6
Short but intense rainfall	12.2
Snow and ice melt	10.2

Since the urbanized areas are located in different morphological and geological environments, a wide range of situations exists in relation to the type of phenomenon (FIG. 3), its degree of development and the position of the urbanized area, with different kinds of damage likely to be caused. Most landslide-prone areas are located in the

Langhe and Monferrato Hills (SE Piedmont), where the lithological features and the attitude of the strata represent the main predisposing causes for rotational and translational landslides (Cigliè, Levice and Montecastello). Similar processes, including rockfalls (Bertodasco and Piandellera), have involved large areas of the Alpine valleys, where two villages (Quassolo and Baio Dora) were damaged by debris flows. In the Alpine and the hilly sectors, the largest landslides, were reactivations of past phenomena, with long quiescent periods interrupted by further movement. This has sometimes caused severe damage (e.g. Civiasco in October 1857 and November 1951; Ciglìè in 1860 and January 1963 (FIG. 4); Montecastello in 1814, 1841, May 1941, December 1959 and March 1978 (FIG. 5).

Although there were many listed urbanized areas where the decree was widely justified, in some rare cases (e.g. Montabone) it was extremely difficult to understand why these villages were included in the list project. These cases may have been dictated politically.

Some instability occurrences were resolved by effective remedial work (e.g. at Aisone and Front Canavese) or because the triggering causes disappeared naturally. This is the case of Montanera, near the scarp of a terrace which over the centuries has suffered erosion caused by the Stura River. Montanera is no longer exposed to risk owing to migration of the river bed.

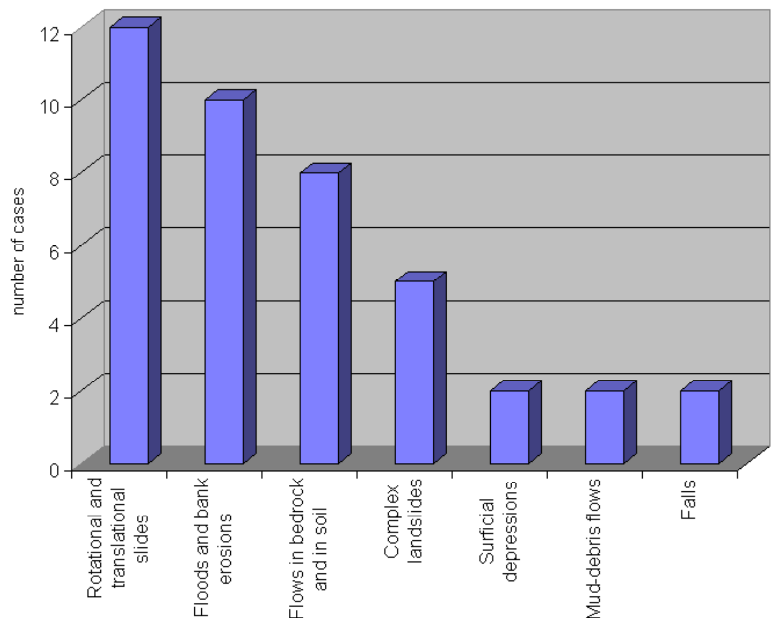

Figure 3 – Subdivision by type of instability processes that made the relocation and/or local reinforcement of the 41 urbanized areas necessary.

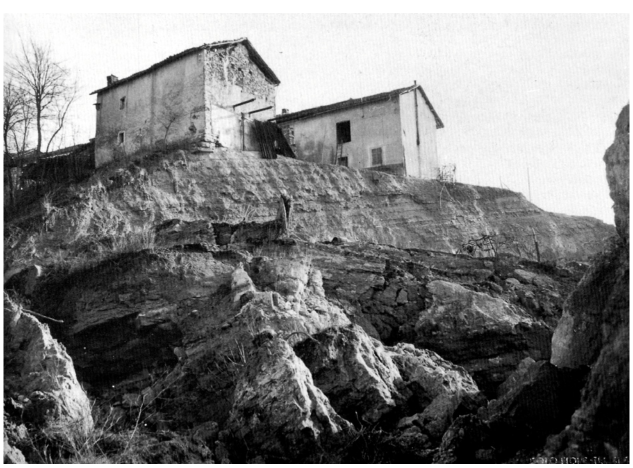

Figure 4 – Ciglìè (Cuneo Province). Rock-block slide of January 1963: 10 buildings damaged and 17 others evacuated.

Of the 41 villages considered, seven satisfied the relocation decree, but only four were actually relocated (Piandellera, Rosone, Grumel and Bertodasco). Rosone, Grumel and Bertodasco, originally located on a slope of the upper Orco Valley, were involved in a vast deep-seated gravitational deformation. However, the size of the phenomenon and its prone area in the event of sudden collapse were underestimated, and the new locations, because they were not far enough away from the original ones, were again damaged in the following years and had to be relocated a second time. The abandoned hamlets were still temporarily occupied during the summer.

A similar situation occurred in Brusaschetto and Cascina dei Frati. Since the end of the 19th century, these villages have been involved in local collapses caused by mining activity. The local inhabitants continued to occupy the old heavily damaged houses despite the relocation decree, because the new buildings were too far away and unsuited for rural activity. After several years the decree was never enforced because mining was stopped, thus terminating the landslides.

Despite a thorough but not exhaustive investigation of historical accounts, the assessment of recurrence time of these processes is not accurate. However the study of historical documents remains an invaluable source of information which is of fundamental importance for investigating the recurrence of triggering causes.

The Example of Montecastello

The village of Montecastello (Alessandria Province) is located on a steep slope bordered at its foot by the Tanaro River. The urbanized areas (from 100 to 180 m a.s.l.), because of repeated landslides, have been reinforced at the State's expense since July 1954.

An in-depth historical study was carried out in many locations. Research in the municipal archives uncovered a wealth of information showing that the village had been affected by landslides since the 16th century (TABLE II). By analyzing the reports we identified the most often affected areas fairly accurately.

Figure 5 – Aerial photograph of the village of Montecastello. The slump-earth flow of 9 March 1978 is clearly visible on the southern slope. The displaced material partially dammed the Tanaro riverbed.

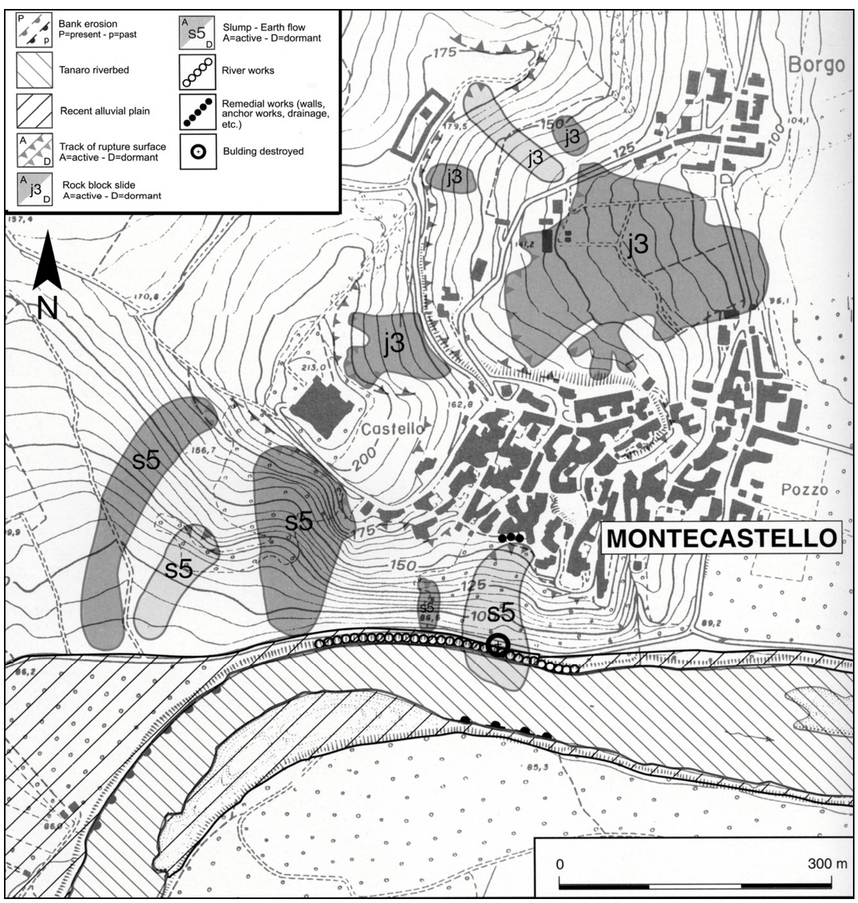

Figure 6 – Representative map of landslide and fluvial processes in and around Montecastello.

Table II – Historical reports from the municipal archives on past instability processes in Montecastello (Oberti et al., 1990).

Date (y/m/d)	Information
1545/05/22	A severe Tanaro flood damaged houses and countryside.
1560/08	Deep erosion at the foot of the hill by the Tanaro: many hectares of countryside flooded.
1564/08/02	Tanaro flood inundated large areas.
1567/10/29	Severe inundation of Tanaro and its tributary Bormida: the lowest part of the village flooded and many farmers drowned.
1666/05/23	A small fortress on the hill collapsed due to landslide.
1700	Large Tanaro inundation: the flood violence destroyed many houses in the lowest part of the village, despite the presence of river works along the banks.
1724/09/26	Two houses swept away by the Tanaro waterfloods.
1804	Three houses demolished as a result of the Tanaro erosion.
1814/autumn	A landslide on the southern slope.
1815	Reactivation of the 1814 landslide 1,200 m² in surface area.
1830	A house collapsed in the village center.
1841/winter	Many houses fell in the Tanaro River because of a landslide
1845/07/19	Landslide on the slope below the castle
1863	Continuous landsliding on the slope towards Tanaro River
1873/01	Landslides of the southern slope and the area near the castle.
1874	Some landslides in the southern part of Montecastello.
1879/spring	Landslide reactivation on the southern slope of the village.
1901/03	Intense rainfall determined several landslides in the village.
1903/12	Landslide in the village center caused a 15-m length of wall to fall.
1907	A landslide on the southern slope interrupted the road running along the Tanaro left bank.
1916/10	Reactivation of the landslide on the southern slope of the village.
1917/winter	Landslide on the southern slope and in Regione Foriara. Collapse of a wall in Via Umberto I
1926/05 and 11	Tanaro waterfloods damaged river works of the left bank at the foot of the hill.
1929	A landslide interrupted Via dello Spalto in the village center: one building destroyed.
1934/autumn	Deep erosion at the foot of the Montecastello hill caused by Tanaro waterfloods. Some landslides triggered on the southern slope.
1937/spring	Tanaro waterfloods eroded and destroyed 500 m of the road running along the foot of the southern slope.
1937/11/02	Exceptional Tanaro flood deeply eroded the foot of the hill: 30 m of the road swept away.
1940	Sudden landslide destroyed 1 house and threatened 3 other buildings.
1941/05	Landslide caused the collapse of 2 houses.
1959/05	A landslide involved a stretch of Via Oberdan
1959/12	A landslide (90,000 m³ in volume) threatened 20 buildings on the southeastern slope of the hill. A 300-m stretch of the road interrupted.
1960/11/22	Reactivation of the December 1959 landslide.
1960/12/27	Landslide in Via Trieste (25 m in width and about 200 m ³ in volume).
1961/04	A stretch of Via Trento was involved by a landslide. Reactivation of the December 1960 landslide.
1964/03/16	Partial collapse of a retaining wall. Evacuation of several houses ordered.
1964/spring	Landslide in Regione Foriara.
1976/11/15	Some landslides interrupted the aqueduct network.
1977/10	Reactivation of the Regione Foriara landslide.
1978/03/09	At 4:30, a landslide of about 6,000 m³ triggered on the southern slope. The displaced material covered 50 m of the road running along the left bank of the Tanaro 6 m in depth. Part of the bulk reached the riverbed and partially dammed the flow. Some houses near the crown of the landslide threatened.
1979/10/15	A retaining wall in Via Battisti and another in Via Cortelunga damaged by a landslide.
1980/01	Two retaining walls in Via Battisti and Via XX Settembre damaged by a landslide.
1983/01	A wall in Via XX Settembre collapsed due to a landslide.
1983/03/29	Reactivation of the Regione Foriara landslide (about 60 m wide).
1984/05	A landslide 90 m in width seriously threatened some houses located in Regione Foriara.

A geological-geomorphological analysis was conducted using multi-temporal aerial photographs and field surveys to verify the reliability of the historical data and to identify the present activity of the natural processes. All data were stored in a technical schedule composed of 10 files (TABLE III) listing the most important geological and geomorphological characteristics. The file also describes the triggering and predisposing factors, past damage and remedial works.

All information from the geomorphological study was then summarized in a detailed map (FIG. 6).

Table III - Example of the technical file for the Montecastello village.

GEOLOGICAL FEATURES	The village is located on the eastern flank of an anticline with direction ax N-S. On the top of the hill yellowish clay outcrop, becoming greyish clay at depth with lentiform intercalations of yellow clay nodules ("Argille di Lugagnano Formation - Pliocene), overlying conglomerate and sandstone strata ("Conglomerati di Cassano Spinola" Formation - Pliocene Inf.). Strata plunge towards East with dip of about 20°.
LOCAL MORPHOLOGICAL FEATURES	The urban area, where houses rise on different benches of a large slope with elevation between 100 and 180 m a.s.l., is located on a hill topped by a castle (213 m a.s.l.). The steep slope is bordered to the south by the left bank of the Tanaro River, which often caused landslides on the facing slope by erosion of the foot in the past, especially during major floods. The northern slope is less urbanized and rarely affected by landslides.
TYPE OF PROCESS	On the southern slope, slump-earth flows involving the weathered soil, the top soil and sometimes the marly bedrock were observed. The gentle northern slope is affected by rock-block slides which move along the bedding planes, often preserving the structural characteristics of the bedrock.
SIZE OF PARAMETERS OF THE PROCESS	The 1959 landslide on the southeastern slope mobilized 90,000 m³. The landslide of March 1978 on the southern slope affected a surface of ca. 1.5 hectares, with a volume of ca. 6,000 m³.
KINEMATIC PARAMETERS	Extremely rapid landslides on the southern slope; slow movements on the northern slope.
PREDISPOSING FACTORS	Southern slope: poor lithological and structural characteristics of the bedrock, steep slope, erosive processes of the Tanaro at the foot of the slope. Northern slope: the dipping of the bedding plane.
TRIGGERING FACTORS	Prolonged and intense rainfall.
DAMAGE	Many houses destroyed and other buildings severely damaged. Collapse of roads, masonry and concrete walls within the urban area. Failures of sewers and aqueduct lines. Interruption of telephone lines and electric power blackout.
REMEDIAL WORKS	Building and reconstruction of retaining walls (gravity and reinforced concrete walls); surface drainage and canalization of the storm sewage system; road surface waterproofing; subhorizontal anchorages and wire meshes; gabions at the foot of the slope along the Tanaro left bank.
NOTES	Village already cited in the Roman era because of its strategic position. In the Middle Ages, presence of a castle on the top of the hill, and houses at the foot, because Tanaro riverbed flowed 2 km south of its present position. Due to the migration of the river course debris and to the frequent flooding, dense settlements are present only on the hill. Nevertheless, houses have often been damaged by landslides and numerous reactivations occurred over the last 150 years.

Conclusion

The SCAI project analyzed 41 urbanized areas in Piedmont. Each hamlet was found to be subject to reactivation of one instability process every 14-15 years on average. Montecastello and Bertodasco had the highest return period, having been involved once every 3-4 years. Analysis of rainfall records often confirmed
the close correlation between the rainfall characteristics of an event and the inception timing of landslides. Rotational and translational slides (29%) and floods (24%) were the most numerous processes involving the 41 villages studied. Poor lithological and structural characteristics of bedrock and soil were found to be the most common predisposing factors (45%), and persistent rainfall was found to be the main triggering factor (77%) for the instability processes. Several past processes were similar to recent ones. Most of the landslides presently involving the villages are total or partial reactivations of past processes. Where recent events differ in dynamics and development from past ones, this is usually because structures or infrastructures have been built in the meanwhile.

The sample study showed that a considerable number of the phenomena over the last 30-40 years has affected the recently urbanized areas of the villages. Land-use planning has not taken sufficiently into account the size and recurrence of past phenomena, because areas once considered as not being exposed to risk or hazard have now become so, owing to the natural evolution of the processes. These usually take place gradually but may sometimes develop very rapidly during an extreme hydrological event, also due to modifications caused by man in some cases.

References

GOVI M. (1990) - *I processi d'instabilità naturale nella regione Piemonte*. In: *Banca Dati Geologica.* Regione Piemonte, SPRGMS, 17-34, Turin, Italy.

GOVI M., MORTARA G. & SORZANA P.F. (1985) - *Eventi idrologici e frane*. Geol. Appl. e Idrog., 20 (2), 359-375, Bari, Italy.

GUZZETTI, F., CARDINALI M., REICHENBACH P. (1994) - *The AVI Project: A bibliographical and archive inventory of landslides and floods in Italy*. Environmental Management, 18 (4), 623-633.

LUINO F., RAMASCO M. & SUSELLA G. (1993) - *Atlante dei centri abitati instabili piemontesi*. Tip. L'Artistica, Savigliano (CN), Italy.

LUINO F., ARATTANO M. & BRUNAMONTE F. (1996) - *Vulnerability of urban areas to flooding: events in the North-West Italy, November 1994*. VI Congreso Nacional y Conferencia Internacional de Geologia Ambiental y Ordenación del Territorio, 22-25 de Abril de 1996, 309-327, Granada, Spain.

OBERTI R., TRUCCO F. & ZILIANI A. (1990) - *Un esempio metodologico di ricerca dei dati d'archivio*. In: *I processi d'instabilità naturale nella Regione Piemonte*. Regione Piemonte, SPRGMS, Turin, Italy.