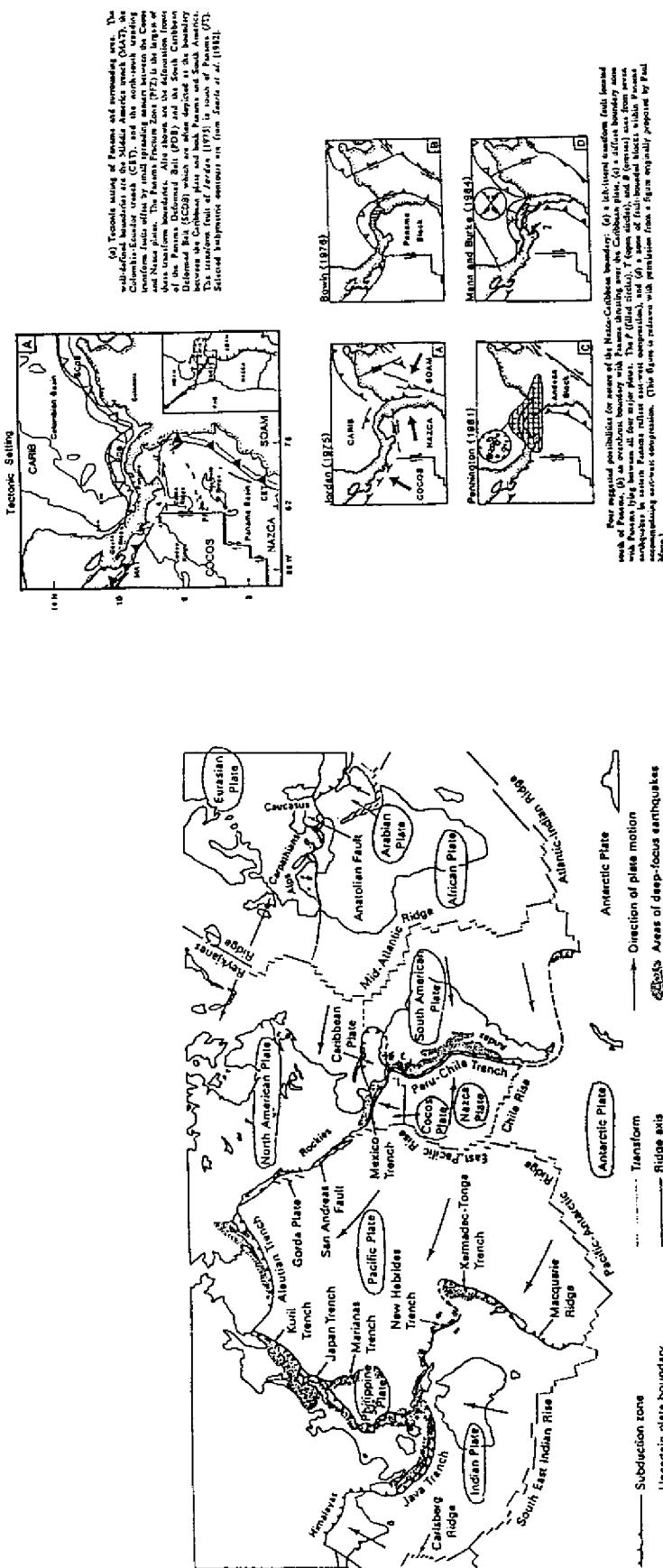
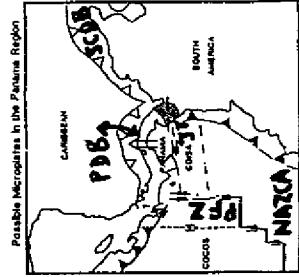




FIG # 2. POLITICAL MAP OF COLOMBIA.



(a) Tectonic setting of Panama and surrounding areas. The well-defined boundary of the Middle America trench (M.A.T.), the Colombian Escalier trough (C.E.T.), and the north-south trending volcanoes indicate very much spreading motion between the Cocos and Nazca plates. The Panama Friction Zone (P.F.Z.) is the angle of least resistance indicated. All above and the continuation of the C.E.T. and M.A.T. indicate that the Cocos plate is moving to the northwest relative to the Nazca plate. The Cocos-Nazca boundary between the Caribbean plate and both Panamanian and South American plates is located near the Panama Canal. The boundary between the Caribbean plate and South American plate is located near the Isthmus of Panama. Selected historical earthquakes are from Searle et al. (1981).



**FIG # 4. RECENT PLATES MODELS NEAR COLOMBIA**

( ADAMEK ET AL, 1988 )

Geological map of eastern Colombia, showing the Cocos, Nazca, and South American plates. The Cocos plate is moving to the east, the Nazca plate to the west, and the South American plate to the north. The map shows various geological features and plate boundaries. An inset map at the top left shows the location of the main map relative to the world map.

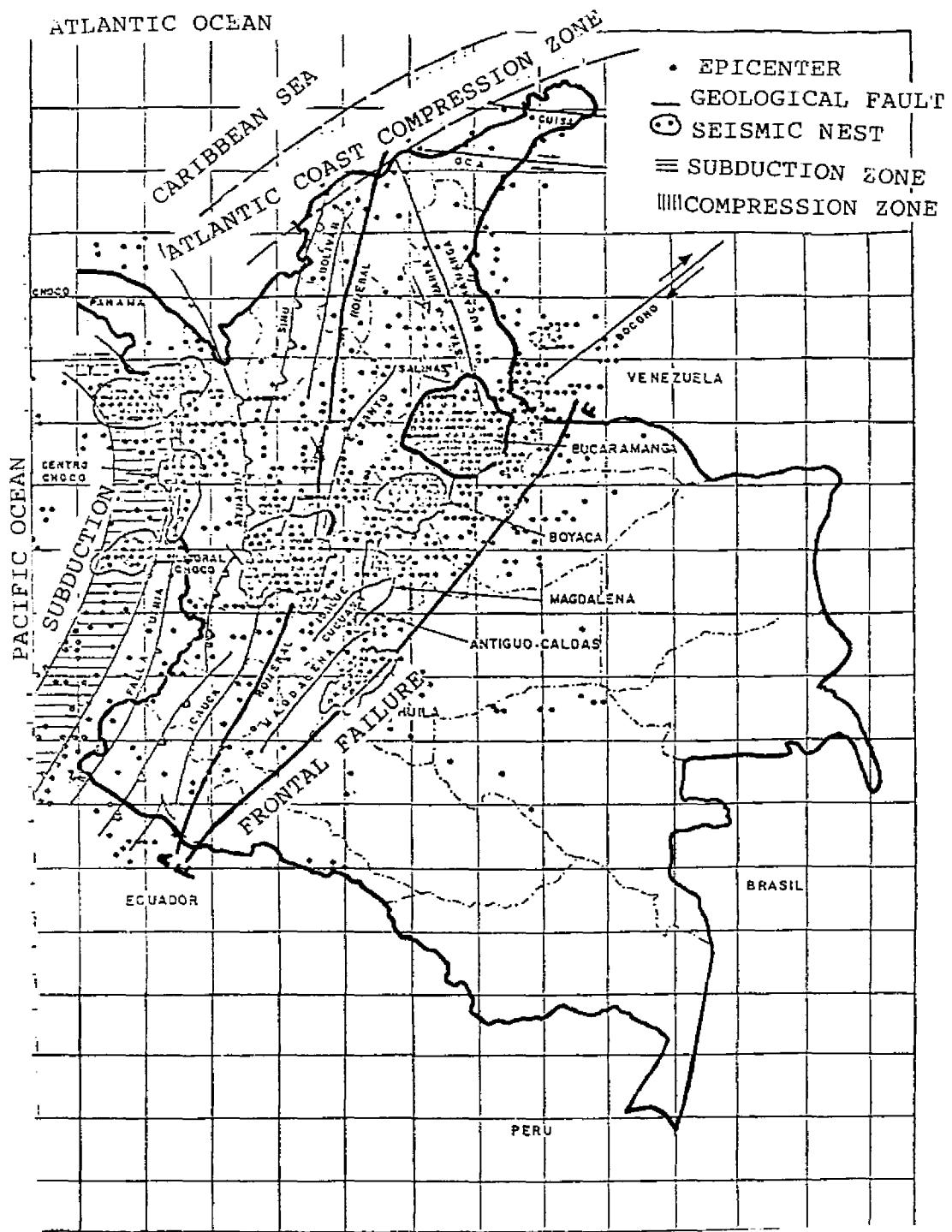


FIG # 5. MAIN ACTIVE FAULTS AND SEISMICITY IN COLOMBIA.

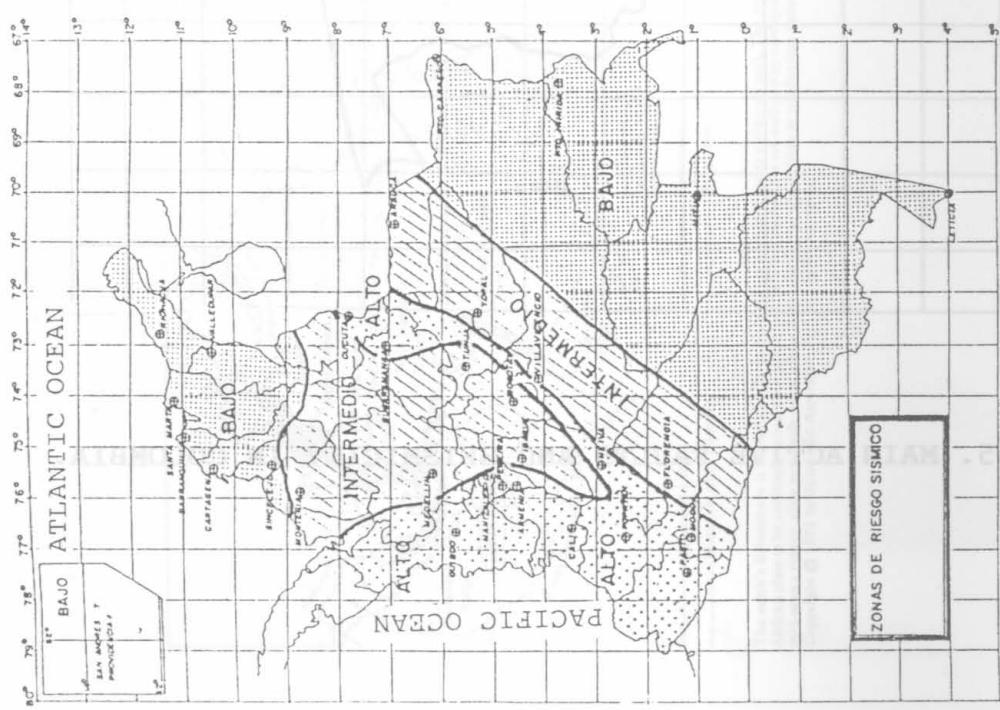
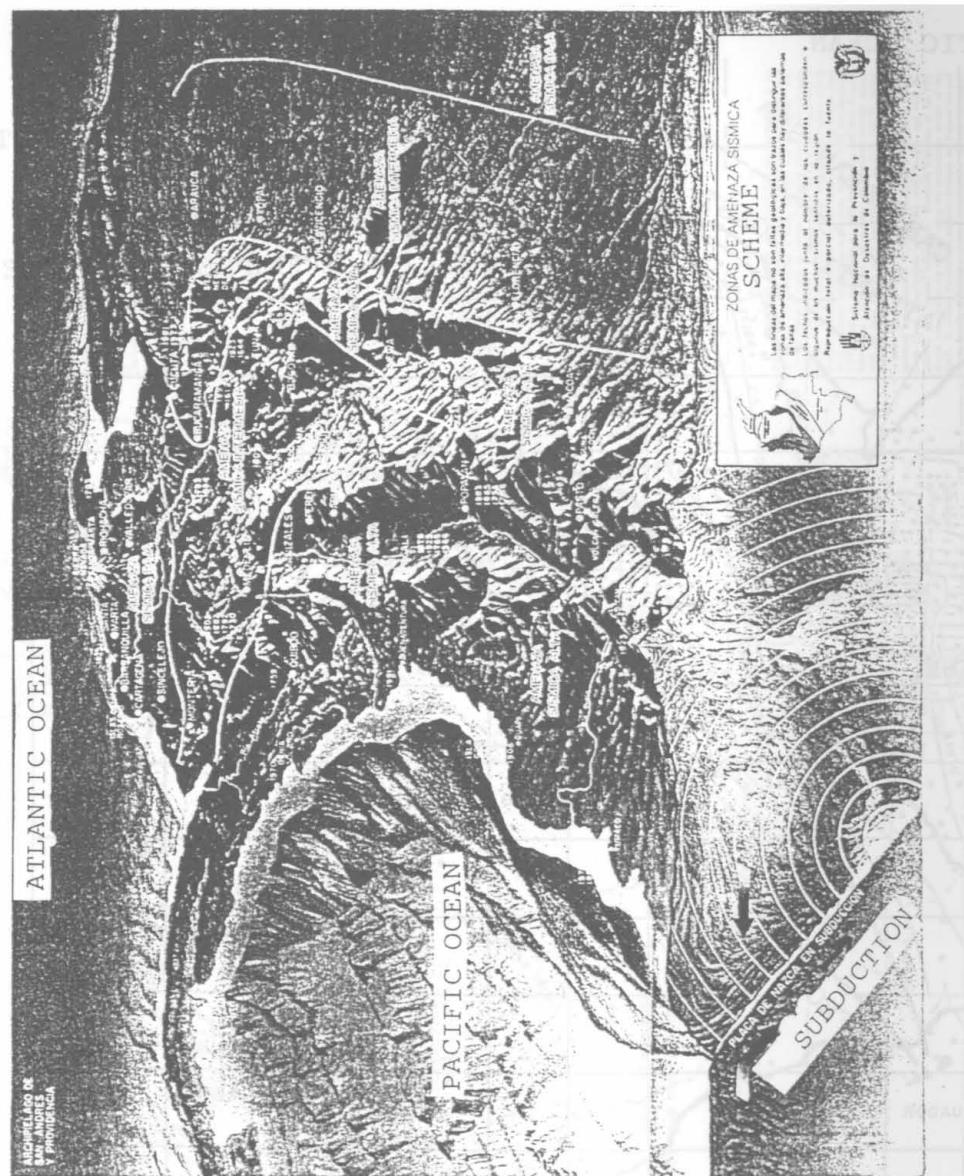


FIG # 6 . SEISMIC RISK ZONATION OF COLOMBIA ( 1984 )

## Sistema Nacional para la Prevención y Atención de Desastres de Colombia

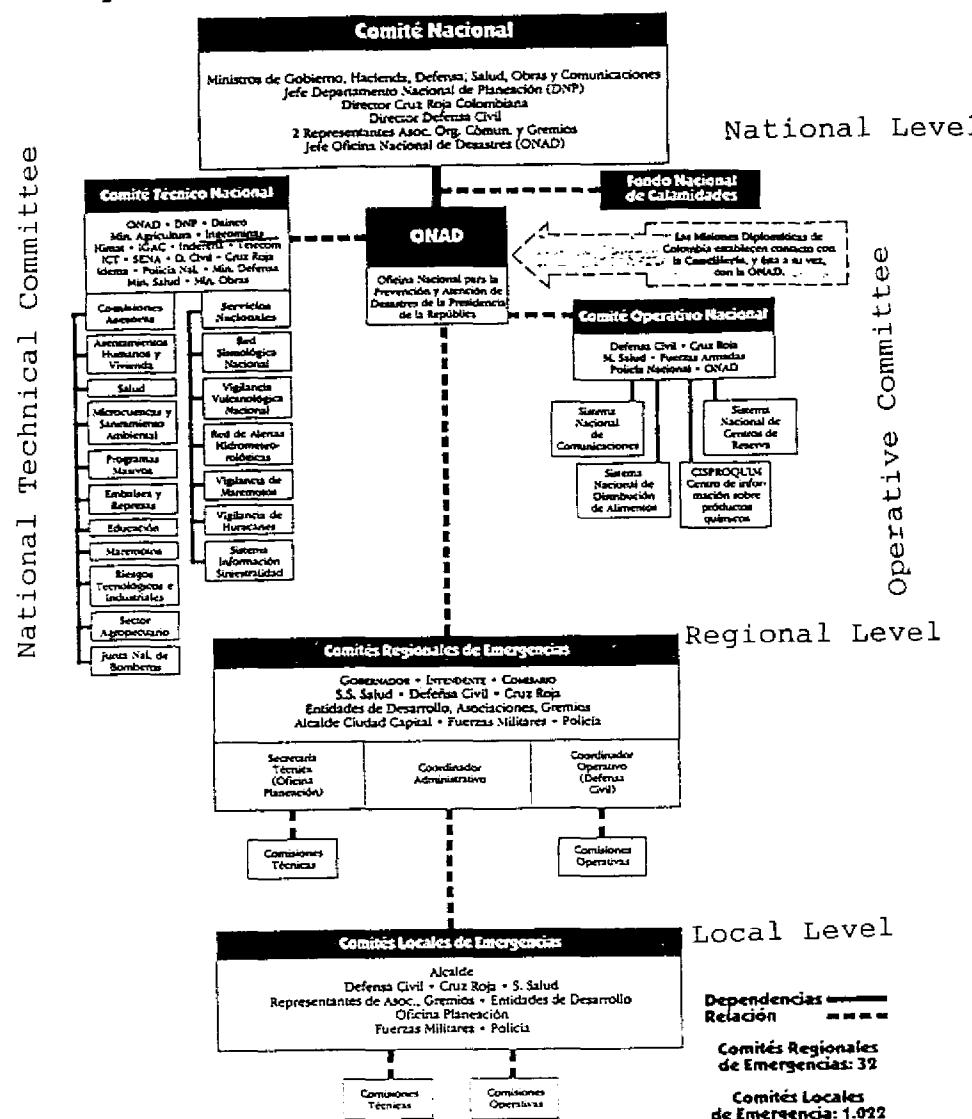


FIG # 7. NATIONAL SYSTEM FOR DISASTER PREVENTION AND ASSISTANCE.

TO COMPILE THE EXISTING INFORMATION  
( CLIMATE, PRECIPITATION, AEREAL PHOTOS )

PHOTOGEOLOGICAL INTERPRETATION  
( ESC 1:20.000 - 1:40.000 )

FIELD VERIFICATION OF THE GEOLOGY

ELECTRICAL RESISTIVITY SURVEY AND DIRECT IN SITU SAMPLING

HYDROGEOLOGIC ANALYSIS

STABILITY ANALYSIS IN TYPICAL PLACES

GEOTECHNICAL ZONATION

FIG # 8. METHODOLOGY OF THE ZONATION OF SANTAFE DE BOGOTA.

TO COMPILE THE EXISTING INFORMATION  
(CLIMATE, RIVER DISCHARGE, AGROLOGY, LAND USE, AEREAL PHOTOS)

PHOTOGEOLOGICAL INTERPRETATION  
ESC 1:25.000 - 1:50.000  
(EMPHASIS IN QUATERNARY DEPOSITS DIFFERENTIATION)

FIELD VERIFICATION AND HAZARDS DESCRIPTION  
(GEOLOGIST, GEOTECHNICAL ENGINEER)

GEOLOGY, GEOMORPHOLOGY, TECTONICS, GEOTECHNICS, SAMPLING, IN SITU TESTS ( GEOLOGIST, GEOTECHNICAL ENGINEER )

GEOPHYSICAL PROSPECTION

TOPOGRAPHICAL WORKS  
ESC 1:100-1:1.000

LABORATORY ANALYSIS

MAPS OF GEOLOGY, GEOMORPHOLOGY, IN DETAIL INCLUDING VERTICAL SECTIONS IN THE UNSTABLE AREAS. (GEOLOGIST).

DESIGN OF COUNTERMEASURES  
(GEOTECHNICAL ENGINEER)

FINAL REPORT  
(GEOTECHNICAL ENGINEER, GEOLOGIST)

FIG # 9. METHODOLOGY OF THE LANDSLIDE STUDY AND STABILIZATION IN CUNDINAMARCA, 1st PHASE.

## AVALANCHE RISK EVALUATION AT UTICA (COLOMBIA)

### SPECIFIC METHODOLOGY

#### 1.- EVALUATION OF RAINS TRIGGERING EVENTS

##### 1.1.- Seismology

- a) Seismic Hazard Evaluation (rock level horizontal acceleration) for different return periods.

##### 1.2.- Hydrology

###### 1.2.1.- Rainfall

- a) Data analyses, evaluation and complementation of existing雨量計 stations for monthly and daily rainstorms.
- b) Isohyetal maps
  - for October-November 1988
  - mean annual rainfall
  - Mean monthly rainfall for April, October and November
- c) Intensity-Duration-Frequency Curves.
  - Rainstorms for return periods between 1 and 100 years and durations of 0.5 and 24 hours.

###### 1.2.2.- Streamflows

- a) Data analyses, evaluation and complementation of existing雨量計 stations in Rio Negro for mean and maximum annual, monthly and daily flows.
- b) Rainmax and Negro Flows for different return periods at Utica and at other 7 stations between Villalba and Puerto Libre
- c) Peak flows due to river dam breaks at Sta. Barbara
- d) Calculation of runoff and peak streamflows in 13 sub-basins of Quebrada Negra Basin. Flow routing along the streams and hydrographs of annual and 100-year peak streamflows.
- e) Estimation of solid transport in Quebrada Negra and its effects in peak streamflows.

#### 2.- GENERAL SUSCEPTIBILITY AND STABILITY EVALUATIONS

- a) General stability zoning.
- b) General stability evaluation of movements and rain potential unstable zones, with semi-quantitative indexes.
- c) Probabilistic hillslope stability analyses by means of Shik's Natural Slope Methodology (NSM) and total probability theories.

#### 3.- HAZARD EVALUATION IN QUEBRADA NEGRA

- a) Identification of dangerous dam-producing landslides.
- b) Calculation of maximum probable dam heights and impounded volumes of water.
- c) Estimation of possible avalanche peakflows and levels at the entrance to Utica, including damping due to distance, hydrological peakflows and sediment transport.
- d) Probabilistic analyses of occurrence of avalanche peakflows.

#### 4.- HAZARD EVALUATION DUE TO SANTA BARBARA LANDSLIDE

- a) Calculation of possible landslide volumes and corresponding dam heights and reservoir values.
- b) Evaluation of possible sequence of landslide volumes.
- c) Probabilistic analyses of river damping.
- d) Estimation of avalanche levels and peakflows at Utica.
- e) Estimation of arrival times.

#### 5.- RIVERINE RISK EVALUATION AT UTICA

- a) Exposition to Floods
- b) Regional Material Risk due to Rio Negro
- c) Regional Material Risk due to Quebrada Negra
- d) Joint Regional Material Risk

#### 6.- IDENTIFICATION AND PREDICTIONING OF WORKS IN QUEBRADA NEGRA

- a) Prioritization of Protective Measures for Utica:
  - Avalanche Control Rockfill Permeable Dam and Tunnel
  - Riverine Channel
- b) Identification of Corrective Measures in Landslides (drainage, earthmoving, foresting)
- c) Identification of Preventive Measures to Reduce Avalanches:
  - Torrent control works in tributary streams
  - Bridge-dams in axis stream
- d) Preliminary cost estimation

#### 7.- IDENTIFICATION AND PREDICTIONING OF WORKS IN RIO NEGRO

- a) Prioritization of measures to avoid river damping (dams, pipes)
- b) Prioritization of measures to increase the stability at Santa Barbara:
  - Horizontal drains
  - Brisk galleries
- c) Prioritization of protective measures at Utica
  - River dyke
- d) Preliminary cost estimation

#### 8.- MONITORING SYSTEMS AND ALARMS

- a) Extensometers
- b) Water-level sensors
- c) Alarms
- d) Education and Awareness of Populations

#### 9.- SIMPLIFIED COST-BENEFIT ANALYSIS

#### 10.- CONCLUSIONS AND RECOMMENDATIONS

- a) Short Term Works and Studies
- b) Medium and Long Term Works and Studies

**FIG # 10. METHODOLOGY IN THE DEBRIS FLOW AVALANCHE RISK EVALUATION IN UTICA TOWN.**