Veðurstofa Íslands
Greinargerð

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# Kynnisferð til Frakklands í boði franska sendiráðsins á Íslandi og Menntamálaráðuneytisins, 9. - 22. september 1996

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## Inngangur

Ferð sú sem hér er lýst var farin í boði Franska sendiráðsins á Íslandi og Menntamálaráðuneytisins þann 9. september 1996. Tilgangur ferðarinnar var að bjóða starfsmanni snjóflóðavarna Veðurstofu Íslands til Frakklands að kynna sér að eigin raun hvernig staðið er að rannsóknum á snjóflóðum, aurskriðum og grjóthruni og viðvörunarkerfi því sem viðhaft er þar í landi. Sá aðili sem sá um skipulagningu ferðarinnar í Frakklandi var Gilles Borell sem starfar við CEMAGREF, í Grenoble, á deild sem heitir "Division Nivologie". Undirritaður flaug til Parísar þann 9. september og snéri þaðan aftur þann 22. september.

Áður en lagt var af stað til Frakklands voru undirbúnir spurningarlistar varðandi skipulagsmál Frakka, annars vegar í snjóflóðamálum og hins vegar í aurskriðu og grjóthrunsmálum. Vonast var til að svörin við spurningunum gætu gefið okkur nánari hugmynd um hvernig staðið væri að þessum málaflokkum í Frakklandi og hvað við getum lært af þeim. Upphaflega var gert ráð fyrir að fjalla um snjóflóðin sér og aurskriður og grjóthrun sér, en vegna þess hve umfjöllun og öll vinna við þessa tvo málaflokka er samtvinnuð í Frakklandi þá er þessum spurningarlistum svarað sameiginlega.

Almennt var fólk mjög viljugt að svara spurningunum og var mikill áhugi á framvindu slíkra mála hér á landi, sér í lagi eftir slysin á Súðavík og Flateyri. Sumar spurningar voru Frökkum þó framandi, átti það helst við um alla yfirsýn þessara mála í Frakklandi. Þetta stafar fyrst og fremst af því að ábyrgð og allar framkvæmdir í þessum málaflokki eru mjög dreifðar, þ.e. hver "department" (hálfgerðar sýslur) sjá sjálfstætt um sín mál, en þessu verða gerð betri skil hér á eftir.

Fyrst verður gerð grein fyrir ferðinni frá degi til dags og stuttaraleg lýsing á því sem fyrir augun bar. Því næst koma svörin við spurningunum sem lagðar voru fram.

## Ferðalýsing

### *Mánudagur 9. september*

Lagt var af stað til Parísar árla morguns þann 9. september. Millilent var í Kaupmannahöfn og því ekki komið til Parísar fyrr en um klukkan 16.00. Starfsmaður í utanríkisþjónustu Frakka, Antoinette Attié, tók á móti mér á flugvellinum og ók mér til lestarstöðvarinnar, þar sem ég síðar tók lest til Grenoble. Um klukkan 22.30 kom ég til Grenoble. Þar tók Gilles Borell á móti mér á brautarstöðinni og ók mér til hótelsins.

### *Þriðjudagur 10. september*

Fyrsti dagurinn í Grenoble fór í að heimsækja Cemagref þar sem Gilles Borell vinnur. Hann byrjaði á að sýna mér hvernig hægt er að skanna inn kort og flytja á milli tölvukerfa, frá Mac yfir á PC. Ég var síðan kynntur fyrir flestum sem vinna á "Division Nivologie" og fékk sæmilegt yfirlit á því hvað hver gerir þar. Seinni part dagsins var síðan umræða um hverjar væntingar mínar voru til ferðarinnar og hvað ég vildi helst sjá á meðan á dvöl minni í Frakklandi stæði. Upp úr þeim umræðum spunnust ýmsar hugmyndir sem ætlunin var að framkvæma á næstu dögum.

Við byrjuðum á því að fara í gegnum hvernig loftmyndatúlkun er notuð við hættumatsgerð í Frakklandi.

Í Cemagref fer meðal annars fram gerð snjóflóðakorta, það er útbreiðslukorta byggð bæði út frá þekktri snjóflóðasögu og einnig út frá túlkun snjóflóðafarvega með loftmyndatúlkun.

*Miðvikudagur 11. september*
Á öðrum degi ferðarinnar fékk ég tækifæri á að fara með Robert Marie (Rob) í skoðunarferð til Printe de Friolin. Rob er starfsmaður hjá RTM í Grenoble (nánari kynning á RTM fer fram hér á eftir). Við ókum sem leið liggur frá Grenoble, í gegnum Albertville og að litlu þorpi Peisey Nancroix sem er í um 130 km fjarlægð frá Grenoble. Þar bættust Jerome Lievois jarðfræðingur frá RTM í Haute-Savoie og Jean Lomp Boisset verkfræðingur, einnig hjá RTM í Haute-Savoie. Farið var til les Lanches sem er lítið fjallaþorp í um 1500 hæð.

Í hlíðum Printe de Friolin, sem er um 2700 m hátt fjall beint fyrir ofan þorpið, átti sér stað feiknar mikið grjóthrun 1982 og var ætlunin að skoða ummerki eftir það. Ástæðan fyrir þessu hruni var lagskipting berggrunnsins. Undir þykku lagi af gneiss liggur þykkt lag af kalki. Þegar koltvísýringsblandað grunnvatn seytlar um kalkið leysist það upp. Stórar neðanjarðarhvelfingar geta myndast við þetta ferli. Þegar hvelfingin er orðin það stór að burðargeta yfirliggjandi jarðlaga heldur ekki lengur uppi þunga sínum, hrynur efnið niður í hvelfinguna. Yfirborðsummerki slíkra atburða eru djúpir gígir sem nefnast karst, sem alþjóðlegt orð fyrir slík fyrirbæri. Í því tilfelli sem við skoðuðum átti hrunið sér stað í brattri hlíð þannig að í stað þess að ofanáliggjandi efni hryndi ofan í hvelfingu og myndaði gíg þá hrundi efnið niður fjallshlíð. Áætlað magn efnis sem hrundi niður er um 10 milljón $m^3$. Efri brún skriðunnar er í um 2700 m hæð en neðri brún brotsársins er um 250 m neðar.

Komið var seint tilbaka til Grenoble eftir ævintýralega ferð niður af fjallinu og mjög ánægjulegan kvöldverð hjá Jean Lomp Boisset og fjölskyldu hans í Savoie.

Í hlíðum som de Bellecote, sem er um 3384 m hátt fjall beint fyrir ofan les Lanches þorpið, er feiknar mikill snjóflóðafarvegur. Þar átti sér stað stórt snjóflóð fyrir nokkrum árum. Húsin lentu undir 5 til 10 metra þykkum snjó en vegna fleigmyndaðra varnargarða fyrir ofan hvert hús og styrkingar þeirra sluppu þau með minniháttar skemmdir. Engin slys urðu á mönnum eða búpening í þessu flóði, þó svo að til rýming hafi ekki verið framkvæmd. Hafa skal í huga að þetta þorp er gamalt og varnirnar líka. Þetta er gott dæmi um það hvernig fólk lærir að lifa með náttúrufarslegum ógnum í Frakklandi.

*Fimmtudagur 12. september*
Þennan dag var fyrirhugað að fara í gengum nokkrar spurningar af listanum með Gilles Borell og hafði hann undirbúið dagskrá fyrir daginn. Gilles hafði þá veikst um nóttina og mætti því ekki til vinnu. Ég notaði daginn því til að skoða loftmyndir sem hann hafði látið mig fá fyrsta daginn. Loftmyndatúlkun er stór þáttur við hættumatsgerð í Frakklandi. Það er hins vegar mjög frábrugðin aðferð sem þeir nota, en sú sem kæmi okkur að gagni hér á landi. Frakkar nota loftmyndatúlkun nær eingöngu til að skoða ummerki eftir snjóflóð og byggja stóran hluta hættumats á þeirri aðferð. Aðferðin byggir á því að greina mismunandi tegundir skóglendis út frá loftmyndum. Þekkja þarf vel þróunarferli skóga til þess að geta notað þessa aðferð, það er hvaða tegundir trjáa vaxa fyrst og síðan hvaða tegundir leysa þær af.

Þennan dag fékk ég einnig tækifæri á að fylgjast með tilraun sem verið var að gera á yfirborðskortlagningu setmyndana eftir "landslide" og mælingar á skriðharða slíkra atburða. Þeir sem stóðu að þessari tilraun voru Mohammed Naaim og stúdent á hans vegum. Tilraunin var framkvæmd á þann hátt að ákveðið magn steina, af sömu kornastærð, var sett í hólf "upptakasvæði" fyrir ofan fallbraut. Breidd fallbrautarinnar var hægt að breyta milli tilrauna, þannig að skriðan gæti haft mismunandi breidd. Einnig var hægt að breyta halla fallbrautarinnar. Í fallbrautinni hafði verið komið fyrir þremur skynjurum til að mæla hraða efnisins niður hana. Fyrir neðan fallbrautina var um tveggja fermetra plata, "úthlaupssvæðið". Þar var einn skynjari til viðbótar sem átti að mæla hraða efnisins þegar það kom niður á plötuna, það er "brekkufótinn". Á úthlaupssvæðinu hafði verið teiknað rúðunet og var setmyndun hvers ferhyrnings mæld og kortlagning á yfirborðslögun setmyndarinnar gerð. Mest af útskýringum á þessari tilraun fór fram á frönsku.

*Föstudagur 13. september*
Þennan dag var Gilles Borell enn veikur en Sandrine Sanches, sem dvaldi á Veðurstofu Íslands í janúar 1996, bauðst til að kynna mig fyrir nokkrum einstaklingum á mismunandi stofnunum innan snjóflóða og hættumatsgeirans í Frakklandi. Jean Paul á ANENA var sá eini sem var viðlátin þennan dag. Við ræddum vítt og breitt um samskipti Íslands og Frakklands í snjóflóðamálum og ástæðu þess að ég var staddur í Frakklandi. Farið var nokkuð djúpt inn í snjóflóða- og hættumatsmál í Frakklandi og svör við mörgum spurningum fengust í þessu viðtali. Rætt var um starfsemi ýmissa stofnanna og samtaka svo sem Cemagref, Meteo France og ANENA. Síðar um daginn tókst okkur að komast í samband við Meteo France og fórum við í skoðunarferð þangað. Farið var almennt í gegnum starfsemi stofnunarinnar og viðvörunarkerfi sem Frakkar hafa í snjóflóðamálum. Yves Durant sýndi okkur veðurfarsmódel og líkanreikninga. Þeir nota ákveðin módel, SAFRAN (meteorological analysis) og CROCUS (snow model) sem þeir keyra saman í MEPRA (expert model) til að meta hættu á snjóflóðum Nánari útlistun á þessum forritum er í viðauka 1.

*Mánudagur 16. september*
Þessi dagur var notaður til að fara í skoðunarferð um nærliggjandi svæði til að skoða snjóflóðavarnarvirki og snjóflóðafarvegi. Ekið var víðsvegar um nágrenni Grenoble. Einnig var lögð talsverð áhersla á aurskriðu- og grjóthrunsmál og ýmsir staðir tengdir þeim náttúruváum skoðaðir.

*Þriðjudagur 17. september*
Næst síðasti dagur ferðarinnar fór ég í heimsókn RTM í Savoie. Þar tóku á móti mér Jerome Lievois jarðfræðingur frá RTM í Haute-Savoie og Nicolas George sem meðal annars heimsótti VÍ síðastliðin vetur. Farið var í gegnum hættumatsferli sem RTM vinnur og kortagerðin tekin skref fyrir skref. Nánari útlistun á því fer fram hér á eftir. Eftir hádegismat voru snjóflóðafarvegir, aurskriðu og grjóthrunsstaðir í nágrenni Savoie skoðaðir.

*Miðvikudagur 18. september*
Síðasta degi ferðarinnar var eytt í Grenoble. Farið var yfir restina af spurningalistanum með Gilles Borell, loftmyndatúlkunin skoðuð betur og ýmis málefni rædd. Meðal annars var tölvuforritið ELSA (Etude et Limites de Sites Avalancheux) kynnt fyrir mér. Nánari útlistun á þessu forriti er í viðauka 2.

*SNJÓFLÓÐ / AURSKRIÐUR / GRJÓTHRUN*
*spurningar*

### *1. Skipulagsmál Frakka á snjóflóða-, aurskriðu- og grjóthrunsmálum*

#### *1.a. Hvaða stofnanir standa að snjóflóða-, aurskriðu- og grjóthrunsmálum Frakklandi?*

Nokkrar stofnanir standa að snjóflóða-, aurskriðu- og grjóthrunsmálum í Frakklandi. Fyrst má nefna:

CEMAGREF: Þessi stofnun er staðsett í Grenoble. Þar eru meðal annars stundaðar rannsóknir á snjóflóðum, líkangerð, kortlagning á snjóflóðafarvegum út frá loftmyndatúlkun, auk ýmissar ráðgjafaþjónustu.

CEN (Centre d'Etudes de la Neige): Þetta er deild sem tilheyrir Meteo France. Á þessari deild fer fram megin hluti allrar snjóathugunar starfsemi Meteo France. Þaðan er viðvörunarkerfi snjóeftirlitsins stjórnað. Nánari útlistun á þeirri starfsemi er lýst í viðauka 1.

RTM (Restauration des Terrains en Montage): Þessi stofnun sér aðallega um framkvæmd og gerð hættumats og hættumatskorta vegna náttúrufarslegra ógna í Frakklandi. Hún starfar undir landbúnaðarráðuneyti Frakklands. Hvert "department" þar sem náttúrufarslegar ógnir steðja að hefur sína eigin skrifstofu, en stærri skrifstofur eru til staðar, svo sem í Grenoble sem geta þjónustað þær minni.

ANENA (Association Nationale pour l'Etude de la Neige et des Avalanches): Þetta er einkarekin stofnun. Mjög öflugt starf er unnið þar og sér hún meðal annars um fræðslu til fólks sem vinnur þar sem snjóflóðahætta ógnar öryggi þeirra s.s. starfsfólk skíðasvæða, vegavinnumenn og þess háttar. Einnig getur allur almenningur fengið fræðslu. Nánari útlistun á starfsemi ANENA er í viðauka 3.

#### *1.b. Hversu margir starfsmenn vinna að snjóflóða-, aurskriðu- og grjóthruns málum í Frakklandi og hvernig skiptast hlutverk þeirra niður (stofnanir / landsvæði)?*

Það er mjög erfitt er að fá allar yfirlitstölur í Frakklandi en í Cemagref vinna um 20 starfsmenn auk 20 í veðurþjónustu á Meteo France. ANENA hefur um 4 til 5 starfsmenn á sinni könnu. Hjá RTM vinna um 100 til 200 manns þar af um 25% í snjóflóðum. Það eru um 10 RTM skrifstofur í Frakklandi, þar af 5 í Ölpunum og 5 í Pyreneafjöllunum.

#### *1.c. Hverjir bera ábyrgð á skipulagsmálum (byggðaskipulagsmálum, t.d. hvar má byggja) í Frakklandi?*

Sýslumaður/bæjarstjóri/borgarstjóri gefur út byggingarleyfi fyrir íbúðarbyggð, iðnaðarhúsnæði og starfsleyfi fyrir skíðasvæði.

#### *1.d. Hvernig er hættumatsvinna framkvæmd í Frakklandi? Hver fer fram á að hættumat verði gert fyrir ákveðið byggðarlag og hverjir sjá um framkvæmd.*

Það er bundið í lögum í Frakklandi að ríkið verði að sjá um öryggi þeirra sem búa á hættusvæðum gagnvart náttúruvá. Eitt megin viðfangsefnið er að framkvæma hættumat og útbúa hættumatskort fyrir viðkomandi svæði. Í hverju "department" er tengiliður við ríkistjórnina og á hann að sjá til þess að hættumat verði framkvæmt fyrir hvert bæjarfélag eða landsvæði fyrir sig. Það eru nokkur ráðuneyti sem koma að þessu máli en sá sem biður um hættumat er sýslumaður/bæjarstjóri/borgarstjóri. Ef sýslumaður/bæjarstjóri/borgastjóri biður ekki um hættumat þá er honum bent á að gera slíkt því hann er persónulega ábyrgur fyrir öryggi íbúa sinna.

RTM stofnunin í Frakklandi sér hins vegar um gerð hættumats og hættumatskorta. RTM hefur skrifstofur í nær öllum "department" og sér hver og ein um kortagerð fyrir sitt svæði með aðstoð frá höfuðstöðvunum, til dæmis í Grenoble.

### 1.e. *Hvaða tegundir af hættumatskortum eru til í Frakklandi? Hver er mælikvarði og tilgangur hverrar tegundar?*

Þau hættumatskort sem gerð eru ná yfir nær alla náttúruvá sem steðjar að í Frakklandi. Þar má nefna snjóflóð, grjóthrun, aurskriður, "landslides" og vatnsflóð.

Hættumatskort eru gerð í mismunandi mælikvörðum, eftir þéttleika byggðar. Til dæmis eru byggð svæði teiknuð í 1:1000 til 1:5000. Þetta á bæði við um þá staði sem eru þegar byggðir og svo þá þar sem byggð er fyrirhuguð.

### 1.f. *Hver er ábyrgur fyrir öryggi á snjóflóð-, aurskriðu- og grjóthrunsmálum í Frakklandi?*

Sýslumaður/borgarstjóri/bæjarstjóri ber ábyrgð á öryggismálum hvers svæðis fyrir sig og er hann persónulega ábyrgur. Þetta á bæði við um bæi og þorp og svo útivistarsvæði s.s. skíðasvæði. Á útivistarsvæðum er samningur milli viðkomandi sýslumanns/ borgarstjóra/bæjarstjóra og eigenda t.d. skíðasvæðis um að öryggismálum sé framfylgt en viðkomandi sýslumaður/borgarstjóri/bæjarstjóri þarf að ganga úr skugga um að öryggismálum sé fullnægt.

## 2. *Tjón - slys*

### 2.a. *Eru þorp / bæir í snjóflóða-, aurskriðu- og grjóthrunshættu í Frakklandi? Hve margir? Hve margt fólk?*

Flest þorp / bæir í Frakklandi eru örugg og hefur ekki verið dauðsfall í þorpi vegna snjóflóða undanfarin ár. Ekki fengust neinar tölur um hve margir eða hve margt fólk.

### 2.b. *Hve margir hafa farist í snjóflóðum, aurskriðum og grjóthruni undanfarin 50 ár (t.d.)?*

Ég náði ekki í neinar yfirlitstölur um fjölda fólks sem hefur farist í snjóflóðum undanfarin 50 ár. Hins vegar farast um það bil 20 til 40 manns á ári í snjóflóðum einum saman aðallega skíðafólk og fjallgöngumenn. Þessi tala er þó ekki samanburðarhæf frá ári til árs vegna þess að þó svo að öryggi og fræðsla eykst frá ári til árs sem ætti að draga úr dauðsföllum þá eykst fjöldi ferðamanna einnig, sem leiðir af sér að mun meiri umferð er í dag en til dæmis fyrir 10 árum.

Í viðauka 4 eru yfirlitstölur um hversu margir fórust í Haute-Savoie "department" árið 1992. Í heild eru um 400 kommúnur (einskonar hreppar) innan marka þessa svæðis og á þessu tímabili urðu 212 fyrir náttúrufarslegum skakkaföllum.

### 2.c. *Eru til einhverjar yfirlitstölur (upphæðir) um skaða á mannvirkjum?*

Allar yfirlitstölur er mjög erfitt að fá í Frakklandi aðallega vegna þess hversu stjórnun á þessum hlutum er í margra höndum.

### 3. *Ásættanleg áhætta*

***3.a. Hvernig eru mörk hættusvæða skilgreind? Eru fleiri en ein gerð af hættusvæði (sbr. rauð/gul/blá í Sviss)?***

Sjá spurningu 4.d. við hluta þessarar spurningar. Af því sem ég best skildi þá eru úthlaupsvæði snjóflóða látin ráða mestu um mörk þessara svæða. Alfa / beta mótelið er t.d. ekki notað í Frakklandi.

***3.b. Eru einhverjar viðmiðunartölur um ásættanlegan endurkomutíma eða ásættanlegar dánarlíkur? Hverjar? Eða er e.t.v. miðað við ákveðna stika í ákveðnum líkönum?***

Ekki fékkst svar við þessari spurningu.

### 4. *Hættumatsgerð, almenn og byggð á loftmyndatúlkun*

***4.a. Hvaða stofnun sér um framkvæmt hættumatsgerðar?***

RTM sér um gerð hættumatskorta og vinna þar meðal annars jarðfræðingar, verkfræðingar og aðrir aðilar eftir því á hvaða stigi og hvers eðlis verkefnið er.

CEMAGREF sér hins vegar um öflun og túlkun gagna vegna snjóflóða og byggir megin hluta þess starfs á loftmyndatúlkun. Út úr þeirri gagnasöfnun er gert útbreiðslukort snjóflóða þar sem bæði metnar og þekktar útlínur koma fram (sjá viðauka 5).

***4.b. Hvaða kort eru til, byggð á loftmyndatúlkuninni, í hvaða mælikvarða eru þau og hvernig nýtast þessi kort?***

CEMAGREF gefur út útbreiðslukort í mælikvarða 1:25.000 sem er byggt á þessari aðferð, auk þess að innihalda upplýsingar um skráðar sögulegar heimildir. Á þessum kortum kemur einnig fram mat á hugsanlegum upptakasvæðum snjóflóða (sjá viðauka 5). Þessi kort eru síðan notuð til grundvallar hættumatskorta sem unnin eru hjá RTM.

***4.c. Hvernig er mat á útbreiðslu snjóflóða byggð á loftmyndatúlkun framkvæmd?***

Þessi aðferð er byggist fyrst og fremst á túlkun loftljósmynda. Notaðar eru bæði svarthvítar, lit og innfrarauðar myndir í þessari athugun. Skoðaðar eru breytingar sem sjást á uppbyggingu skóglendis. Hægt er að greina mismunandi tegundir trjáa á loftmyndum sem gerir þessa aðferð mögulega. Haldgóð þekking á þróunarferli skóga er nauðsynleg. Nauðsynlegt er að geta greint mismunandi trjátegundir í sundur og þekkja hvaða tegundir koma í stað annarra. Þessi aðferð krefst mikillar þjálfunar og er fólki ekki treyst án leiðsagnar fyrstu árin. Hugsanleg snjósöfnunarsvæði eru einnig skoðuð á loftmyndunum. Megin drættir í tópógrafíunni skoðaður, landhalli áætlaður og gefið mat á hvort um hugsanlegt upptakasvæði er að ræða.

***4.d. Hvert er ferlið við gerð hættumatskorta hjá RTM***

Eins og áður hefur komið fram þá sér RTM um gerð hættumatskorta, hvort svo sem þar er fyrir snjóflóð, aurskriður, grjóthrun eða aðrar náttúrufarslegar ógnir. Miklar kröfur eru settar á þann mannskap sem vinnur við slík kort og þarf viðkomandi að fá mikla og langa þjálfun áður fullt traust er borið til hans. Mikill fjöldi jarðfræðinga og annarra náttúruvísindamanna vinnur að þessum málaflokki í Frakklandi.

Fyrsta skref þessarar vinnu felst í því að merkja inn á staðfræðikort, í mælikvarða frá 1:1000 upp í 1:25.000 (fer eftir þéttleika byggðar). Öll þau fyrirbæri sem vitað er um, s.s. snjóflóð, grjóthrun, "landslide" og þess háttar, eru merkt inn á þessi kort og svo túlkun sem viðkomandi setur inn. Upplýsingar eru teknar bæði frá rituðum heimildum, loftmyndatúlkun og ekki síst frá skoðunarferðum út í mörkina. Þetta kort er síðan borið undir bæjarráð og útskýrt og þau gögn sem liggja til grundvallar lögð fram (sjá viðauka 6).

Næsta skref er framkvæmd á hættumati. Þar er hættan metin og mismunandi hættustig sett inn. Í Frakklandi eru þrjú mismunandi hættustig metin.

| | |
|---|---|
| Stig I. | Lítil hætta, Hér getur vel byggt hús staðið án frekari varna. |
| Stig II. | Varna er þörf. Mismikil hætta til staðar. |
| Stig III. | Svæði sem ekki er hægt að verja. |

Stig hættumats er auðkennd með mismunandi litum, til dæmis er rauður notaður í mesta hættuflokknum t.d. *rauð*fjólublátt = mesta hætta, *ljós*fjólublátt = minni hætta. Þar sem hætta er miðlungs eða lítil eru svæðin auðkennd með bláum lit. Þar sem engin hætta er talin vera eru svæðin auðkennd með hvítum lit.

Á rauðu svæðunum eru allar nýbyggingar bannaðar, en eldri byggð metin. Ef hættan er talin vera of mikil þá eru hús yfirgefin, en lög um uppkaup fasteigna hafa ekki verið notuð mikið í Frakklandi enda tiltörulega ný. Á bláu svæðunum er byggð leyfð ef hús eru styrkt eða hafa kjallara þar sem fólk getur viðhafst ef hættuástand ríkir. Lögun húsa fer eftir reglugerð. Hús þurfa að þola 3 tonna þrýsting á fermetra. Opnanir eiga ekki vera upp á móti hugsanlegu snjóflóði. Á þessum svæðum geta bæði verið um miðlungs og litla hættu að ræða. Engar byggingar eru leifðar 10 metrum frá árbökkum vegna flóðahættu.

Þar sem hús hafa verið styrkt, varin eða byggð samkvæmt ákveðnum staðli sem mælt er með vegna yfirvofandi hættu þá getur rautt svæði breyst yfir í blátt.

Nánari útlistun á starfsemi RTM er að finna í viðauka 7.

## 5. *Gagnasafn um snjóflóð, aurskriður og grjóthrun*

### 5.a. *Er til gagnasafn um snjóflóð, aurskriður og grjóthrun í Frakklandi? Er til samantekt eða skýrsla á ensku um helstu kennistærðir safnsins?*

Nei, ekki sem ég fékk upplýsingar um.

### 5.b. *Hefur verið gerð tölfræðileg greining á úthlaupslengd snjóflóða á grundvelli slíks gagnasafns og á hverju byggist hún?*

Nei, ekki í vitund þeirra sem ég talaði við enda notast þeir nær eingöngu við söguleg gögn og loftmyndatúlkun.

## 6. *Snjóflóða-, aurskriðu- og grjóthruns spár og vöktun*

### 6.a. *Hvernig er rekstri snjóflóða-, aurskriðu- og grjóthrunsviðvörunarkerfis í Frakklandi háttað og hverjir hafa umsjón með því?*

Meteo France sér um rekstur viðvörunarkefis Frakklands. Þeir telja sig hafa eitt besta viðvörunarkerfi í Evrópu sem byggt er á CROCUS, SAFRAN og MEPRA (sjá viðauka 1).

Svipað og í Sviss þá fá þeir send inn gögn frá um 140 stöðum daglega. Mest af því er frá snjóathugnarmönnum. Þau gögn sem berast daglega er veðurlýsing, snjósöfnun og yfirborðsásýnd snjóþekjunnar. Þeir fá upplýsingar úr snjógryfjum einu sinni í viku. Um 90% af þeim koma frá skíðasvæðum og 10% frá snjóeftirlitsmönnum og björgunarsveitum. Viðvaranir eru gefnar út daglega fyrir stór svæði í einu. Þetta kerfi er virkt frá 15.12 til 01.06 ár hvert.

*6.b. Hvernig er vöktun á snjóþekjunni eða jarðvegsþekjunni háttað og hverjir framkvæma þá vöktun?*

Um 90 % allra gryfjusniða koma frá skíðasvæðum en um 10 % þeirra koma frá snjóeftirlitsmönnum og björgunarsveitum. Um 140 stöðvar framkvæma veðurathuganir sem þeir byggja spár sínar á. Þar kemur fram veður og yfirborðsásýnd snjóþekjunnar. Meteo France sendir út aðvaranir um yfirvofandi snjóflóðahættu en þær eru oftast færri en 10 á ári. Veturinn 1995 til 1996 var aðeins send út ein slík viðvörun. Þeir senda út daglegar viðvaranir en aðvaranir sjaldnar.

Aðvaranirnar eru sendar til almannavarna og hvers sýslumanns/bæjarstjóra/borgarstjóra. Viðkomandi sér um sitt "department" þar með talin skíðasvæði sem liggja innan hans lögsögu.

## 7. *Varnarvirki*

*7.a Er mikið um þéttbyggð svæði á snjóflóða-, aurskriðu- og grjóthrunssvæðum í Frakklandi sem varin hafa verið með varnarvirkjum, hverjir sjá um hönnun og framkvæmd og hverjir fjármagna þessar framkvæmdir?*

Talsvert mikið er af húsum sem hafa verið varin. Þó er oftast um styrkingar húsa að ræða. Nánari svör við þessum spurningum er að finna í viðauka 8.

Yfirvöld viðkomandi svæðis sjá oftast nær um að fjármagna varnarvirki fyrir heil byggðarlög, en ríkið lætur af hendi um 50%. Þegar verið er að verja einstaka nýbyggð hús, svo sem verksmiður eða annað atvinnuhúsnæði þá sér viðkomandi byggingaraðili um varnirnar, þetta er þó ekki algilt. Oftast eru varnarvirki hönnuð á einkareknum verkfræðistofum sem sérhæfa sig í slíku en ef ríkið sér um greiðslu á varnarvirkjum þá sér RTM stundum um þá hönnun.

***7.b. Hvert er umfang varnavirkja í Frakklandi og hvers konar varnarvirki er um að ræða (heildarlengd netvirkja, flatarmál upptakasvæða með netum, lengd, hæð og rúmmál stærstu þvergarða og leiðigarða, brattir leiðigarðar eða þvergarðar (?), o.s.frv.)?***

Sama sagan hér eins og annars staðar með allar yfirlitstölur. En nokkrar upplýsingar fékk ég þó. Lengsti vegskáli sem gerður hefur verið í Frakklandi er um 400 m. Stærsti varnarkerfi er í nágrenni Charmoix, það var byggt í byrjun níunda áratugarins. Kostnaður var í kringum 35 milljónir Franka. Lengst cartex er um 7 km.

Í Brages í Pyreneafjöllunum hefur verið unnið að snjóflóðavörnum frá árinu 1880. Þetta er stærsta varnarvirkjasvæði í Frakklandi

***7.c. Eru til kennitölur eða viðmiðunartölur byggðar á reynslu fyrir kostnað við byggingu varnarvirkja (pr. lengdarmetra af netum, rúmmetra af görðum)?***

Ekki fengust upplýsingar um þessi mál í þessari ferð. Það má helst skýra á þann hátt að allar framkvæmdir um hönnun varnavirkja í Frakklandi eru í höndum einkastofa og því mjög erfitt að afla þeirra gagna. Ég bendi hins vegar á viðauka 8 til glöggvunar á þessari spurningu.

7.d. ***Hversu miklu er varið til snjóflóða-, aurskriðu- og grjóthrunsvarna á ári í Frakklandi?***

Þessar upplýsingar eru vandfundnar aðallega vegna þess hversu dreift framkvæmdarvaldið er. Megin niðurstaða úr þessari spurningu er þó að mjög erfitt er að sannfæra pólitíkusa að verja fjármunum í slíkt.

7.e. ***Er til yfirlitsgrein um snjóflóða-, aurskriðu- og grjóthrunsvarnarvirki í Frakklandi?***

Nei, ekki sem ég komst í tæri við.


## Þakkir

Ég vil þakka Franska sendiráðinu og Menntamálaráðuneytinu fyrir að gera mér kleyft að heimsækja Grenoble og kynna mér starfsemi Frakka í snjóflóðamálum og öðrum málaflokkum sem tengjast náttúruvá. Sérstakar þakkir fær Gilles Borell sem skipulagði ferðina fyrir mig og allir þeir sem gáfu sér tíma til að ræða við mig á meðan á dvöl minni í Frakklandi stóð.

# Viðauki 1

Tools for avalanche forecasting in France

Anne Choquet

# TOOLS FOR AVALANCHE FORECASTING IN FRANCE

To evaluate the avalanche hazard, it is necessary to analyse the stability of the snow cover and to use the meteorological forecast to know about the likely evolution of this snow. Several models have been developed by the Centre d'Etudes de la Neige (C.E.N.) of Meteo France (the center of snow studies in the French meteorological office, Grenoble) to help this evaluation. Three models are used actually working together for the avalanche forecast. Those are CROCUS, SAFRAN and MEPRA which really gives an evaluation of the avalanche risk.
So far, there are 9 meteorological "mountain" offices in France which are working on the avalanche forecast for their own region, collecting the data from the local observers of the area. They are using the help provided by these informatic tools in Grenoble.

CROCUS is a numerical model made to follow with more accuracy the evolution of the snow cover because the data collected in the field were not complete enough (in time and space). This model takes into account thermical conduction, compression of the snow cover, free water percolation, melting, refreezing and metamorphism. It simulates the evolution of every layer as well. It has be tested during the winter 88/89 and gives very good results.

SAFRAN is another application which has been set up to complement CROCUS for the avalanche forecast performed by MEPRA. It enables the using of punctual data. The results are given in real time. It estimates the IR and sun radiations (taking in account nebulosity...), wind, temperatures, humidity, precipitation, arriving on the ground. Satellite's pictures will soon be automatically used. SAFRAN gives directly some information to CROCUS.

Using SAFRAN and CROCUS, MEPRA forecasts the avalanche risk.

## What is MEPRA ?

MEPRA system is an avalanche-expert system. This means that it was set up to work as an expert in avalanches would do, following the same procedure using an encoded symbolic logic. Expert systems seem to be required to be able to forecast the avalanches because there are a lot of important non-numerical information experts use. That's why the numerical procedures need to be completed with this kind of system.
MEPRA was installed in 1986 by the C.E.N. Its aim is to help the avalanche forecast at the regional scale (mountain range, 200 up to 1000 km2) by using fragmented information. The data which are used are both collected in the field (snow profiles...) by local observers and given by the other informatic systems SAFRAN (for meteorological conditions) and CROCUS (for the evolution of the snow cover).
Using on different ways CROCUS and MEPRA allow to separate the mechanical stability of the snowpack and the avalanche risk.

At the beginning, Mepra were used to give more information about the snow (hardness...) and an hazard analysis taking in account the top of the snowpack and the avalanches which already occurred. There were then several problems : at first, the total snow cover were not taken in account and then, it was always difficult to know about all the avalanches which already occurred. That's why, modifications have been made in the last few years.

Now, except for the avalanches due to local condition (drifting snow, wind slabs ...), the avalanche hazard is evaluated by comparing similar avalanche tracks (altitude, exposition, slope...). Every day the avalanche forecaster should analyse the differences on the snow cover on low and high altitude, south or north exposition.... That's what MEPRA is doing now, after a long training period. The data are given for every 300 m of altitude, for 6 expositions (N, E, SE, S, SW, W) chosen because of the French Alps conditions and 2 different steepness of slopes (20 and 40 degree).

How is MEPRA working ?

- At first, it will analyse the mechanical stability.
The snow cover is studied in a static way in order to find the weakest layers. It is done by comparing the shear strength of each layer which is linked to the density, the grain type, the tangential component of the gravity. A correction has been made in MEPRA for the wet snow, because the mechanical stability is then more complicated. The percolation has in this case a big importance.
- Then, the hazard estimation is made for each massif, every 300 m height, for 6 expositions and for different steepness of slope.
Six levels of avalanche risk have been set up, from very low up to very important risk. This estimation will take in account the worst instability level, the thickness of the snow above the weak layer, and the estimated evolution of the snow cover.
The type of avalanche (wet loose-snow, dry loose-snow, slab avalanche...), is specified by MEPRA .

Validation of MEPRA

The first modifications were made after a training period during the winter 1992/1993.
The second validation has been carried by comparing the observed avalanches to the MEPRA answers, during the last 10 winters (till 1994) on the Vanoise massif. To be able to compare, the observed avalanches should be evaluated by the same scale of risk as MEPRA. This has been solved by several formulas taking into account the number of avalanches observed in each local station, for each day.

The results show that :

- MEPRA gives a good analysis for the spring condition. The correction for the wet snow, taking into account the percolation, seems to be available.
- In the case of high intensity of precipitation, it is more difficult to know whether MEPRA work because then, observations are becoming very difficult and even impossible in some cases.
- It is still difficult to take in account the drifting snow for a global approach at the regional scale.

So, MEPRA seems to be a good tool for avalanche forecasting.
Those three systems SAFRAN, CROCUS and MEPRA should now compare the snow cover structure observed in the field and the predictions given by these models.

# Viðauki 2

Avalanche modelling and integration of expert knowledge
in the ELSA system.
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Annals of Glaciology 18, 1993

*Annals of Glaciology 18 1993*


# Avalanche modelling and integration of expert knowledge in the ELSA system

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ABSTRACT. The choice of the best protection system against avalanches on a particular path requires an accurate description, or *image*, of these avalanches. In order to get this image, avalanche consultants can use several numerical models which are often difficult to handle. Moreover, these models deal only with a part of the phenomena involved in avalanches and ignore the others. As a result, the consultants must use their experience and knowledge to imagine the avalanches on any particular path.

This paper presents ELSA (Etude et Limites de Sites Avalancheux), a computer system dedicated to the modelling of the knowledge of avalanche experts and to the *integration* of the new symbolic computer models with the classical numerical models. The basic aim of integration is to build a unique computer system incorporating all these models.

After a description of the terrain representation, we present the different scenarios that ELSA takes into account. Then, the methods which deal with some phenomena occurring in avalanches are described. The problems involved in the integration of these methods close this paper.

## INTRODUCTION

The consultants responsible for avalanche path analysis must answer the following questions: Is there any avalanche hazard on the path? Which kinds of avalanche can occur? In which conditions? What are the properties of these avalanches (magnitude, velocity, extension, pressure fields, etc.)? These analyses will give the basic information to recommend the best protection strategy (Buisson and Charlier, 1989).

The consultants have several tools to analyse an avalanche path. First of all, they can use their experience. They can make comparisons between a particular avalanche path and some other well-known paths. They can make assumptions based on terrain and vegetation features. But more and more, in avalanche hazard zoning, velocity and run-out distance are required for building design. Snow specialists can use simulation methods based on mechanical equations. Numerous models have been developed from Voellmy's model mainly to describe a flowing avalanche (Bakkehøi and others, 1981; Beghin and Brugnot, 1983; Brugnot and Vila, 1985; Norem and others, 1989; Salm and others, 1990; Martinet, 1992; Brandstätter and others, unpublished).

ELSA is a computer tool dedicated to avalanche path analysis (Buisson and Charlier, 1989). It tries to provide not only some of these numerical simulation methods, but also some empirical methods developed by using the experience of avalanche experts. These methods provide input data for the numerical models. Recent developments in computer science enable the knowledge of avalanche experts to be captured. *Symbolic models* based on this knowledge can then be implemented (Buisson, 1990a).

There is no conflict between these two kinds of method. They are complementary and can be combined to produce an improved output.

## DESCRIPTION OF TERRAIN

ELSA must be provided with an accurate description of terrain, which plays an important part in avalanche path analysis. Topography, vegetation and the nature of the soil surface are the parameters which, in combination with meteorological conditions, control the release and flow behaviour of avalanches. In numerical models, the terrain profiles are used to describe the geometry of the avalanche track. The vegetation and the the soil surface are important in the choice of roughness coefficients. In symbolic models, slope, topography around the ridges, and exposure to prevailing wind direction are used as determinants for the computation of snowdrift, snow cover stability and fracture propagation.

### Three zones

The different models available in ELSA cannot be used on the whole avalanche path. As a result, we assume that the user is able to define the *starting zone*, the *avalanche track*, and the *run-out zone* clearly (Fig. 1). This decomposition is common. The starting zone is that part of the terrain where the mass of snow which will be involved in the avalanche is released. The fracture propagation

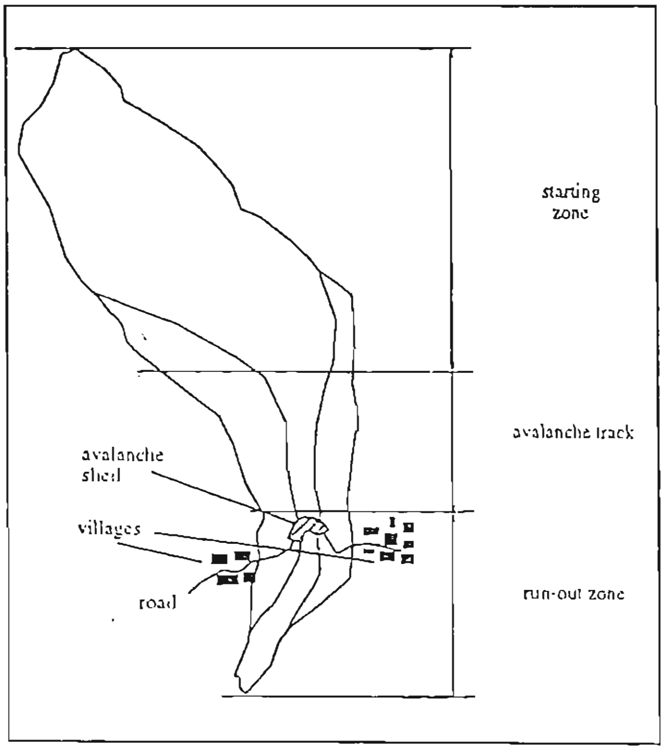


*Fig. 1. The Drayre avalanche path in Vaujany, Isère, Région Rhône-Alpes, France.*

and the acceleration of the avalanche are principal features of this zone. The avalanche track is where the avalanche simply flows and the run-out zone is where the avalanche decelerates and finally stops.

### Triangles and topography

In order to describe the topography mathematically, a digital terrain model (DTM) is required. A triangulation method is used which describes the natural terrain as planar triangles (Fig. 2) with each triangle defined by the coordinates of its vertices. This method was suggested by Toppe (personal communication) in order to keep the number of triangles low and to get an accurate DTM adapted to the terrain features.

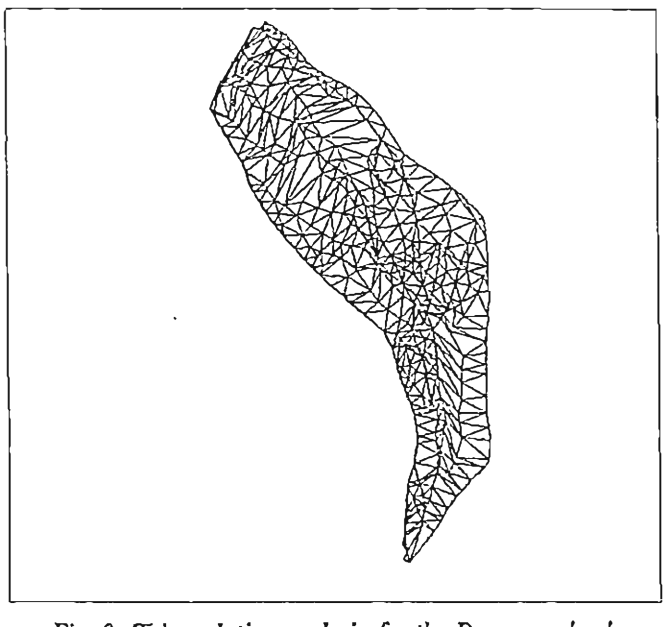

*Fig. 2. Triangulation analysis for the Drayre avalanche path.*

### Panels

The same symbolic models are based on experts' knowledge. As a result, ELSA must use the same terrain analysis methodology as these experts do. The experts do not reason in small triangles; instead, they use a unit of terrain called a *panel*. A panel is considered to be homogeneous according to the criteria of the avalanche path analysis: slope, exposure, vegetation, soil and distance to the main ridges. Panels are represented in ELSA as *polygons* defined by the union of several connected triangles. The panel represents the minimum topological decomposition of the terrain (Fig. 3). ELSA does not consider units of terrain which are less than the size of a panel.

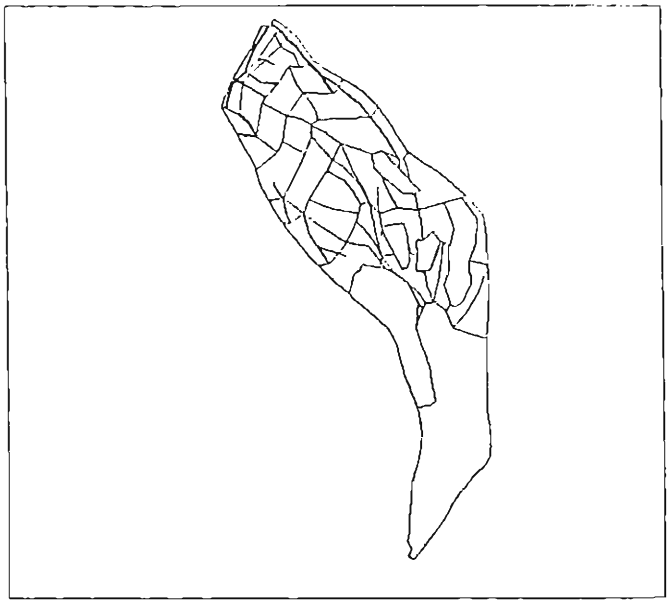

*Fig. 3. Simplification of the Drayre avalanche path into panels. Ridges and breaks of slope are represented by lines.*

### A construction system

The triangle and panel specifications suggest the process of their construction. The basic idea is to use the data which are easily obtained from sources such as (1) contour line maps, (2) ridges and breaks of slope maps, (3) singularity line maps (showing changes in aspect, gullies, furrows, etc.), and (4) vegetation and soil surface maps. All of these polygonal lines will become constraints in the building of triangles: i.e. these lines cannot cut through a triangle.

According to the specifications of the panels, these polygonal lines may have several meanings. Some must be panel boundaries (e.g. vegetation or ridge line); others may be included in the interior of a panel (a contour line for instance). In this latter case, the lines are used only for the construction of the triangles.

The terrain construction system is based on polygonal lines. Each vertex of these lines must be known through its three coordinates. If $x$ and $y$ are defined through the digitization of the map, the $z$-coordinates can be provided *only by the contour line map.* As a consequence, we decided not to work with the initial data maps (2), (3) and (4) (Fig. 4a) but with the lines defined by the intersection of these data with the contour lines from map (1) (Fig. 4b). Naturally, the user is allowed to keep one particular point on a line of maps (2), (3) and (4) but he must provide the elevation of this point (Fig. 4c).

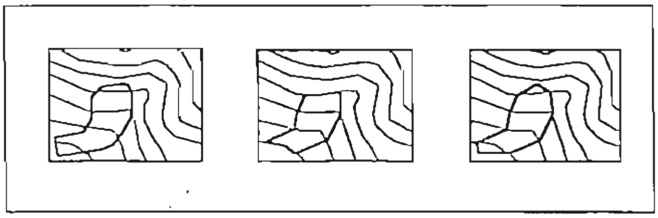

*Fig. 4. a, b and c: polygonal lines used in the construction.*

The contour lines maps are purchased at l'Institut Géographique National which is in charge of mapping in France. The available digitized contour lines are adapted to a scale of 1 : 10 000. The other maps (2), (3) and (4) are digitized by the user on the graphic interface of ELSA. This operation requires a good analysis of the natural terrain.

## METEOROLOGICAL CONDITIONS

An avalanche occurs when a particular scenario takes place on an avalanche path.

A *scenario* is described through an *initial condition* and a sequence of *events.* An initial condition defines the distribution of the snow in the starting zone. The last event is called the *critical event* and it ends with an avalanche release.

ELSA is able to deal with two scenarios:

a heavy snowfall on an existing snow cover triggers an avalanche;

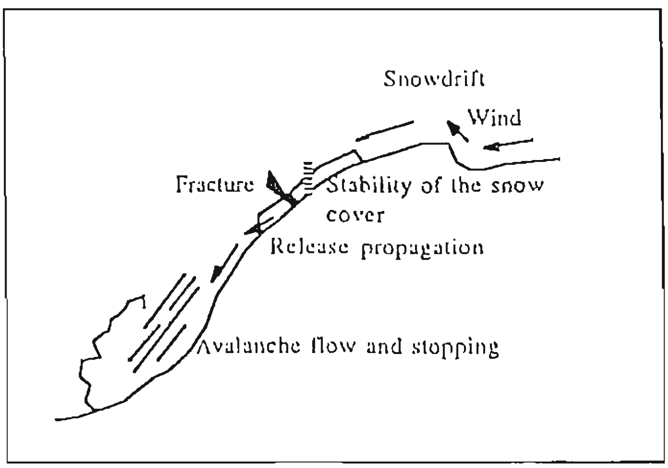


*Fig. 5. Avalanche phenomena taken into account by ELSA.*

a snowfall on an existing snow cover creates a new snow cover and an artificial release is triggered later on a panel.

In both scenarios, the snowfall event can occur with or without *snowdrift.* The user can choose the wind direction and the empirical level of snowdrift. The user can also choose the character of the snow available for avalanche (e.g. the new snow from a snowfall) in both scenarios. The character is defined by physical parameters: density, cohesion, friction angle. The existing snow cover (called the *old snow*) in the initial condition is not supposed to contribute mass to the avalanche but is described by its upper surface (the *sliding surface*). The initial condition provides a distribution of snow heights.

## MODELLING SEVERAL PHENOMENA

During an avalanche, several phenomena take place in the avalanche path as shown in Figure 5. Four phenomena are analyzed: snowdrift, snow cover stability, release propagation and avalanche flow and stopping. The first three are located mainly on the starting zone, the last on the avalanche track and on the run-out zone.

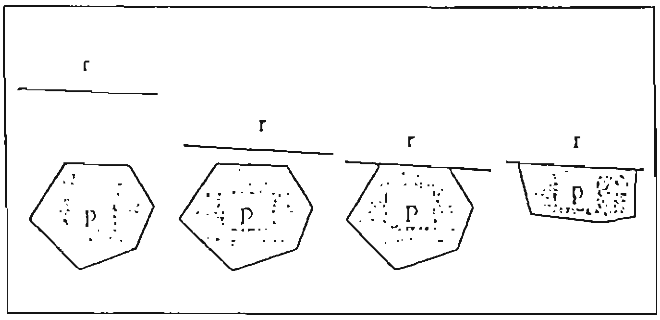


*Fig. 6. Four relative positions between a ridge, r, and a panel, p, considered by ELSA: near, very near, juxtaposed and on.*

### Snowdrift

Snowdrift and its influence on avalanches have been studied both theoretically and experimentally (Föhn and Meister, 1983; Meister, 1989). In ELSA a symbolic simulation of snowdrift is based on empirical knowledge. The first assumption is that the spatial analysis of panels is *relevant* and yields homogeneous units with reference to this phenomenon. Several parameters are used to estimate snowdrift on each panel: relative position of the panel to the ridge (Fig. 6); shape of the ridge (assumed to be symmetric); distance to the ridge; incidence angle between the wind and the ridge; and position of the panel and the ridge relative to wind (*lee-* or *windward*). The result of the snowdrift analysis is an empirical distribution of a coefficient between 0 and 5. A coefficient of 1 means that snowdrift has no effect. A coefficient less than 1 means that there is wind erosion; a coefficient greater than 1 means that there is wind deposit. The limit of 5 is the maximum value.

**Snow cover stability**

Two methods are used in order to estimate the snow cover stability. This stability is then used in the analysis of release propagation. The first one is based on a single rule: if the upper snow layer is a slab (i.e. with a good cohesion) and if it lies on a weak layer with no cohesion or a sliding surface without anchorage, the stability depends only on the relative values of the slope angle $i$ and the external friction angle $\phi$. As a result, the stability condition is $\phi \geq i$.

If this condition is not true, we consider that the upper snow layer is held by its lateral anchorage. This will explain the fracture propagation.

Another very simple model is used in the starting zone to calculate the stability. It is based on the soil mechanics interpretation which gives, for a homogeneous material and an infinite domain, the critical depth $h_{crit}$ (measured vertically) of material above which a slide can appear:

$$h_{crit} = \frac{c \cos \varphi}{dg \cos i \sin(i - \varphi)},$$

where $g$ is acceleration due to gravity, $i$ is slope angle, $d$ is density of the material (in this case, the upper snow layer), $c$ is cohesion of the material, and $\varphi$ is internal friction angle of the material.

In this case, the condition for stability is $h_{crit} \geq h$.

If $h > h_{crit}$, the upper snow layer is considered to be unstable. In both cases, if there is a release, the whole unstable snow layer is considered to be involved.

For both methods, we take into account the mean particle size at the soil surface. For example, in a slope covered with scree (size 0.5 m), we assume that no slide can occur in the layer between 0 and 0.5 m. In other words, the snow which smoothes the terrain is not taken into account for the calculation of stability (Fig. 7). We use the same approach for grass, bushes and small trees. For forests and large trees, we use an arbitrary association between types of tree cover and size of screes. In determining this slide surface, we also take into account the old snow described in the initial condition of the scenario. Therefore, in this paper, we speak of the efficient snow height, that is, the height of the snow which can slide.

Also, in ELSA the user is always allowed to control the stability in a particular panel.

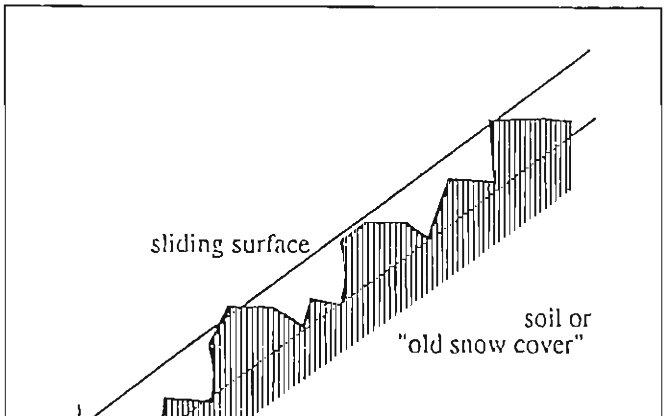


*Fig. 7. The sliding surface on a natural terrain.*

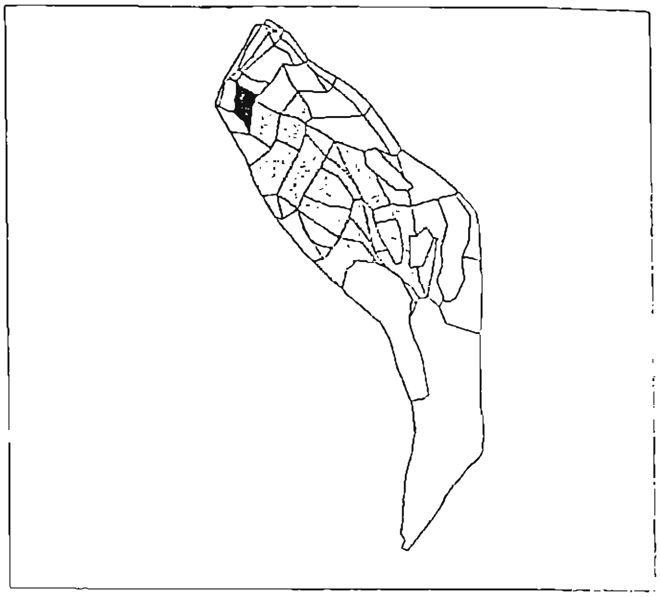

*Fig. 8. An example of release in the Drayre avalanche path. The panel in black is considered to be the trigger. The shaded panels are considered to be released.*

**Release propagation**

In the release propagation, two phenomena occur with different characteristic times. The faster is a wave propagation which takes place in a cohesive snow layer where the slab stability condition is exceeded; it is the *fracture propagation*. The slower is the gradual entrainment of snow masses moving down slope and is called *movement propagation*. These two phenomena act together to determine the part of the starting zone released (Fig. 8).

The wave-like fracture propagation is based only on the stability inferred according to the first method (slab stability). If a panel $p_1$ is seen as unsteady according to this method, then it is released as soon as a neighbour, $p_2$, is released.

The second phenomenon is dealt with by exploiting another simple model. A panel $p_2$ with an area $\Sigma_2$ was not released by the first propagation phenomenon; i.e. there was no slab or weak layer. Moreover, the snow height $h_2$ was lower than the critical snow height $h_{2c}$. A volume of $\Omega_1$ of snow arrives on $p_2$. If it is large enough to overload $p_2$, there is propagation. This condition is

$$h_{2c} \leq h_2 + \frac{\Omega_1}{\Sigma_2}.$$

When the condition is not fulfilled, we consider that the propagation has stopped.

The character of the snow plays a large part in the computation of $h_{2c}$. We assume that the character of the movable snow and the moving snow are the same everywhere. The spatial analysis of panels plays a large part in this model.

### Avalanche flow

As explained above, the avalanche motion can be simulated by several methods, but only two of them are available in ELSA: the method presented by Bakkehoi and others (1981, modified from the Voellmy's method) and the Saint-Venant's model solved by the numerical scheme created by Vila (1984) and developed by Martinet (1992).

The first method requires an estimation of the mass of snow involved in the avalanche. The second method requires a hydrograph, i.e. a flow rate versus time at the beginning of the avalanche track. The mass is given by the analysis of the fracture propagation. The user must choose a flow time.

## INTEGRATION

*Integration* is used here to mean the introduction and the articulation of several methods in the same computer system.

This paper presents several methods used in ELSA. Some methods have been used already (especially the last ones, dedicated to avalanche flow); some are new and need more work to be validated. These methods are integrated in ELSA. The knowledge-based system architecture allows for the development of *problem solving environments* (Buisson, 1990b).

ELSA is built on an object-oriented knowledge representation system, SHIRKA (Rechenmann and others, unpublished), which is written in Le-Lisp, a Lisp dialect (Ilog S.A., 1991). ELSA runs on a SUN IPC workstation with UNIX.

### Sharing data

One of ELSA's main strengths is the sharing of data between several methods. The best example is topography. All the different methods use triangulation to represent terrain. However, the first three methods make intensive use of the decomposition in panels. The main advantage of data sharing lies in consistency and in time saving.

### Cooperation

The output of the symbolic simulation can drive the numerical simulation and vice versa. As a result, all the phenomena described above are linked to one another in the analysis.

### Interactive interface

The interactive interface allows non-computer specialists to use ELSA. The user-friendly colour interface based on a mouse and a high definition screen highlights the important parameters. The keyboard of the workstation is hardly used and the user does not need to know or use the computer operating system or programming languages.

The language Le-Lisp is provided with Aïda, an object-oriented environment for the development of graphic applications (Ilog S.A., 1992). The figures in this paper come from the interface. It is used for the construction process (definition of the lines presented in Figure 4a) and for the presentation of results: snow heights map, stability distribution, initial fracture location and release propagation. The scenarios are also displayed in a graphic representation.

## FUTURE DEVELOPMENTS

ELSA is still being developed. Besides the capabilities presented in this paper and which have already been implemented, further developments are being considered: terrain validation of some methods; further analysis of stability in a forested or tree-covered area; integration of the AVAER (AValanche AERosol) program for aerosol avalanches (Rapin, unpublished); and integration of a statistical method for the estimation of the run-out distance such as described by Bakkehoi and others (1981).

## ACKNOWLEDGEMENTS

This research has been supported by grants from La Région Rhône-Alpes in 1989 and 1990 and from La Délégation aux Risques Majeurs (Ministère de l'Environnement) in 1990 and 1991.

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*The accuracy of references in the text and in this list is the responsibility of the authors, to whom queries should be addressed.*

# Viðauki 3

ANENA: THE FRENCE ASSOCIATION FOR SNOW AND AVALANCHE STUDY. RESEARCH, TRAINING, COORDINATION AND INFORMATION IN THE SNOW AND AVALANCHE FIELD

Francois Sivardiere

IGS and ANENA abstract volume,
Chamonix 1997

# ANE A: THE FRENCH ASSOCIATION FOR . OW AND AVALANCHE STUDY. RESEARCH, TRAINING, COORDINATION AND INFORMATION IN THE SNOW AND AVALANCHE FIELD.

François Sivardière

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## 1. SHORT HISTORY

ANENA was created in October 1971. A dramatic avalanche killed 39 people in a chalet in the northern Alps in February 1970. This avalanche was the starting point for an investigation into safety in ski resorts and in snow-covered mountains.

At that time, more than 15 organizations dealt with snow and avalanche problems, but bad coordination harmed their efficiency. That is why the working group involved in the above investigation recommended the creation of an organization to develop and coordinate research in the snow and avalanche field. For various reasons it could not be an institute comparable to the Swiss Federal Institute for Snow and Avalanche Research. Instead, an association was created with the following aims:

- to facilitate the coordination between specialists and users, and to promote the exchange of experience and knowledge with foreign countries;
- to encourage and assist all research undertaken by any person or organization, to recommend research, and;
- to distribute and popularize information on snow, avalanches and safety in snow-covered mountains.

## 2. ANENA'S ORGANIZATION

ANENA includes any professional or private person or organization interested in any aspect of snow and avalanches as well as safety in snow-covered mountains: professionals (ski-patrollers, mountain guides, ski instructors, cable-car organizations, etc.), elected representatives of ski resorts, research institutes, rescue teams, French public administrators, etc.

It is administered by a board composed of 30 people elected by the members of ANENA. From this a seven-member executive board is selected. There is also a scientific and technical council that reviews research projects submitted to the association for support. In addition, there are six committees that work on the following: communication, training, avalanche forecast, review, avalanche rescue, and judicial aspects.

Finally, five permanent staff are charged with the smooth running of ANENA: a director, an accountant, a clerk and two secretaries.

## 3. ANENA'S ACTIVITIES

Since 1971, ANENA has had four kinds of activity (research, training, coordination and information) and one mission (to increase safety and prevention of accidents in the snow and avalanche field).

### 3.1. Research

In 1971, the priority was on the improvement of knowledge. Then, ANENA was the place where practitioners and scientists could meet, discuss and define research projects. ANENA proposed studies, encouraged rese by specialized organizations, and facilitated the coordi on between them. ANENA either controlled the work itself or facilitated the collaboration of others. The principal concern was efficiency. ANENA was resolutely situated where basic research and field practice came together. The following examples might be mention: the improvement of avalanche forecasts, avalanche hazard mapping, artificial avalanche release, avalanche defence structures and rescue systems.

In 1997, ANENA has a different role. After getting things started, introducing everyone to each other, and establishing what they were working on, its actions are now more discreet. It manages research projects involving many laboratories and supports individual research projects with some of its partners. The main reason for this evolution is lack of money.

### 3.2. Training

Since 1971, ANENA has organized many training courses. It is the French establishment for artificial-avalanche-release training courses. More than 2000 ski patrollers have already taken the course in how to use explosives to release avalanches. Just before each winter, ANENA organizes four or five training courses in the Alps and Pyrenees for about 100 people. It also organizes a two-day training course for future users of the French avalauncher system.

In France, ANENA is responsible for the training of avalanche dog handlers. In a period of slightly more then two weeks, about 20 dog-handler teams learn how to locate a buried avalanche victim.

ANENA has also trained many of those responsible for avalanche safety in how to take into account the various parameters related to snow and avalanches and how to manage the avalanche hazard so as to minimize the risk in the area in which they are working.

### 3.3. Coordination

ANENA was created to ensure that everyone had an opportunity of meeting others working on, or interested in, snow and avalanches both in France and in other countries. Since the beginning, ANENA has facilitated meetings and exchanges and encouraged new investigations.

For example, every four years it organizes an international symposium in French and English to create a forum for exchange and understanding amongst theoreticians and practitioners, to establish the latest scientific research contributions to safety, and to determine specific applications in the field. Thus ANENA is also a link between the French and foreign communities involved in the snow and avalanche field.

ANENA plays an important role in France: it is the place where many practical problems are discussed and resolved. All the involved parties are represented in the association so all can give their opinion and contribute to the solution. The implementation of the solution in the field by their "troops" is thus much easier. Current discussions include: the "avalanche flag" (and more generally, public information on the avalanche danger in ski resorts), systems for rescuing avalanche victims, and the writing of a glossary of snow and avalanche terms (so everyone speaks the same language and understands each other better).

### 3.4. Information

This is the area where development has been the most important.

For internal communication, ANENA publishes a 32-page quarterly review. The print run exceeds 1400 copies and is distributed to more than 20 countries. For non-French speaking readers, English abstracts for the articles have been provided since 1995. It allows all ANENA members to be familiar with the activities of their Association and to receive news of French and international work in the snow and avalanche field.

Information is also of course directed to the public. The first way is indirect, through the media (reviews, radio and TV), either those specialized in skiing, snowboarding or mountaineering, or not specialized at all. The other way is direct, through the distribution and sale of pamphlets, books, reports, slides, video tapes, etc. edited by ANENA. Many conferences and displays on snow and avalanches are organized and a lot of information is also given to students and children of school age. Over the years, ANENA has developed an important documentation centre where anyone can obtain more information on snow and avalanches.

Furthermore, since 1996 ANENA has been organizing a two-day practical training course for skiers and mountaineers to teach them how to use a beacon and provide them with essential snow and avalanche knowledge.

## 4. CONCLUSION

This year ANENA celebrates its 26th birthday: 26 years of research, training courses, coordination and information in the service of safety in snow-covered mountains. Important work has been completed, thanks to all members of the Association, and its activities have evolved: now less research and more public information. The fact that it is still very much in demand is proof of the importance of its existence and the interest generated by its activities.

# Viðauki 4

Skrá yfir tjón af völdum náttúruhamfara
í Haute-Savoie, 1992

# LES RISQUES NATURELS EN HAUTE-SAVOIE

## Quelques chiffres

212 communes recensées comme ayant des risques naturels sur l'Atlas national.

En 1992 :

- 42 communes reconnues sinistrées
- 113 routes départementales ou communales coupées
- 1 mort et 4 blessés (les accidents liés aux activités de loisirs en haute montagne ne sont pas ici recensés)
- 130 bâtiments ont subi des dégâts, 1 a été entièrement détruit
- environ 13 millions de dégâts directs

---

NB : *ALEAS NATURELS* **X** *VULNERABILITE* = **RISQUES NATURELS**

# Viðauki 5

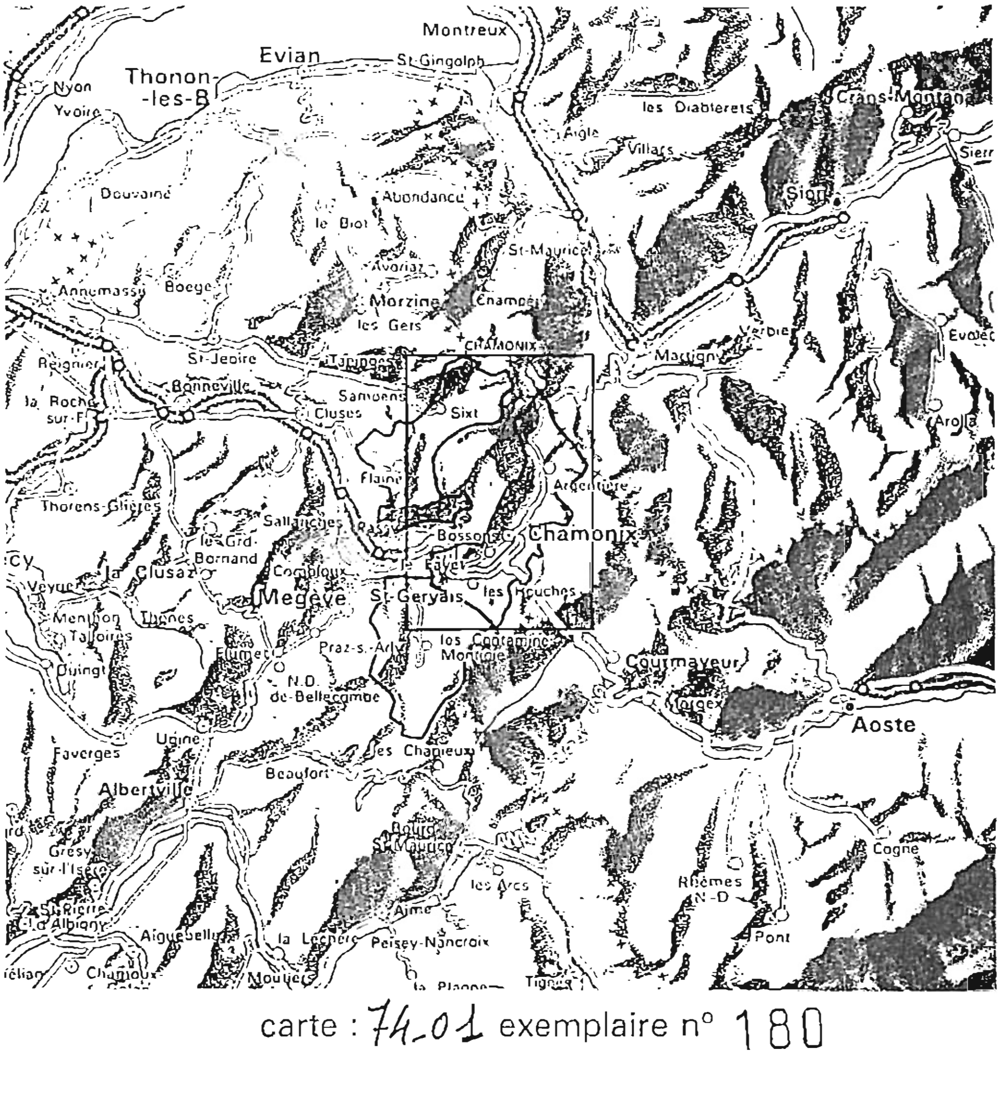
Útbreiðslukort snjóflóða í mælikvarða 1:25.000
gefið úr af CEMAGREF
Ef nánari skoðun er óskað þá liggur eintak af þessu
korti hjá höfundi

CENTRE NATIONAL DU MACHINISME AGRICOLE DU GÉNIE RURAL DES EAUX ET DES FORÊTS

CEMAGREF

CARTE DE LOCALISATION PROBABLE DES AVALANCHES
ÉDITION 1991

# CHAMONIX




carte : 74-01 exemplaire n° 180

échelle 1 : 25 000

CARTES IGN

Avec la participation financière de :

Collaboration technique CEMAGREF Nivologie - INSTITUT GÉOGRAPHIQUE NATIONAL
Photo-interprétation et enquête sur le terrain 1971 à 1975 ; Révision 1991

Direction de l'Eau et de la Prévention des Pollutions et des Risques
Délégation aux Risques Majeurs

**MINISTÈRE DE L'AGRICULTURE ET DE LA FORÊT**
Direction de l'Espace Rural et de la Forêt

# Viðauki 6

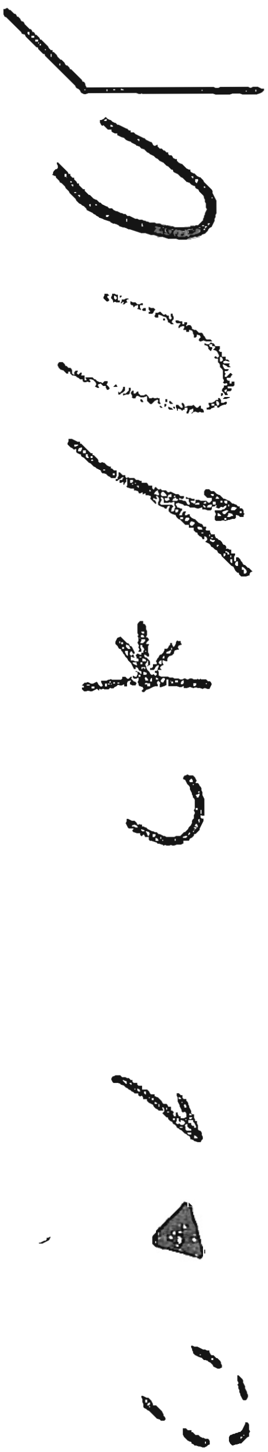
Frumdrög af hættumatskorti gert á RTM skrifstofunni
í Haute-Savoie

DIRECTION DEPARTEMENTALE
DE L'AGRICULTURE ET
DE LA FORET
PREFECTURE DE LA
HAUTE-SAVOIE

RESTAURATION DES
TERRAINS EN
MONTAGNE
DE LA HAUTE-SAVOIE

# NOVEL (74)

## CARTE INFORMATIVE
de localisation des phénomènes (2)



: limite de commune

: avalanches reconnues sur le terrain et/ou confirmées par des témoins

: couloirs ou extensions probables mais non confirmés

: torrents avec divagation

: marais

: glissements actifs ou récents

: fluages ou déformations anciennes

: ravinements actifs

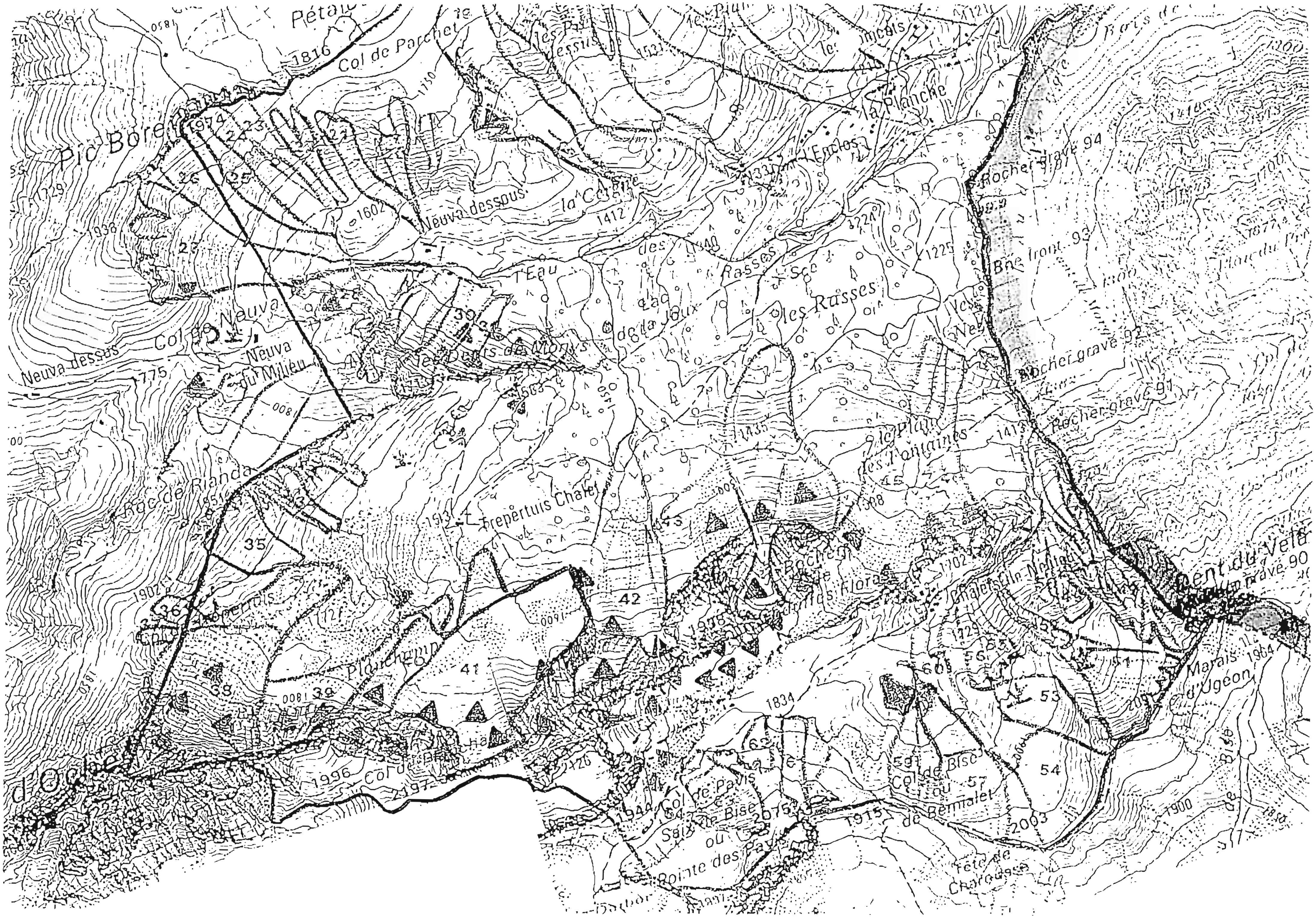
: chutes de pierres ou de blocs

: limites d'écroulements

Vu pour être annexé à mon arrêté
du ..............................

Albert DUPUY

Echelle 1/10.000
Juillet 1995
J.L



Col de Parchet
Pic Boret
Neuva dessous
la Cergne
la Planche
l'Enclos
Col de Neuva
Neuva dessus
Neuva du Milieu
les Rasses
Lac de la Joux
Rocher gravé 94
Rocher gravé 92
Rocher gravé 91
Rocher gravé 90
Bne front. 93
le Plan des Fontaines
Roc de Rianda
Trepertuis Chalet
Planchamp
Col de Pavis
Col de Bise
de Bennalet
Marais d'Ugeon
Pointe des Pavis

# Viðauki 7

The application of natural hazard mapping: the example of the method followed by the RTM Service of Haute-Savoie, France

Nicolas George

# The application of natural hazard mapping: the example of the method followed by the RTM Service of Haute-Savoie, France

In the French Alps, natural hazards have been traditionnally considered by the inhabitants, so preventing these hazards is essentially done by controlling the establishment of new buildings. This is done mainly by regulation documents such as the Foreseeable Natural Hazards Prevention Plan, in french *Plan de Prevention des Risques naturels prévisibles* (*PPR*). This plan consist of three stages, at the scale of the french "*commune*" (township); first it takes the census of all the phenomena that can lead to a risk, second it extends that census to all the potential risks and third it fixes the regulations needed to protect from the resulting hazards.

## 1. The natural phenomena localisation map

The first step to follow is to take the census of all the existing risks, even if they do not threat any human activity, so as to give a complete view of the natural phenomena on the studied area.

### 1.1. Finding the information

The information should be looked for in any place it could be: in Haute-Savoie the main part of it is in the RTM's records, but it can be also found in other govenmental services like the Equipment that deals mainly with roads, or the Agricultural Department that deals with rivers; the rescue services and insurances can also be of good help by keeping a record of their actions on natural phenomena, and a close look should be given to local newspapers. The local communities, townships mainly in France, and even more so the inhabitants themself often give the last part of information and can be useful too. Each of these origins has a subjective view on natural risks that shall be kept in mind: newspapers often look for spectacular events and may embellish the facts, while local communities may see the risk mapping only as a constraint and sometimes reduce the gravity of the events, for example.

This of course is completed by ground observation, both in reality and by photo-interpretation, that shall detect all the pheunomena that are not seen as dangerous because of their distance from human activities and so are not recorded or even remembered (falling rocks in a unexploited forest or avalanches in a uninhabited valley, for example), but are useful for a global understanding of all the natural processes.

### 1.2. Gathering the information on the map

The questions to answer are about the exact nature of the observed phenomena and their date of occurrence and localisation. All this information is gathered on a detailed map (we generally use a topographic map at the scale 1/10.000 or sometimes 1/25.000), called "*Carte de localisation des phénomènes naturels*", or «natural phenomena localisation map»; it is completed by a list of the phenomena, giving information about their exact nature, intensity and frequency.

# 2. Determining the probable risks: the risk map

2.1. The risk notion

Recording all the past events shall lead to find, somehow, a mechanism of occurrence for these events, and so determine the probable occurrence of events of the the same type in the future.

At this stage, the influence of these events on human activities is not really considered. However, we may map only areas where human presence is possible; the accuracy of the mapping may also be rougher in areas with very little *potential* vulnerability; it shall not be forgotten to consider not only the present human occupation, but the possible future ones when making these choices.

2.2. Determining the risk

*2.2.1. The principles of mapping*

Finding that "mechanism" of occurrence is a real expert's job: it can be considered that the occurrence of a phenomenon is linked to the existence of favourable factors; some are invariable (topography, geology...) and can be easily considered, but the factors that trigger off the event are often less predictable (amount of fallen and drifted snow for an avalanche, changes in hydrology for a landslide...) and shall generally be taken as the worst probable, as we consider the *probable* events. Beyond this modelisation, the choices of the expert are much more directed by a fine ground appreciation and experience; at this stage too, ground observation and also photo-interpretation are of great help.

The attention paid to all the possible favourable factors can also lead to find risks that were not recorded during the first stage of phenomena census; the phenomena localisation map shall of course not be seen as exhaustive. Particularly, events caused by human action shall be carefully considered; for example, deforestation can create new avalanches and accelerate erosion; at the contrary, the abandon of traditionnally cultivated and drained areas can favour landslides; there are also cases of subsidence due to mining or underground water pumping.

Much attention is paid to take the census of *all* the risks on the same document, so that the "white" areas of the regulation map are really without any significant hazard, and not only without any of the studied ones.

*2.2.2. To use or not to use models: two examples concerning avalanches*

It is important to notice that we do not use any special investigation to fix the risk, such as close geotechnical investigations for landslides or trajectory modelisation for falling rocks or avalanches; the cost in time and money needed by these methods to give appropriate validity and accuracy is generally much too big for mapping large areas. Meanwhile, we may use hydraulic studies to help appreciate floods (the expert's look alone is not really sufficient for that kind of phenomenon), and pre-existing detailed studies when they are available.

For the case of avalanche risk, we have tested the Norvegian statistic method (Lied & Bakkehoi, 1980 - Bakkehoi *et al.*, 1983) that uses topographic parameters to determine the maximal runout of an avalanche, with the good statistic material existing since 1900, mainly on avalanche paths around Chamonix. The result was a globally poor adaptation of this model to our region, due to the variable shapes of avalanche paths. Indeed, this model assumes that the path, in a vertical plan, can be fitted by a second-degree polynome; this is often not the case because of all the topographic accidents one can find in the Alps. For example, a glacier valley will show a "U" profile, and so avalanche paths with steady slope until a flat runout zone; there were also, in that study, several paths with an intermediate flat runout zone before a second track. That study has also shown a great influence on the final results of the starting zone dimension, that is generally not easy to measure precisely. It was so concluded that the Norvegian model did not generally fit Alpine avalanches.

On the other hand, we have an example of successful use of modelisation for avalanche risk, on the avalanche of Le Bourgeat (Les Houches), near Chamonix. On December 26, 1993, an exceptionnal *powder* avalanche made some damage in an area of neglectable risk, according to the existing *P.P.R.*. It was then thought that numerical modelisation could help the expert on assessing the path of a future powder avalanche. The model used was a 3-dimensions flowing model, already validated with a physical model. First the model was levelled on the occured avalanche: the model should give an avalanche with a zone of over 100 daN/m$^2$ pressure coinciding with the zone of significant damage, as seen by the expert; the calculated height of avalanche during flowing was also compared with photographs of the real avalanche. Once the model levelled, the amount of snow in the starting zone was increased and then reduced of 30%, to assess what could be a greater avalanche. On this basis a new risk map was determined, taking into account as much as possible all the badly known parameters of the modelisation (for the levelling, speed and density of the avalanche have only been estimated; a deflecting dam 5 m high was ignored in the modelisation). In this case, a careful use of complex (and costly) models has proved to be helpful in determining powder avalanche risk, that is always hard to assess by the expert's look alone. This has been done experimentally; but the cost of that study prohibits the use of the method for all the powder avalanches.

### 2.3. Quantifying the risk

The resulting risk shall be quantified. The preeminent factor is the intensity of the phenomenon, taking into account its physical importance (deplaced volume for a landslide, speed and height of water for a flood, strength on obstacles for an avalanche...); as the result of the Plan consists mainly of building control, the levels of intensity can be linked to the influence it could have on a potential building, if the studied area allows it (that method asks for great imagination if used on an area where building is unconceivable, because of the steepness for example). Anyway, a thought shall be given to that as the risk levels will somehow determine the regulation mapping.

The second factor is the frequency of the phenomenon, especially with low intensities: an annual low-intensity phenomenon is generally considered as a strong or mean risk, but the same one can be seen as neglectable if only centennial. This mechanism can be used as soon as the risk is acceptable (i.e. only low, material damage); large intensities often mean important damage and sometimes death hazard, that can not be accepted even one only time. In the French Alps, it has been chosen to consider only the probable events in the next century; that is the average lifetime of an ordinary human building, and it has also been found looking at the past that human activities can change quickly, making the regular document outworn beyond this limit.

Crossing these two factors leads to define several risk levels. In Haute-Savoie we use three levels: weak, mean and strong (in french *faible*, *moyen* et *fort*). There is of course a null level that means null or neglectable risk, and the three other ones are defined for every type of risk. That is not the only system: for example, the RTM Service of Savoie uses six different risk levels to avoid crossing intensity and frequency: there are weak, mean and strong intensity levels for both low and high frequencies. Because of the Haute-Savoie RTM's habit to work very close with local communities, we prefer more concise ways to show risk, that can be easily read by non-expert.

### 2.4. The risk map

This leads to a second map, called risk map (in french *carte d'aléas*). It has generally the same scale and presentation (topographic map) as the localisation map, but sometimes the land registry (that will support the regulation mapping) is used, with then a smaller scale (1/5.000 or even 1/2.000), leading more easily to the regulation map. Pay attention to the fact that a too small scale only gives illusory accuracy: with the only expert appreciation of the risk, a scale of 1/10.000 is largely enough; a pen's stroke 0.5 mm thick represents 5 m on the ground, and we can hardly assume less than a 10 m precision in the risk mapping.

## 3. Assessing the vulnerability: the regulation mapping

We now have a precise mapping of the probable future phenomena, so as to be able to protect the populations by avoiding them to be exposed to these events, or more precisely to those that present a higher hazard than the maximum acceptable hazard: while a risk is only a probable event, the hazard represents the potential damage made by this event. Therefore, we have to fix that acceptable hazard, of course by common consent with the exposed population. The part of the mapper slides from the natural risks technician to the developper's one, and the work has to be done in close contact with local communities.

### 3.1. From risk to hazard

The basis principle of translating the risks map into a regulation map is to look for suitable measures to neutralize the risk's effects on the studied area, according to the occupation of this area. Measures can be detailed preliminary studies, draining or building reinforcement for landslide risks, building reinforcement, arrangement or occupation for avalanche risks, building raising for flood risks... If the protection measures are impracticable, because of technical impossibility or too much elevated cost (we assume in Haute-Savoie that the protection cost should generally not exceed about 10% of the total building cost, but for a new building the choice is let to the builder), the building is forbidden. That leads generally to forbid building on strong risk areas (these areas are then called *red* areas), and to set protection measures on mean and weak risk areas (*blue* areas). Nevertheless, it is possible to build in a strong risk area if the size of the project can justify costly protections; at the contrary, any occupation is often forbidden in weak or mean floods risk area, to preserve the flood damping capacities of submerged areas: the work shall be done studying any particular matter.

### 3.2. The notion of acceptable hazard

The aim is not to protect from *any* hazard: for example, the seismic risk is unavoidable; paraseismic construction allows to reduce it, but there is still a residual hazard for big earthquakes, that is necessarily accepted by the inhabitants if they do not leave the country. The aim is therefore to set this residual hazard, the hazard remaining after protection measures, at an accepted size.

Another example: in 1892, the breaking of an underglacier water pocket on the Tête Rousse glacier, in the Mont-Blanc range, caused a big mudflow that devastated the thermal establishment of Saint Gervais built downstream, killing 175. The probability of occurrence of such a drama on other glaciers of the range is very low but not null (maybe more than one event in one thousand years); nevertheless, this probability is not taken into account because it would lead to forbid occupation in all the higher part of the valley, evacuate 50.000 to 100.000 inhabitants and stop also any economic activity; the cost of that is completely unstandable for the community, and so that is an accepted hazard.

3.3. The protection measures

The stipulated measures are often building measures (reinforcement of walls, size and layout of the openings, drainings...) but can also set the occupation, for example forbidding it in periods of avalanches if it is suitable with the building's use, or the arrangement of buildings so as to have only a few exposed buildings protecting the other ones, or the maintenance of the forests, or the information of the inhabitants about risks... For the mentioned reasons of cost, large protections as dams or paravalanches in starting areas are exceptionnally prescribed

In the red areas, where establishment of new buildings is forbidden, changes to existing buildings can be authorized if these changes tend to reduce the hazard in or around the area; in blue areas, it is not possible to prescribe protection measures costing more that 10% of the existing building's value.

3.4. The regulation map

All these prevention measures are gathered on a regulation map, based on the land registry (scale 1/5.000 to 1/1.000), so that every land plot can be linked to the suitable regulations. The areas where building is forbidden are shown in red, the ones where protection measures are needed are shown in blue; for every area a number leads to the regulations that are gathered in a list enclosed to the document. The area where risk is neglectable or null remains in white.

This regulation concerns only areas with potential vulnerability; we generally consider the only areas reached by a carriage-road. The other areas are generally concerned by the risk map, that can lead by the same way to a particular regulation if needed (for example, in the case of a ski resort project in a previously uninhabitated area, not concerned by the regulation map).

3.5. Other methods of vulnerability assessing

That is the way we consider vulnerability, but it is of course not the only one; there are particularly more quantitative methods to evaluate the precise cost threatened by the risk, that have been applied in several cases in France, especially with flood risks. The example taken here comes from the french *Major Risks Department* (in french "*Délégation aux Risques majeurs*"), a department of the Environment Ministry that tries to federate the hazard administration in the country.

First, the method distinguishes human vulnerability (the probability to have killed, injured or homeless persons) from economic vulnerability (cost of material damages and losses of productivity) and public interest vulnerability (damages to public equipments such as communication means, hospitals, schools...).

The risk is then quantified into endamagement levels, which size the damage caused, according to those three types of vulnerability: for example, the economic risk is weak if the cost of the prevention does not exceed 10% of the cost of an individual house, and is strong if this prevention can only be supported by the collectivity.

For every risk and endamagement level, a damage cost is assumed in relation with the ground occupation (population, economic activity...) and multiplied by the mathematical probability of the damage; these probable costs are then summed into the total probable cost, that represents total vulnerability.

This method can therefore be applied to risk where probabilities and costs of damages are well known, to obtain a reliable value of vulnerability; that limits its use to hazards that have already caused a statistically reliable amount of damages.

3.6. The final presentation of the Plan

Finally, the Plan contains the three maps (localisation, risk and regulation maps), enclosed with a general presentation booklet that presents the township and the method used, and details for every risk zone the exact nature of risk and an history review of past events, justifying the regulation; a second booklet lists the regulation areas and the corresponding regulations.

A special word is also given about seismic hazard. This hazard has been mapped at a regional scale in France, so that every district is classified according to the historical and instrumental seismic activity (*historical* activity is based on all the related earthquakes, that can be found in history while *instrumental* activity is based on the present earthquakes, that are precisely measured and localised). The Plan gives therefore the classification of the township and the corresponding paraseismic building regulation. It has been tried to make a precise seismic mapping in the region of *Nice*, in the south of France, taking into account topography's and geology's local influence, but the cost of such a study is out of proportion with the seismic hazard in the Haute Savoie (no earthquake with more than VIII MSK intensity has been recorded in the region).

# 4. Conclusion

The exposed method shall be seen as particular to the Haute-Savoie, and probably not directly appliable outside the French Alps. First, hazard mapping methods are almost as numerous as hazard mappers in France, so there are many other methods than the one presented here, each one making particular choices adapted to particular situations.

The French Alps have been inhabited all year through at least since the Antiquity, very probably during Prehistory; we have reports on its natural hazards since the Romans, know the greater disasters for about one thousand year and have relatively precise records concerning the XXth and often XIXth centuries. The permanent habitation has led to regulations concerning natural hazards since a long time; although they were generally unwritten traditions in the mountain communities, there was an edict in the *Dauphiné* (Grenoble's region) forbidding deforestation in 1282. All that historical background facilitates the natural hazards mapper's task, giving him some good and sometimes even statistical information on past events and giving also the populations a relative *hazard culture*, generally remaining even if the meltings of populations and new uses of the mountain areas, as tourism, occured in the last century tend to reduce it.

The intrinsic nature of the phenomena is also particular: for example, our middle-altitude forests keep a good trace of past avalanches, for about 50 years for the greater ones thanks to the photo-interpretation tool.

Because of all these factors, any adaptation of this method should be very carefully made, maybe particularly in Iceland where natural as historical and cultural backgrounds are quite different.

We have described here the method we use the most commonly to *prevent* hazards; keep also in mind that even with the historical hazard culture in our region, we often have to deal with existing hazards in inhabited areas. The problems are often solved with civil engineering (paravalanche engineering for example) to act directly on the risk. The avalanches can also be controlled by artificial release, mainly in ski resorts but sometimes also in inhabited areas; the aim of the «avalanche releasing plan» (in french "*Plan d'Intervention pour le Déclenchement des Avalanches*" or "*PIDA*") is to fix the evacuations needed and the general security of the process . More generally speaking, the *ORSEC* plans («rescue organization plan») consider the problems of recue organisation and evacuation, they are fixed at the scale of the french *"département"* (county) and can be applied to any type of risk. The Plan described here is only one of the numerous tools of natural hazards management.

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# Viðauki 8

A summary of French avalanche protection techniques

Francois RAPIN

# A SUMMARY OF FRENCH AVALANCHE PROTECTION TECHNIQUES

*François RAPIN* [1]

## ABSTRACT

The different kinds of an avalanche protection must be well organized for to be well exploited. One elements can be good in a special situation and bad in another. A comparison safety - cost of different protections can to resume advantage and drawback. French special fields are the snow rake, the artificial release tecniques and the standardization.

## INTRODUCTION

The collective solutions for avalanche protection can be presented in 2 ways :

- **according to the duration** of the protection :
  - **permanent** protection, that works by building durable structures (more than one year) for reducing risk;
  - **temporary** protection, that tends to protect for a limited time (a few hours to several days), in times of great risks, but in a strong manner, very often with the help of nivo-meteorological forecast ;
- **according to the point of intervention** with the avalanche :
  - **passive** protection, that aims to protect existing equipment in the run-out and flow zones from the avalanche;
  - **active** protection, that attempts to control the avalanche through actions in the starting zone.

**PERMANENT PROTECTION**

- **Passive** Table 1
  - Deflecting : snow shed, dam, dyke, wedge
  - Braking and stopping : mound, tooth, wall
  - Stopping : wall, dam (storage : deposit field)
  - Zoning : inquiry of localisation
  - Adaptation, reinforcement of the buildings to the site/phenomena
- **Active** Table 2
  - Reforestation : plantation
  - Modification of the ground surface : terrace (small), grass cutting, drainage
  - Use of wind action : snow fence, drift defense
  - Supporting snow cover : snow rake, snow bridge, snow net

**TEMPORARY PROTECTION**

- **Passive** Table 3
  - Regulation : ban, evacuation
  - Warning : means of signalling, avalanche road detector
- **Active** Table 4
  - Packing down
  - Artificial release
    - with skis
    - with explosive
      - hand-thrown charge
      - helicopter
      - gun
      - pneumatic gun
      - carrying cable : CATEX
    - with gas : gas exploder : GAZEX

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Together, these can be summarized in 4 tables (see the following pages. without zoning). This summary does not claim to be exhaustive. For example, temporary building, packed snow and avalanches released with a gun are not discussed. It simply sums up the most common French avalanche protection techniques.

The goal of any protection proposal is to test the assumption that there is one solution to the "equation" :

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| geographic site | + | avalanche phenomena | + | protection goal | + | constraints techniques, finances, regulations | = | acceptable protection solution |

A thorough knowledge of each parameter is indispensable. if one is to correctly solve the equation. It is possible to determine that this "equation" does **not have a solution**. In **time**, one is often able to find a solution using the knowledge of a new avalanche phenomena, the modification of the protection goal or the adoption of a new technique. Often, a suitable protection solution can be found only by **combining several types of protection**.

USE : FOUR FIELDS :

| LIVING PLACES | COMMUNICATION ROADS | SKI AREAS | "INDUSTRIAL" DEVELOPEMENTS |
|---|---|---|---|
| Single house<br>Hamlet<br>Village | National, Local Road<br>highways<br>Railway | Ski-lifts (pylon. station)<br>Open ski runs<br>Cross-country ski runs ? | Snow making installation<br>Dam, Electric ligne |

FRENCH SPECIAL FIELDS :

1 Use of **snow rake** rather than snow bridge ;
Historical habit rather than technical.

2 Development and use of **artificial release techniques** ;
Development of the avalanche blasting ropeway (CATEX in french) and of the pneumatic gun since the end of 70, of the gas exploder (GAZEX) since the end of 80 ; Special rules since 1980.

3 **Standardization** of few types of protection equipments against avalanches.
- 3 approved standards since 1992 december : snow bridge, snow rake, snow fence - Design specifications
- 1 future approved standard in august 1994 : Passive concentrated anchors for soft ground - Pull out tests method
- 4 standards in run on the artificial release (General technical principles, CATEX, GAZEX, Pneumatic gun).

## Table 1 : PERMANENT PASSIVE PROTECTION

| TYPE OF ACTION | DEFLECTING | | | BRAKING | STOPPING | SELF-ADAPTATION |
|---|---|---|---|---|---|---|
| | **Over** | **Laterally,** on one way | **Laterally,** on two ways | Slowing down ; dispersal of energy | Blocking ; storage | **Architectural requirements** to the site/ phenomena |
| **TYPE OF WORK** | **Snow shed,** springboard, tunnel | **Dam,** dyke | **Splitting wedge** (prow) | Mound, tooth, storage field | Wall, dam, storage field | **Reinforcement,** thickening, blindness |
| **EQUIPMENT CONCERNED BY THE PROTECTION** | Linear : roads, railway... | Large or faraway area : urbanization, roads.. | Limited : pylon, house | Large or faraway area : urbanization, roads.. | Large or close area: urbanization, roads... | Limited : pylon, house |
| **SAFETY LEVEL** | Very good (if rather long) | Good (but variable) | Good (if rather high) | Low (but variable, good if near the extreme deposits limit) | | Good (but rather variable) |
| **COST LEVEL** (Investment) | Very expensive | Medium (but very variable) | Expensive | Low (mound), very expensive (tooth) | Low (dam), expensive (wall) | Very low (with exceptions) in front of post-solutions |
| **ADVANTAGE** | Makes safety way by all kind of weather | Good value for money (quality - price ratio) | Can be easily added | Reduction of the natural stopping distance (if protection in this area) | | Unobtrusive |
| **DRAWBACK** | Increases length to protect because of slope reducing uphill | Not convenient for aerosol ; Angle | Preservation of the free height ; direction | Preservation of the free height and volume ; requested area ; calculation of ideal dimensions with regard to the major phenomena only | | Must be viewed from the conception |
| **REMARK** | Pay attention to the width in bend | Better with a vertical uphill wall ; Be careful if other adjoining structure | | Needs to be in net | Better with vertical uphill wall | People must be sensitive |

# Table 2 : PERMANENT ACTIVE PROTECTION

| TYPE OF ACTION | MODIFICATION OF THE GROUND SURFACE | | | USE OF WIND ACTION | | SUPPORTING SNOW COVER | |
|---|---|---|---|---|---|---|---|
| | Reforestation | Agricultural activities | Excavation works | Displacement of a deposit | Modification of a deposit | Stiff | Supple |
| **TYPE OF STRUCTURE** | Plantation | Drainage, grass cutting | small **terrace** (l = 1 m) | **Snow fence** | Drift defense, jet-roof | **Snow rake, snow bridge** | **Net** |
| **EQUIPMENT CONCERNED BY THE PROTECTION** | Recorded in times | Large or faraway area but less sensitive or very marginal | | Large or faraway area : urbanization, roads ... Help for the supporting structures | | Large or faraway area : urbanization, roads ... Sometimes ski area | |
| **SAFETY LEVEL** | Medium (starting zone, height) | Low (only against a ground avalanche) | | Medium (if well located) | | Very good (but rather variable) | Good (but rather variable) |
| **COST LEVEL** (Investment) | Medium : very low for each unit but concerned great area | | | Expensive | Very expensive | Very expensive | Expensive |
| **ADVANTAGE** | Pleasantness ; fight against erosion | Simple technique | Association with reforestation | Good value for money if pair site/equipment perfectly adapted | | Solid technique | Discreet ; If small rockfall |
| **DRAWBACK** | Initial life without protection ; Degradations risks | Uncertain durability | Resumption of erosion ; Difficult maintenance | Snow fall without wind or with wind in a bad direction : winter surveillance ; delicate settling | | Less efficient with snow cover without : cohesion | good cohesion |
| **REMARK** | Ecological conditions ; "productive" investment | Only for low snow cover ; inefficiency against major phenomena | | Permanent or removable ; self-adjustable | Division in 2 sub-sectors ; deletion of a cornice | Must cover all the starting zone ; layout in continuous lines ; essential emergence ; required settling | |

## Table 3 : TEMPORARY PASSIVE PROTECTION

| TYPE OF ACTION | RESTRICTING REGULATIONS | | | WARNING | |
|---|---|---|---|---|---|
| | Ban | Evacuation | Consignment | Signalling | Avalanche road detector |
| TYPE OF STRUCTURE | Police ability of the Mayor :<br>written (in urgency, in first, only oral order) ;<br>Advice of a safety staff ; | | | Flag (in France, with black and yellow check : danger ; all black : acute and general danger) ; road signs | Detections (cables, radar) in the path, broadcasting, red lights on the road |
| EQUIPMENT CONCERNED BY THE PROTECTION | Large or linear area : roads, ski-run, ski-lift | "Limited" :<br>block of flats, hamlet, building site | | Large or linear area : ski area, roads | Only roads |
| SAFETY LEVEL | Medium : depends on :<br>- the quality and on the speed of the mayor and his safety staff<br>- the plan of action giving the information | | | Medium :<br>depends on the timeliness | Good<br>(but supervision of the good working) |
| COST LEVEL (Investment) | Very low (but variable) | | | Low | Medium<br>(except exceptions) |
| ADVANTAGE | Very good quality/price ratio ; large abilities ; urgency ; easily to start | | | Simplicity | Automatic |
| DRAWBACK | Needs serious danger ; intervention neither untimely, nor inadequate ; difficult to stop ; decision and liability problems ; requires to allow some "assistance or intervention plans" | | | Risk of every day fact | Essential adaptation of the path and of the road |
| REMARK | In France no indemnity is given in this case to the threaten owner in spite of the possible heavy economical loss | | | | |

## Table 4 : **TEMPORARY ACTIVE PROTECTION** : ARTIFICIAL RELEASE

| **TYPE OF ACTION** | | **WITH FOOT** | **WITH EXPLOSIVE** | | | | **WITH GAS** : GAZEX |
|---|---|---|---|---|---|---|---|
| | | | Hand-thrown | Helicopter | Pneumatic gun | CATEX | |
| **TYPE OF EQUIPMENT** | | Skis, rope, ARVA | Skis, cord, sled, ARVA | Special box for the explosives | Avalancheur ; "arrow" ; liquid explosive | Carrying cable ; options : descender, automatic control | 2 gas mixing(oxygen and propane) in one strong open tube |
| **EQUIPMENT CONCERNED BY THE PROTECTION** | | Ski area | | Insensible (ski run...) ; free area unknown | Ski area | Ski area, road | |
| **SAFETY LEVEL** | | Very low for user | Medium (but variable) | | Good | Good | Very good |
| **COST LEVEL** | Invest. | Very cheap | | | Medium | Expensive | Very expensive |
| | Running | Medium | | Very expensive | Expensive | Expensive | Medium |
| **ADVANTAGE** | | Quite easy (with very rigorous preliminary organisation) | | Practical | Good precision ; discreet ; no explosive storage | Can work on many parallel tracks or on 2 sides | No explosives ; easy management |
| **DRAWBACK** | | Very dangerous | Dangerous (especially at the time of moving) | Meteorological conditions ; authorization | Range ≤ 2000 m ; difference in height < 500 m ; | Location ; rime, wind, lightning ; management | One track per tube ; very hard cold, lightning, regulations |
| | | | Use of explosives, regulations, misfiring problem | | | | |
| **EFFICIENCY** | | Low | Medium (but variable) | | | Good | Very good |
| **REMARK** | | **Goal :** To bleed starting zone as soon as a snow fall height reaches 20 to 30 cm within 3 days : preventive measure (not for urbanizable area) ; **Regulation :** * 2 goals : public and user safety + control of the use of explosives to pacific goals ; * 3 **French obligations :** special plan (precises : where, with whom, how) for the aera + firing specifications (precises the role of each) + special certificate (with option "Firing in mountain") and administrative authorization for the tecnical man ; **Mean :** maximal efficiency if explosion from 1 to 5 m above snow cover | | | | | |

## Table 5 : COMPARISON SAFETY - COST

(non exhaustive list and put in a living place protection context)

| Protection type | Safety level | | Cost level without taxes (in France) in 1994 | | | | Ratio safety/costs |
|---|---|---|---|---|---|---|---|
| | | | Investment | | Running/year | | |
| Deflecting dam | Pay attention to : the deflecting angle, the height, the verticality of uphill face | ★ | 6 $/m$^3$ | ★ | ? | ★★ | ★ / (★ + ★★) |
| Braking mound | Needs a storage field and others protections ; requires a situation in a natural run-out zone | ■ | 7 $/m$^3$ | ★ | ? + the snow clearing | ★ | ■ / (★ + ★) |
| Stopping dam | | ■ | 6 $/m$^3$ | ★ | | ★ | ■ / (★ + ★) |
| Zoning | Needs a dialogue leaded to the goal in good conditions | ★ | 30 000 $ | ★ | 0 $ | ★★ | ★ / (★ + ★★) |
| Terrace | Only for a ground avalanche | ■ | 20 to 75 $/m | = | 0.5 $/m | ★ | ■ / (= + ★) |
| Snow fence | Needs adapted site ; others protection are essential | = | 600 $/m | ■ | 2 $/m | ■ | = / (■ + ■) |
| Snow rake | All the starting zone must be treated ; be careful with the height | ★★ | 1 000$/m | ■■ | 2 $/m | ■ | ★★ / (■■ + ■) |
| Regulation | Practical and juridical problems | = | 2 500 $ | ★★ | ? $ | ★★ | = / (★★ + ★★) |

**Appreciation key :**

| ★★ | ★ | = | ■ | ■■ |
|---|---|---|---|---|
| Very good | Good / cheap | Neither good, nor bad | Bad / expensive | Very bad |

## Table 6 : COMPARISON SAFETY - COST

(non exhaustive list and put in a road protection context)

| Protection type | Safety level | | Cost level (in France) Investment | | Cost level (in France) Running/year | | | Ratio safety/costs |
|---|---|---|---|---|---|---|---|---|
| Snow shed | Be careful with the length | ★★ | 18 000 $/m | ■■ | 0 | | ★★ | ★★ / (■■ + ★★) |
| Stopping mounds | Needs other measures ; situation in stopping zone | ■ | 5 $/m³ | ★ | ? $ | | ★ | ■ / (★ + ★) |
| Ban | Problems with the closing and with the new opening | = | 2 500 $ ? | ★★ | ? $ | | ★★ | = / (★★ + ★★) |
| Avalanche road detector : ARD | Needs path and road adaptations | ★ | 70 000 $ | [illegible] | 1 000 $ [illegible] | + the snow-clearing cost | ★ | ★ / ([illegible] + ★) |
| Helicopter bombing | Meteorological difficulty risk ; needs explosive | = | 4 000 $ | ★★ | 8 000 $ | | ■■ | = / (★★ + ■■) |
| CATEX | Be careful with the access way ; needs explosive | ★ | 100 000 $/km | ■ | 4 000 $ | | ■ | ★ / (■ + ■) |
| GAZEX | Needs nobody in the starting zone but all its areas must be treated | ★★ | 90 000 $/U spreadable | ■■ | 3000 $ /shelter | | = | ★★ / (■■ + =) |

**Appreciation key :**

| ★★ | ★ | = | ■ | ■■ |
|---|---|---|---|---|
| Very good | Good / cheap | Neither good, nor bad | Bad / expensive | Very bad |

## Table 7 : COMPARISON SAFETY - COST

(non exhaustive list and put in a ski run protection context)

| Protection type | Safety level | | Cost level (in France) | | | | Ratio safety/costs |
|---|---|---|---|---|---|---|---|
| | | | Investment | | Running/year | | |
| Snow fence | Needs adapted site | = | 600 $/m | ■ | 2 $/m | = | = / (■ + =) |
| Snow rake | All the starting zone must be treated ; be careful with the height | ★★ | 1 000 $/m | ■■ | 2 $/m | = | ★★ / (■■ + =) |
| Ban | Problems with the closing and with the new opening | = | 2 500 $ ? | ★★ | ? $ | ★★ | = / (★★ + ★★) |
| Hand-thrown charge | Needs one relatively easy approach when bad nivo-meteorological conditions | = | 2 500 $ | ★★ | 1 000 $ | ★ | = / (★★ + ★) |
| Avalanche pneumatic gun | Pay attention to the approach to shooting place ; liquid explosive making | ★ | 30 000 $ | = | 5 000 $ | ■ | ★ / (= + ■) |
| Helicopter bombing | Meteorological difficulty risk ; needs explosive | = | 4 000 $ | ★★ | 8 000 $ | ■■ | = / (★★ + ■■) |
| CATEX | Be careful with the access way ; needs explosive. | ★ | 100 000 $/km | ■ | 4 000 $ | ■ | ★ / (■ + ■) |
| GAZEX | Needs nobody in the starting zone but all its areas must be treated | ★★ | 90 000 $/U spreadable | ■■ | 3000 $ /shelter | = | ★★ / (■■ + =) |

**Appreciation key :**

| ★★ | ★ | = | ■ | ■■ |
|---|---|---|---|---|
| Very good | Good / cheap | Neither good, nor bad | Bad / expensive | Very bad |