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FLOOD SIMULATION EXPERIENCES IN ALPINE WATERSHEDS

ERFAHRUNGEN IN HOCHWASSERSIMULATIONEN FUER KLEINE EINZUGSGEBIETEN DER OSTALPEN.

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Summary

A reliable evaluation of flood discharges in alpine watersheds is of the utmost importance, especially when intended to reduce flood damages, and concerns both flood assessment for the design of hydraulic works and real time flood forecasting problems.

In small alpine watersheds, flood discharges are usually assessed using very simple deterministic techniques, such as the rational method. Now, an improved availability of rainfall and discharge data allows a larger use of more sophisticated and efficient techniques, that are already widely used in other geographical regions.

Simulation of flood events in some watersheds of the eastern Italian Alps, ranging from 10 to 200 km^2 areas, has been carried out using unit-hydrograph based models. More particularly, the Clark's unit hydrograph has been used for the analysis. Rainfall excess has been computed using the Curve Number technique.

The paper illustrates the results obtained: model performances are usually good and the unit hydrograph and rainfall excess parameters lie in a realistic range.

Zusammenfassung

Eine zuverlaessige Einschaetzung von Hochwasserabfluessen der Alpeneinzugsgebieten ist sehr wichtig, besonders als Mittel zur Hochwasserschadensverringerung, sowohl fuer die Dimensionierung von technischen Verbauungen wie auch fuer die Belange der real-time Vorhersagen.

Oft werden Hochwasserabfluesse der kleinen Alpeneinzugsgebiete, mit sehr vereinfachten Verfahren, wie die rationale Methode, berechnet. Heute gestattet eine verbesserte Verfuegung von Niederschlags- und Abflussdaten die Anwendung von feineren und effektiveren Verfahren, die in anderen Gebieten seit langem in Betracht stehen.

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Hochwassersimulationen in einigen Einzugsgebieten der italienischen Ostalpen, die eine Flaeche bis zu 200 Km² aufweisen, wurden mit Modellen berechnet, die auf der Methode des Einheitshydrogrammes - in dem Fall des Clarkschen - beruhen. Der Niederschlagsueberfluss ist mit dem Verfahren der Curve Number berechnet worden.

Der Beitrag zeigt die Simulationsergebnisse: die simulierten Daten liegen den aufgenommenen nahe und die Parameter von den jeweiligen Einheitshydrogrammen und Niederschlagsueberschuessen im Bereich der Wirklichkeit.

1. - Introduction

A reliable evaluation of flood discharges of a river is the necessary basis for any, though non-structural, design approach.

When flow peak evaluation is required for ungauged watersheds, it is necessary to use indirect methods, based only on spatially and time distributed rainfall data and on watershed geology, morphology and vegetation.

Many studies on high intensity rainfalls have been carried out in Italy, resulting in an enhanced knowledge and in new methodological approaches to this problem (Della Lucia, Fattorelli, Provasi, 1975; Della Lucia, Provasi, 1985).

In the Eastern Alps, many basins have been gauged, though to different purposes, and the number of cases is now sufficient to begin an experimental research on flood discharges in mountain watersheds using deterministic models.

The objectives of this research are to define the role and the influence of different factors (climatical,

geological, morphological and vegetational) in flood production and to choice the most suitable rainfall-runoff methods to describe the actual system.

2. - Investigation methods

Based on watershed characteristics and data availability, unit-hydrograph models have been selected for the study. These models are widely used in the world, due to their simple structure and good performances.

HEC-1 (HEC, 1985), a well-known simulation model, provides among its characteristics, the possibility to utilize some different methods to compute rainfall excess and to transform it into discharge.

Previous investigations (Cazorzi, 1983) and numerous preliminary trials have shown that the SCS Curve Number method provides good results in small alpine watersheds.

Furthermore, it is well-documented in literature (SCS, 1972) and the CN can be computed also for ungauged watersheds, from soil and land use characteristics. It should be pointed out that the CN tables commonly used in the latter case are not well fit for alpine basins, because they have been mainly devised for agricultural watersheds. Further investigations to the alpine environment will allow to devise improved detailed tables.

The method requires another parameter, the Initial Abstraction, commonly related, a priori, to the CN.

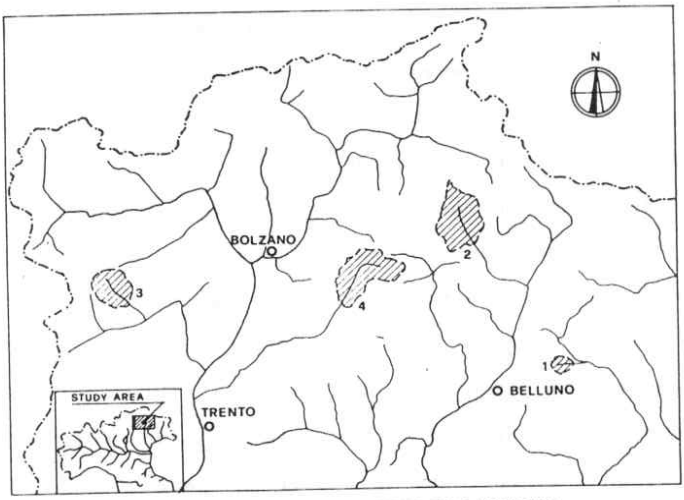
Theoretically, the CN ranges from 0 (no rainfall excess for any precipitation) to 100 (no losses after IA).

In this study the values of both parameters have been determined, for each flood event, with a trial and error calibration procedure.

Previous investigations (Fattorelli, Marchi, 1986) have also shown the validity of the Clark syntetic unit hydrograph (Clark, 1945). This method allows a good flexibility because the two basin parameters, Tc and R, are integrated by a time-area curve obtained subdividing the watershed with isochrones (Laurenson, 1964). Tc is the concentration time of the basin and R is a storage factor. Both have been estimated, for each watershed, by the combined calibration of the available flood events.

3. - Watersheds investigated

The study concerns four watersheds of the Eastern Italian Alps, ranging in area from 10 to 200 km^2. Figure 1 shows the geographical location of the watersheds considered in this paper. Their principal morphometric characteristics are summarized in table 1. These watersheds have been chosen based on the availability of reliable rainfall and discharge data and on their representativity of morphological, geological and vegetation characteristics of small catchments in the geographical region under study.



1 PRESCUDIN TO TORBIDE
2 BOITE TO CORTINA
3 RABBIES TO S. BERNARDO
4 AVISIO TO SORAGA

Fig. 1 - Geographical location of studied watersheds
Abb. 1 - Geographische Lage der untersuchten Einzugsgebiete

Tab. 1 - Principal characteristics of study watersheds
Tab. 1 - Einige Merkmale der untersuchten Einzugsgebiete

Watershed	Area (km)	Average slope (%)	Length of main stream (km)
Prescudin to Torbide	13.4	83.5	5.1
Boite to Cortina	166	48.6	19.5
Rabbies to S. Bernardo	102	63.	14.8
Avisio to Soraga	199	56.6	22.9

4. - Simulation of flood events

Seven flood events were available for simulation in the Prescudin watershed, six in the other watersheds under study. Both summer and autumn events have been considered, in order

to analyse the response of the watersheds under different conditions. Flood events were recorded from 1972 to 1985, so they can be considered representative of the present conditions in the watersheds.

As referred in the previous paragraph, rainfall losses and unit-hydrograph parameters were obtained by calibration using a trial and error procedure. Besides, the model used in the study allows the automatic calibration of these parameters by an optimization routine. This option was used in the first trials of each simulation, in order to identify the roughly approximate values of the parameters.

A constant value has been found in each basin for unit hydrograph parameters Tc and R.

Computing the precipitation excess, should be taken into account the moisture conditions of the basin at the beginning of the rainfall event. As a matter of fact, IA and CN parameters have been found to be rather variable for each flood event.

In table 2 the values of Clark unit-hydrograph parameters are illustrated for the four basins. All the parameters range within the values usually accepted for similar watersheds.

Table 3 to 6 report the IA and CN values and the percent simulation errors as regards discharge volume, peak flow and time to peak for each basin and for each flood.

Tab. 2 - Calibration values of Tc and R
Tab. 2 - KalibrierteWerte von Tc und R

Watershed	Tc (hours)	R (hours)
Prescudin	1.6	5.0
Boite	3.2	7.0
Rabbies	1.1	8.0
Avisio	3.0	7.2

Tab. 3 - Prescudin to Torbide, calibration results
Tab. 3 - Prescudin in Torbido. Kalibrierte Ergebnisse

Event	IA	CN	Percent error		
			Volume	Peak	Time to peak
12.06.72	0.0	12.7	-4.8	0.1	0.0
10.09.76	7.0	11.4	-8.4	0.7	-9.1
19.08.77	0.0	20.0	-2.1	0.6	0.0
22.05.78	15.0	17.0	-5.6	12.9	0.0
09.10.80	60.0	43.0	33.0	1.2	11.8
17.10.80	0.0	31.6	-0.9	-1.4	6.7
25.10.80	5.0	39.7	11.1	-1.3	28.6

Tab. 4 - Boite to Cortina, calibration results
Tab. 4 - Boite in Cortina. Kalibrierte Ergebnisse

Event	IA	CN	Percent error		
			Volume	Peak	Time to peak
31.07.77	1.0	40.2	-0.4	0.4	0.0
22.05.78	1.0	38.0	-3.3	2.0	0.0
08.08.78	1.0	52.2	-2.7	1.4	66.7
22.09.79	1.0	35.0	-6.6	2.8	5.0
15.10.79	1.0	40.0	-0.9	0.2	0.0
09.07.80	1.0	62.8	-0.8	0.6	4.2

Tab. 5 - Rabbies to S. Bernardo, calibration results
Tab. 5 - Rabbies in St. Bernardo. KalibrierteErgebnisse

Event	IA	CN	Percent error		
			Volume	Peak	Time to peak
26.07.77	0.0	42.0	0.2	0.3	0.0
17.10.80	1.0	24.0	3.2	1.9	0.0
28.08.82	0.0	42.0	-2.1	-0.2	0.0
07.09.82	0.0	37.2	-2.0	0.7	25.0
16.09.83	0.0	39.5	0.7	0.0	0.0
06.08.85	0.0	43.2	-0.5	0.6	15.4

Tab. 6 - Avisio to Sorage, calibration results
Tab. 6 - Avisio in Sorage. Kalibrierte Ergebnisse

Event	IA	CN	Percent error Volume	Peak	Time to peak
30.09.76	0.0	48.73	-0.7	0.0	0.0
03.10.78	0.0	24.5	-0.3	-3.9	13.3
09.07.80	0.0	44.5	-4.9	2.2	8.0
27.05.81	0.0	25.4	-0.8	-0.6	7.4
07.09.82	0.0	42.6	-1.9	0.5	20.0
06.09.85	0.0	45.0	14.9	-5.0	0.0

The initial abstraction parameters prove to be really variable only for the Prescudin watershed. In this basin, deep alluvial deposits cause relevant initial losses when they are not saturated by previous rainfalls. In all the other cases the initial abstractions have been found to be almost negligible.

The Curve Number varies for each basin within a rather narrow range. A slightly larger variability has been observed, among the smallest values, for the Prescudin watershed.

Errors are seldom relevant. The time to peak percent errors show to be the most variable, probably due to the quick response of steep alpine watersheds.

For instance, figures 2 and 3 compare the observed and simulated discharges for two floods of the Boite river.

5. - Conclusions

Based on simulation results, some observations can be made on the performance of the investigation method and on

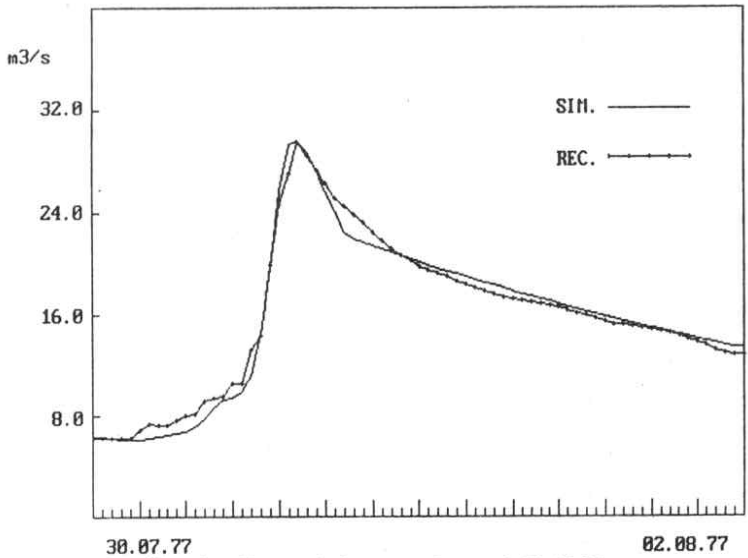


Fig. 2 - Boite of Cortina, flood of 31.07.77
Abb. 2 - Boite in Cortina. Simulierte und beobachtete. Hochwasser Ganglinie vom 30.07 bis 2.8.1977

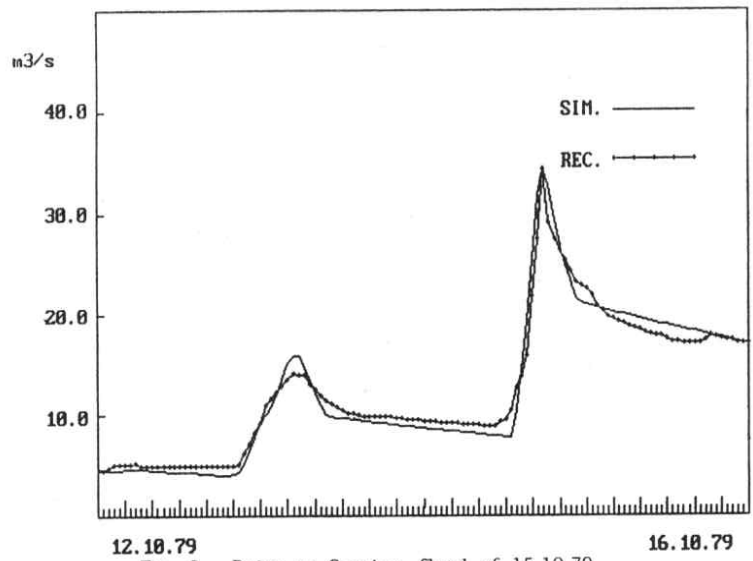


Fig. 3 - Boite to Cortina, flood of 15.10.79
Abb. 3 - Boite in Cortina. Simulierte und beobachtete Hochwasser Ganglinie vom 16.10.bis 16.10.1979

the parametrs values required by such methods.

As pointed out, the percent error between simulated and observed flow shows that the simulation results are generally satisfactory. The study show that, among rainfall-runoff models, the unit-hydrograph approach is able to assess flood events in small alpine watersheds.

With reference to simpler deterministic methods (as the rational method), the unit-hydrograph models only requires a few more detailed data and need a personal computer. On the other hand, they offer a really better resolution and an improved operation flexibility.

When more studied cases are available, it will be possible to develop techniques for estimating rainfall excess and the unit-hydrograph parameters starting from the morphological, hydrological and land use characteristics of watersheds.

6. - REFERENCES

CAZORZI F., 1983. "Indagine sul metodo dell'idrogramma unitario del SCS". Quaderni di Idronomia Montana, n. 3, 45-66.

CLARK C.O., 1945. Storage and the unit hydrograph. Trans. Am. Soc. Civ. Eng. 110, 1419-1426.

DELLA LUCIA D., FATTORELLI S., PROVASI C., 1975. Sul regime delle piogge intense nelle Alpi Orientali. Atti del Congresso Internazionale "Interpraevent 1975", Innsbruck, vol. II, 159-171.

DELLA LUCIA D. e PROVASI C., 1985. Studio sulle piogge intense nel territorio montano della Regione Veneto. Quaderni di Ricerca, n. 2, Regione Veneto, Dip. Foreste, Centro Sperim. Valanghe e Difesa Idrogeologica.

FATTORELLI S. e MARCHI L., 1986. Metodi deterministici per la stima delle piene. Gruppo Nazionale per la Difesa dalle Catastrofi Idrogeologiche. Rapporto 1986.

HYDROLOGIC ENGINEERING CENTER, 1985. HEC-1 Flood Hydrograph Package, User Manual. U.S. Army Corp of Enginners, Davis, California.

LAURENSON E.M., 1964. A catchment storage model for runoff routing. Journal of Hydrology, vol. 2, 141-163.

SOIL CONSERVATION SERVICE, 1972. SCS National Engineering Handbook, Section 4, Hydrology. U.S. Department of Agriculture, Washington, D.C.

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