Consensus Conference

Peak Discharge of the December 2003 Rhône Flood at Beaucaire

Préfet of the Rhône Mediterranean Watershed
Ministry for Ecology and Sustainable Development

Lyon, 26-28 July 2005

FINAL REPORT
25 October 2005

Summary and Conclusions

In response to its charge (see below), the Scientific Committee reached the following primary consensus conclusions regarding the December 2003 flood on the lower Rhône River:

> **The peak discharge at Beaucaire was most likely 11,500 m^3/sec, corresponding to a return period of slightly above 100 years. This is associated with an estimated peak stage at Beaucaire of 11.35 m.**
>
> **This estimate of peak discharge is subject to an uncertainty of the order of 5%, reflecting uncertainty in the discharge measurements, peak stage, and parameterization and extrapolation of the December 2003 gaugings. More precise estimation of this uncertainty was outside the scope of the Committee, but could be undertaken through complementary studies.**
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> **The December 2003 flood was an unusual and significant one for the lower Rhône River and its communities. However, all floods represent particular hydrometeorological and hydraulic influences, and therefore no single flood should, in itself, be used as a single reference event for future planning and design.**

From its analyses and deliberations, the Committee also determined the following:

1) The meteorological and hydrological conditions in the upstream watersheds were conducive to and consistent with the occurrence of a significant flood event.

2) It is physically possible for future meteorological and hydrological conditions to interact in such a way to cause flows at Beaucaire to be higher than they were in December 2003.

3) The flood-frequency values for peak annual flows at Beaucaire as used in the "Étude Globale pour une Stratégie de Réduction des Risques dûs aux Crues du Rhône (EGR)" are consistent with the historical record and confirm 11,300 m^3/sec as an estimate of the centenary peak flow.

4) Uncertainties in modeling the Beaucaire discharge using the upstream model stem from four main sources: tributary rating curves, ungauged tributary flows, dam operations, and model structure/parameters. It is estimated that an uncertainty of as much as ±1000 m^3/s is possible for the modeled peak discharge at Beaucaire from the first three of the above sources (12,750 m^3/sec for Scenario S2). Additional but unquantified uncertainty is associated with the model structure and parameters. Comparison of the computed and measured stage records at the Beaucaire bridge suggests that the model estimates may be biased towards larger values.

5) ADCP flow measurements at Beaucaire conducted during the flood are reliable, and not significantly affected by movement of the river bed.

6) The peak stage at Beaucaire was not measured exactly, as the dynamics of the limnimeters appear to have changed after the peak (as seen by comparison of the staff gauge readings and limnimeters values). The peak stage at Beaucaire can be estimated at 11.35 m.

7) The Beaucaire rating curve in existence prior to the flood event is subject to changes due to geomorphological evolution of the river, and should not be used for analysis of the December 2003 flood event itself.

8) Only staff gauge readings and ADCP discharge measurements taken during the 2003 flood should be used for its hydraulic analysis.

9) Dike-breach effects are already reflected in the flow measurements taken during the flood of December 2003. Hence there is no reason or need to include additional dike-breach effects in estimating the peak discharge at Beaucaire

10) Mobile-bed and bedform dynamics, as well as wind effects, were insignificant factors in the passage of the flood.

11) Unsteady-flow effects must be considered in determining the peak discharge at Beaucaire from ADCP gaugings during the flood. Such effects were included in the Committee's analysis of peak discharge.

The Committee's analyses and deliberations also led to the following recommendations:

1) A more detailed frequency analysis should be performed for the historical floods, taking into consideration their meteorological character and in the context of the fact that several high events have occurred in recent times. Estimates of standard deviation of percentile values should also be determined.

2) The Committee recommends development of an overall distributed or semi-distributed hydrologic model for the Rhône River catchment for diagnosis and analysis of flood events, soil-moisture estimation, and system operation. This model could also provide the basis for real time forecasts of river flows at various key locations in the catchment.

3) Differences in CNR limnimeter and staff-gauge measurements of water stage at Beaucaire during the flood should be reconciled in publication of a unique time series.

4) A new rating curve should be established for Beaucaire, including measurements from the December 2003 flood, in order to account for changes in the river bed conveyance capacity. (The rating curve developed by the Committee for the purpose of estimating the December 2003 peak discharge is 2003-specific, and should not be used as a general tool for future calculations.)

5) Past and continuing geomorphological changes in the lower Rhône River, both natural and man-made, imply the need for regular assessment and updating of rating curves and model parameterization throughout the basin.

6) Discharge measurements during the peak of the flood are of utmost value as this event so well demonstrates. But security considerations make it difficult and unadvisable to make such measurements at night. Techniques for remotely controlled ADCP measurements would be of great value for future works on the Rhône River. Developments in that direction should be encouraged.

7) Considering the socio-economic importance of the Rhône River and its floods,

an in-depth interdisciplinary study of the Rhône system would be of great benefit for future management and planning, with particular focus on characterization of uncertainty for risk management.

8) CNR has an operational obligation to monitor the Rhône River for management purposes. Nonetheless, an external and independent measurement capability at key sections on the Rhône river seems necessary in order to provide neutral, complementary data that could be used for flood analysis and future planning and design.

9) *Post-facto* analysis of events such as the December 2003 flood, and future planning and design, would benefit from availability of a single unsteady flow model covering the entire river from the Swiss border to the sea. The modeling technology and data sets already exist, and such a model would not lead to the awkward interpretation of simulated conditions where separate models join.

Conclusions and recommendations in this report represent the consensus view of the Scientific Committee, as formulated within the limits of the Committee's charge. Narrative discussion of these and other conclusions, including recommendations, are presented in the subcommittee narratives further on in this report.

Background and Organization of Conference

A brief history

Upon request from the French government, a commission including members of the French High Inspectorates of Environment, Agriculture and Civil Engineering has brought out a report about "the safety of the dikes in the Rhône delta". This report was delivered on October 20, 2004, to the Minister of Environment. The members of the commission had benefited from the help of a scientific advisory committee (French acronym = GAES) steered by Gérard Brugnot.

One chapter of this report is dealing with the climatologic and hydrologic data relevant to the December 2003 Rhône flood. Referring to these data, the GAES concluded the peak discharge of the Rhône was close to 11 000 m^3/s at Beaucaire (GAES report, Synthesis 2, page 48: "the one in hundred year discharge is approximately 11 300 m^3/s").

The tight deadline assigned to the commission made it impossible to set up an open dialogue with stakeholders, especially those who could have contributed local knowledge. At meetings organized in order to report the conclusions of the commission, appeared two kinds of controversy:

- Disagreement of stakeholders on the peak discharge value and on the resulting values to be selected for all forthcoming choices regarding structural defences and land planning;

- Disagreement of scientists on the methods used to assess this value, e.g. wishing hydrogeomorphological data had been better taken account of.

These facts are the rationale for setting up this consensus conference.

The question

The question submitted to the scientific committee is:

> ***"depending on the available data, what is the best assessment for the peak discharge of the Rhône at Beaucaire during the December 2003 flood, given the available data, both relevant to the site and to the watershed as a whole, depending on the scientific state of the art"***

Scientific Committee

The following individuals agreed to serve on the Scientific Committee:

V. Anselmo (University of Turin, Italy)
K.P. Georgakakos (Hydrologic Research Centre, USA)
L. Gottschalk (University of Oslo, Norway)
F. M. Holly Jr. (University of Iowa, USA)
P. Kosuth (Cemagref Montpellier, France)
H. Ogink (Delft Hydraulics, The Netherlands)
B. Sigrist (Office Fédéral pour l'Eau et la Géologie, Switzerland)

F. M. Holly Jr. served as Chair of the Committee.

Organization of Committee Deliberations

Once formally appointed in May and June of 2005, the Committee was provided with access to an intranet site containing all of the documents and data to be considered for the conference. Committee members reviewed these documents and data prior to their arrival in Lyon on 25 July 2005.

The committee met for six half-day sessions, 26-28 July 2005 in Lyon. All of the individuals and organizations who contributed documents to the conference were invited to meet with the Committee to answer questions on their contributions. Additional follow-up contacts were made with some contributors during the remaining sessions. Annex A of this report is the schedule of interviews for those contributors who met with the Committee.

The Committee recognized three general areas to be investigated in responding to their charge. Corresponding subcommittees A, B, and C were formed based on the expertise of the Committee members. The overall conclusions and recommendations of the Committee, as summarized in the opening paragraph of this report, are derived from the work of the subcommittees followed by general Committee discussion and consensus. Brief summaries of the investigations, conclusions, and recommendations of each subcommittee are provided below.

A. Watershed Hydrometeorology and Upstream River Hydrology and Management

A.1 Is the event exceptional?

1.1 On the basis of the Météo-France analyses the December 2003 event was characterized by an uncommon meteorological situation and had the largest area of event rainfall greater than 150 mm with more or less spatially uniform heavy rainfall volumes. Compared to documented historical events this precipitation event is unique in the record and, thus, it should be considered exceptional.

1.2 During the December 2003 flood event, in addition to heavy rain of significant extent and duration, soil moisture was identified as particularly high in the southern region of the Rhône River (60% above normal.) This caused tributary response that resulted in high flows on the lower Rhône River.

However, on the basis of CNR hydrological synthesis and general documentation, peak flows higher than that observed at Beaucaire in the December 2003 flood are feasible. Gard and Ardèche as well as Durance could contribute their peak flows in time with those of the Rhône. From this point of view, the December 2003 event should not be considered the highest possible.

Independent computations performed by members of Subcommittee A verified the flow values of the 10, 50, 100, 500 and 1000 return period given by CNR. In this analysis the December 2003 event has not been included. Values of historical flows have been changed from original values and the Subcommittee could not identify how and why this was done. More information about the Subcommittee A analysis and assessment is given in the Annex A.1. Lastly, the hypothesis that unusually high events may be clustered in recent years was tested by CEMAGREF for the subcommittee. These tests did not find this hypothesis significant at the 10% significance level.

A.2 Uncertainties in upstream modeling

2.1 On the basis of tributary rating curve analysis by CNR, estimates of up to 15% for the error in the curve are indicated. In several cases this was determined on the basis of measurements that were several years older than the December 2003 floods. The calibration of the upstream model adjusts to some degree for biases arising from tributary river rating errors. However, the particular combination of rating curve errors present for the December 2003 event is likely to not have been seen during calibration and this combination may generate model biases for this particular event. It is estimated that a ± 500 m^3/s of modeling discharge error is possible due to upstream and tributary rating curve errors.

Main channel inflows from ungauged tributaries have been estimated by an ad-hoc procedure which can lead to significant (but unknown for this study) errors in hydrograph shapes, peak values and timing. Significant improvement in accuracy would result from the use of a Rhône-wide calibrated and validated distributed hydrologic model.

2.2 Earlier sensitivity analyses by the "Étude Globale pour une Stratégie de Réduction des Risques dûs aux Crues du Rhône" (EGR) indicate that the hydropower installation effects during flooding may be of the order of 100 m^3/s for a 2,000 m^3/s flow. These were characterized as not significant. Recent information made available to Subcommittee A by CNR indicates that the discharge error due to the dam operation may reach a 10% level during flooding. A high total error estimate for all four dams from Viviers to Beaucaire assuming error compounding is 804 m^3/s. It is likely that the error is lower than this figure.

2.3 On the basis of the CNR documents, the Subcommittee accepts the assessment that the upstream model structure and parameters were calibrated and validated for the lower Rhône River as part of the EGR. However, there was no information available to the Subcommittee regarding model calibration and or validation errors.

B. Beaucaire-Tarascon Measurements and Rating Curve

B.1 Discharge Measurements

Discharge measurements performed on Dec. 3rd and 4th using ADCP (600 KHz and 1200 KHz with DGPS) have been analysed. They appear to be fully consistent. Their dispersion is very low. Verifications have been made regarding the possible impact of a moving river bottom on the measurement results. This impact was very limited and corresponding adjustments had already been made by CNR.

Current meter measurements realized during this event were only surface measurements and therefore we do not consider them as sufficiently accurate for the purpose of the peak discharge estimation.

Therefore we can use 54 independent ADCP discharge measurements performed at Beaucaire during the flood event (that had been grouped into 8 discharge values). These measurements have been taken for staff gauge readings between 9.88m and 11.11m, and gave discharge values between 8877 m^3/s and 11570 m^3/s.

B.2 Water level measurements

CNR has provided two types of information for water levels during the flood event (03-04/12/2003):

- "staff gauge readings" by the team in charge of ADCP discharge measurements
- reconstructed hourly time series (which we shall call "reconstructed limnimeter")

These two sets of information are not consistent:

"Reconstructed limnimeter" values are 10 cm lower than "staff gauge" before the peak (3rd of Dec.) and 12 cm higher after the peak (4th of Dec.). All analyses tend to confirm that the staff gauge readings were fully reliable (no damage to the gage, smooth water surface allowing correct readings). Therefore the bias of the limnimeter has increased by 22cm during the peak flood. This change has probably been induced by deposition of sediment during the night (see strong oscillations recorded and rehabilitation works in January).

While the reconstructed limnimeter indicates an 11.30 m maximum water level, our estimation, based on available data and relying in priority on existing staff gauge readings of the **maximum water level at Beaucaire during the Dec. 2003 flood is 11.35 cm**.

B.3 Estimating Peak discharge at Beaucaire

Due to the large number of independent ADCP discharge measurements (54) taken during the flood event, and the large range of water level values [9.88 m to 11.11 m] during these measurements close to the maximum water level value (11.35 m), we have considered that establishing a relation between water level and river discharge, and extrapolating this relation up to 11.35 m (peak water level) was relevant for the purpose of estimating the peak river discharge at Beaucaire.

As the measurements on Dec. 3rd were performed with increasing water level and measurements on Dec. 4th with decreasing water level, the Jones correction (see C.3.) has been applied to measured river discharge in order to take into account unsteady flow effects and translate measured discharges into equivalent steady flow discharges. Then a shifted power type equation $Q= c*(H+a)^b$ has been used to establish the relation between discharge and water level. As a result:

Estimated maximum discharge at Beaucaire on Dec. 2003 is 11 500 m^3/s ±600 m^3/s (5%)

(nota: not taking into account unsteady flow effects leads to an estimated peak discharge of 11 700 m^3/s ± 5%)

B.4 Beaucaire Rating Curve

As mentioned above, to determine the peak discharge value on Dec. 2003 we used only ADCP discharge measurements realized on Dec. 3rd and 4th and we analysed the correlation between measured water levels and river discharge.
However the above mentioned relation is specific to the Dec. 2003 flood event, and in particular reflects the downstream conveyance capacity, which includes effects induced by breaches in the embankments downstream, at the time of the flood. This implies that the relation cannot be used as a rating curve for future calculations. In breach-free conditions, the same water level would imply a lower river discharge.
A new rating curve for Beaucaire gauging station will have to be established (see C.2)

C. River Hydraulics at Beaucaire and Downstream Influences

C.1 Assessment of geomorphological changes on the rating curve

The level at Beaucaire for a particular discharge is determined by the downstream conveyance capacity of the Rhône, of which the reach Beaucaire-Arles (PK 270 – PK

280) is most important. Beaucaire can be shown to be free of backwater effect from the Mediterranean Sea.

The river bed downstream of Beaucaire consists of pebbles and sand, the latter with a median diameter of 400 to 500 μm; a median pebble size is about 6 cm. Successive surveys of the river bed in the reach Beaucaire-Arles from 1994 to 2005 indicate a net degradation of the river bed of a few decimetres, whereas also some narrowing of the channel has been observed. Bed changes are due to river bed morphology and dredging activities in the lower section. With respect to the latter, only a part of the dredged bed material has been deposited on the river banks. These changes in the cross-sections will affect the discharge rating curve in Beaucaire and indicate that a regular updating of the curve is required, the more so since for water levels above 8 m at Beaucaire part of the water is conveyed through the downstream flood plain whose roughness varies with the type, density and height of the vegetation. This implies that a rating curve based on discharge measurements carried out in the early nineties should not be applied to the water levels of 2003 to arrive at a valid discharge hydrograph. Therefore, in the assessment of the river flow and associated water levels only use have been made of the discharge measurements during the 2003 flood event (see Section B above).

C.2 Extrapolation of the rating curve

Extrapolation of the rating curve has been carried out in the various studies using empirical approaches, by extending observed tendencies based on regression equations. This may lead to erroneous extrapolation. Reliable extrapolation requires knowledge of the hydraulic conveyance capacity of the reach downstream of the gauging station, which is determined by the cross-section, slope and hydraulic roughness of river and flood plain. Since dimensions and roughness of the river and flood plain differ, a distinction is to be made between the two elements. Also different discharge ratings will be applicable at Beaucaire for in-bank and overbank flow conditions.

The existence of sand in the river bed implies that during floods on the Rhône the bed will, at least partly, be covered with dunes. From the hydraulic and morphological conditions it is estimated that the dimensions of the dunes will approximately be stable when the river is in flood, which means that a constant Strickler roughness value is applicable for extrapolation of the conveyance capacity of the main river. For the flood plain this is not necessarily so as flow depth to vegetation height plays a role. However, since even during high floods only a small part of the total discharge is conveyed through the flood plain the assumption of a constant Strickler value for the flood plain will not affect the outcome significantly.

In view of its resemblance to the Manning-Strickler equation, a shifted power-type rating equation for both river and flood plain is suitable. If the conveyance width does not change substantially from the observed to the extrapolated height a single power-type rating curve fitted to the combined contributions of river and flood plain will be suitable for extrapolation of the discharge rating curve at Beaucaire.

C.3 Assessment of unsteady flow effects

A rating curve assumes a single relationship between stage and discharge. Due to differences in energy slopes before and after the flood peak a looped relationship exists, giving, compared to a steady state for a particular water level, higher discharges when the levels are rising and the opposite when the levels are falling. During flashy floods in moderately sloped rivers these effects can be significant. The Jones correction for unsteady flow can be applied to effectively eliminate the looping in the rating curve. This correction is a function of the river slope, celerity and the time derivative of the water level hydrograph. Application of this correction to the 2003 discharge measurements at Beaucaire indicated correction factors of less than 2% for the measurements in the rising limb (3 December 2003, water level increase of +5 to +8 cm/hour) and 1 to 4% for the measurements in the falling limb (4 December 2003, water level decrease of –10 to –20cm/hour) of the hydrograph. Hence, it appears that for this flood event the unsteady flow effects on the measurements were low. Nevertheless, some effect is apparent; correcting the discharge measurements at Beaucaire for unsteady flow leads to a peak discharge for the maximum observed water level in December 2003 which is approximately 200 m^3/s lower than if estimated from the rating curve based on the same but unadjusted set of measurements.

Investigation of historical flow measurements at Beaucaire since 2001 show that only in a few occasions was a substantial unsteady flow effect apparent. But even though during the measurements the unsteady flow effect may have shown to be generally insignificant, this does not necessarily mean it is insignificant at all stages, and the suitability of such a correction should be further investigated when establishing a rating curve.

C.4 Effect of Breaches and Related Modelling

The Committee examined the general approach taken by CNR to determine the effect of downstream breaches as they affected the peak discharge at Beaucaire. This approach was based on use of the BCEOM STREAM dynamic flow model of the mainstem Rhône and Petit Rhône from Beaucaire to the sea, including simulation of the downstream breaches. The model was calibrated as part of the EGR through comparison with, among other things, the stage records at Arles and Fourques for floods in the 1990s. The calibration effort led to the adjustment of schematized breach parameters and spill of water from the mainstem to the Petit Rhône. The calibrated model was then applied to the December 2003 flood, apparently using the apparent shape of the discharge hydrograph at Beaucaire (deduced from the existing rating curve) scaled to peak discharges of 11,500 and 12,500 m^3/sec. For these two hydrographs, the model indicated that the effect of the breaches would be to lower the peak Beaucaire water-surface elevation by 28 and 35 cm, respectively. From this, CNR adopted 30 cm as the estimated effect of the dike breaches on the peak water-surface elevation that would have occurred at Beaucaire had the downstream dikes not been breached. CNR then entered the Beaucaire rating curve (as revised by CNR after the 2003 flood) with a stage of 11.6 m (the observed peak of 11.3 m increased by the 30 cm breach effect) to estimate the peak discharge that occurred at Beaucaire.

The Committee was not comfortable with this approach, for several reasons. One of the most important is that the breaches apparently opened several hours before the last Beaucaire ADCP measurement on the rising limb of the hydrograph, so that the Beaucaire stage already reflected the effect of the breaches (steepening of the energy slope downstream of Beaucaire with a concomitant increase in discharge). Thus the rating curves developed by the Committee using only the December 2003 measurements (see Section B above) needed no further adjustment for the possible effect of breaches. The Committee was generally uncomfortable with the notion of applying a breach correction to a rating curve whose existence implicitly implies steady conditions not reflecting changing downstream influences.

An alternative approach could have been for CNR to estimate the peak discharge at Beaucaire by constructing and calibrating a quasi-two-dimensional model (of the usual channel-and-cell type) from, say, the Vallebrègues complex down to the sea, using the same downstream boundary conditions and breach schematization as the STREAM model, and the best estimate of the hydrographs from Vallebrègues as the upstream boundary condition (alternatively, the upstream CNR model used in the EGR could have been further extended from Beaucaire to the sea). The model's calibration would include, of course, the measured stage variations at Beaucaire. When applied to the December 2003 flood, such a model would provide a computed hydrograph at Beaucaire, with its estimate of the peak discharge, and could be used to determine the effect of breaches on the peak discharge without recourse to a rating curve whose application to this complex dynamic situation is suspect.

Annex A.1: Interviews with Contributors

Ranking	Time	Time adjusted	Organisation	Responsible	Other attendants
1	14H00	14H10	CETE Méditerr.	P. Fourmigué	J.F. Celle J.F. Brochot
2	14H15	14H30	SYMADREM	R. Fater	M. du Lac
3	14H45		Mairie Fourques	'''''''''''''''	''''''''''''''''
4	15H00	15H00	CNR + Cemagref Lyon	L. Levasseur M. Lang	M. Roult M. Scoti M. Khaladi M. Sinou B. Chastan
		16H15	*pause*		
5	15H45	16H30	D. Duband	D. Duband	----
6	16H15	17H20	Mairie Arles	M. Hautbout	----
7	16H30	17H30	ADPSC	M. Saint-Félix	M. Rigal
8	16H45	17H50	Mairie Aramon	J. Mahieu	M. Moreau
		18H05	*pause*		*supplément d'info M. Kosuth*
9	Tél.	18H15	DIREN PACA	J. de Saint-Seine	*téléphone + HP*
10	Tél.	18H22	M. Provansal	M. Provansal	*téléphone + HP*
		18H45	*The End*		

Additional interviews:
CNR: on the afternoon of July 27th, visit by B. Sigrist and P. Kosuth to CNR office in Gerland to analyse ADCP measurement data and clarify water level measurement results (staff gauge readings and limnimeter data)

Annex A.2: Flood Frequency Analysis

The frequency of extreme floods in the Rhône has been thoroughly investigated in the "Étude Globale pour une Stratégie de Réduction des Risques dûs aux Crues du Rhône (EGR)". For the estimation of return periods for severe floods in the main Rhône from

Lyon down to its outlet the Gumbel distribution has been applied. A standard method for estimating return periods of floods is the Gradex method but this is not applicable to large drainage basins. However, the Gradex method has been used to estimate return periods for all the tributaries to the main Rhône. For the site at Beaucaire a frequency curve is established in EGR based on data for the period 1920-2000 applying the Gumbel distribution resulting in following estimates for return periods: Q10 – 8400 m^3/s; Q100 – 11300 m^3/s; Q1000 – 14160 m^3/s. Historical data do exist for an extensively longer period back in time than for the period used for estimating the frequency curve. The data are quite complete from 1840-2002. In any case, it has been decided to use data only from 1920 due to uncertainty in rating curves for earlier periods.

The complete annual maximum data series from 1840 was made available by CNR to the members of the subcommittee and a complementary frequency analysis was performed applying a non-parametric method as well as the Generalized Extreme Value distribution with parameter estimation with L-moments. (L-moments or linear moments replace ordinary moments as they have some properties that make them advantageous for analysing short records of extreme values. The first l-moment is identical with the first ordinary moment i.e. the mean; the second order l-moment is a measure of range of variability; the third order l-moment is a measure of asymmetry; etc.)

The analysis was performed with data for the period 1840-2002 and 1920-2002, respectively. For Q100, the non-parametric and GEV procedures gave a standard deviation of about 500 m^3/s for the record spanning 1840 – 2002. The standard deviation was 780 m^3/s when the record was 1920 – 2002. The analysis for both data sets affirms the validity of EGR frequency curve. The differences in estimates for return periods are minor and well within the uncertainty involved in the study.

The GAES Synthesis Report also provides data for historical floods. For the events 1840, 1856 and 1886 the flood values differ from those made available to the subcommittee. Although it has not been possible to find the reason for these discrepancies, it is expected that these few individual differences in values do not have any significant effect on the estimated frequency curves. Another more important concern is the fact that for the period 1920-2002, 8 out of 16 “heavy floods” have occurred during the last ten years (1993-2002) and among them the four most extreme ones. Nevertheless, a statistical test based on the Poisson assumption does not allow rejecting a purely random sequence of events.