GEOGRAPHY-REFERENCED REGIONAL EXPOSURE ASSESSMENT TOOL FOR EUROPEAN RIVERS: GREAT-ER

LOW FLOWS HYDROLOGY OF THE LAMBRO CATCHMENT, NORTHERN ITALY

Annex (A)

M.G.R. Holmes
A.R. Young

October 1998

This report is an official document prepared under contract between ECETOC and the Natural Environment Research Council. It should not be quoted by third parties without permission of both ECETOC and the Institute of Hydrology

Institute of Hydrology
Crowmarsh Gifford
Wallingford
Oxfordshire
OX10 8BB

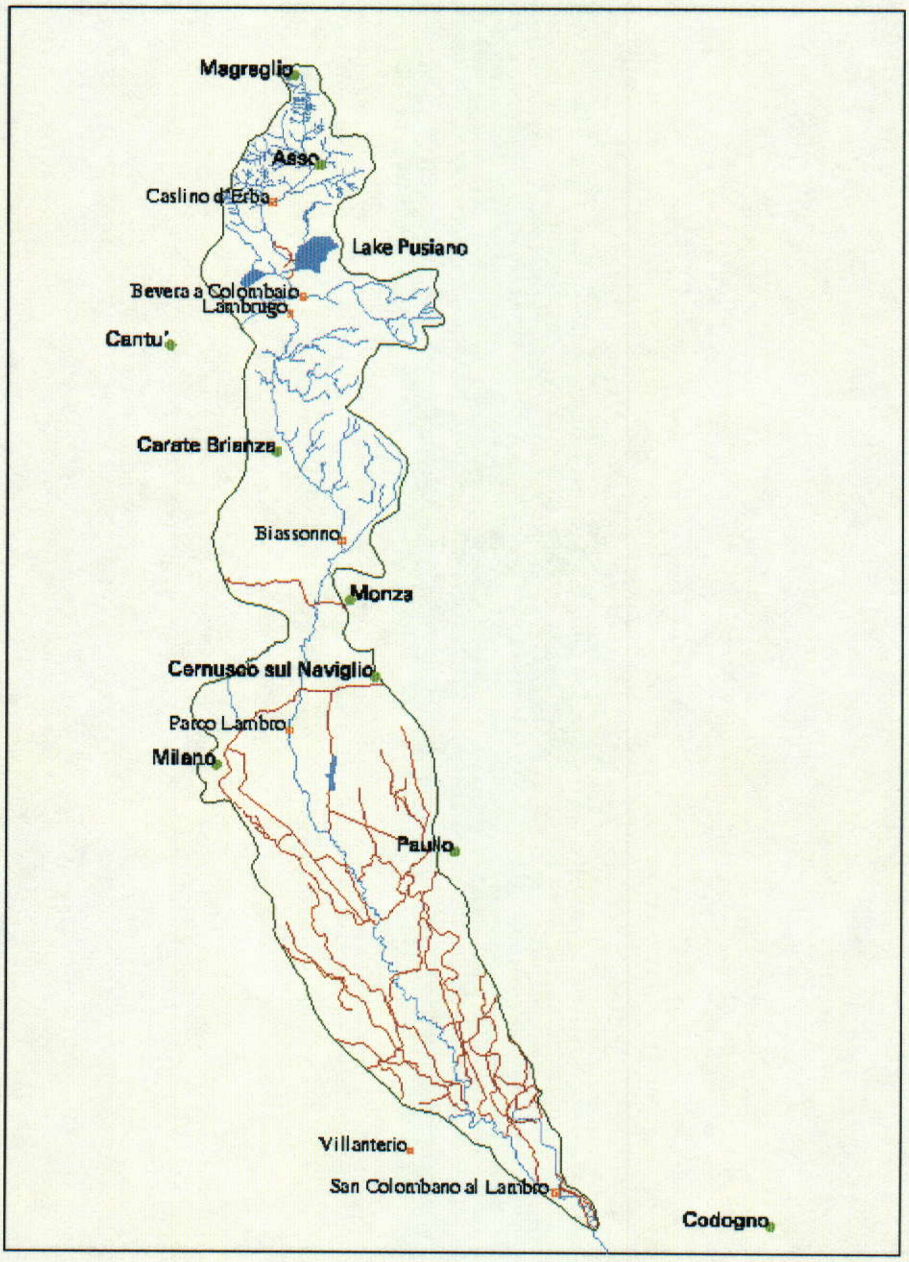
Tel: 01491 83800
Fax: 01491 692424
Telex: 849365 Hydrol G

October 1998

Contents

1.0 Introduction

The European Centre for Ecotoxicology and Toxicology of Chemicals (ECETOC) are currently managing the development of the Geography-referenced Regional Exposure Assessment Tool for European Rivers (GREAT-ER) computer software system. The system will ultimately allow the fate of down-the-drain chemicals to be predicted throughout European surface waters. GREAT-ER will enable the environmental impact of such chemicals to be more accurately forecast and incorporated in risk assessment and planning procedures. The Lambro catchment in the Lombardia region of northern Italy was chosen by ECETOC as a pilot study catchment for the calibration and verification of the GREAT-ER software using LAS as the target chemical, see Locality Plan.



Locality Plan : The Lambro Catchment - Lombardia region, Italy.

1.1 CATCHMENT DETAILS

This pilot study focussed on the portion of the Lambro catchment to the north of the city of Milano with an approximate catchment area of 465km^2. Average annual rainfall for the catchment varies between 900mm and 1500mm. The catchment includes forested mountainous headwaters in the pre-Alps and flatter, undulating agricultural land to the north of Milano. The flow regime in the catchment north of Milano is basically natural. However, the city of Monza, to the north east of Milano, represents an area where major discharges from sewerage works occur and other minor discharges and abstractions are likely to occur. The majority of the water supply for the city of Milano is drawn from groundwater aquifers that do not interact with the Lambro river system.

Five (5) flow gauges were located within the study catchment as shown on the Locality Plan, see Table 1. Several climatic stations in the vicinity of the Lambro catchment were available for use in this study, see Table 2.

Gauging Station	Catchment Area (km^2)
Caslino	53
Colombaio	40.2
Lambrugo	170
Biassono	270
Parco Lambro	465

Table 1: Details of the flow gauging stations in the Lambro catchment

Climatic Station	Type of Station	UTM Co-ordinates		Elevation (m a.s.l.)
Magreglio	P and T	519,730	5085,300	737
Asso	T			427
Cantu	P and T	510,860	5065,640	360
Carate Brianza	P	518,570	5058,010	255
Monza [1]	T	520,000	5047,500	162
Cernusco Sul Naviglio	P and T	525,770	5041,710	134
Milano	P and T	514,280	5035,300	121

Notes: P = precipitation data
T = temperature data
[1] Approximate co-ordinates only

Table 2: Summary of the climatic stations in the Lambro

2.0 Objectives

The objective of the hydrological study was to produce a hydrological model of the flow regimes in the upper part of the Lambro catchment using mean flow (MF) and Q95 (the flow that is exceeded 95% of the time) as regime descriptors. These statistics which describe a measure of central tendency and a measure of variance respectively, underpin the aquatic fate modelling shell of the GREAT-ER software. These flow statistics were required at a reach scale for the Lambro catchment upstream of the Parco Lambro gauge, on the outskirts of Milano.

This study also was designed as a pilot study to determine what difficulties could be expected when deriving low flow statistics for catchments with relatively poor quality flow records.

3.0 Methodology

The first task of the study was to examine the data collected by the University of Milan and to establish the quality of the data sources. This involved extensive collaboration with the University of Milan, a field inspection of the gauging sites and data records, duplication of paper records, transferral of paper records to digital format, searches for additional data and data entry. A number of inquires were made via the University of Milan to organisations responsible for holding the original Italian flow records in order to attempt to reconcile problems encountered with the data records.

As part of the data appraisal process it was necessary to investigate what influence Lake Pusiano, upstream of the Lambrugo gauge, might have on the low flow hydrology of the Lambro.

Secondly, it was necessary to develop methods for producing flow statistics from a common period of record. This was required since the flow records available for the five (5) stations did not include a period of common record. Examination of climatic records from stations within the region indicated that although no long term trends in climate could be identified, short term fluctuations were evident, see Figure 1. This Figure shows that the average annual rainfall for the period 1950 to 1960 was approximately 20% higher than the average annual rainfall for the period 1980 to 1990.

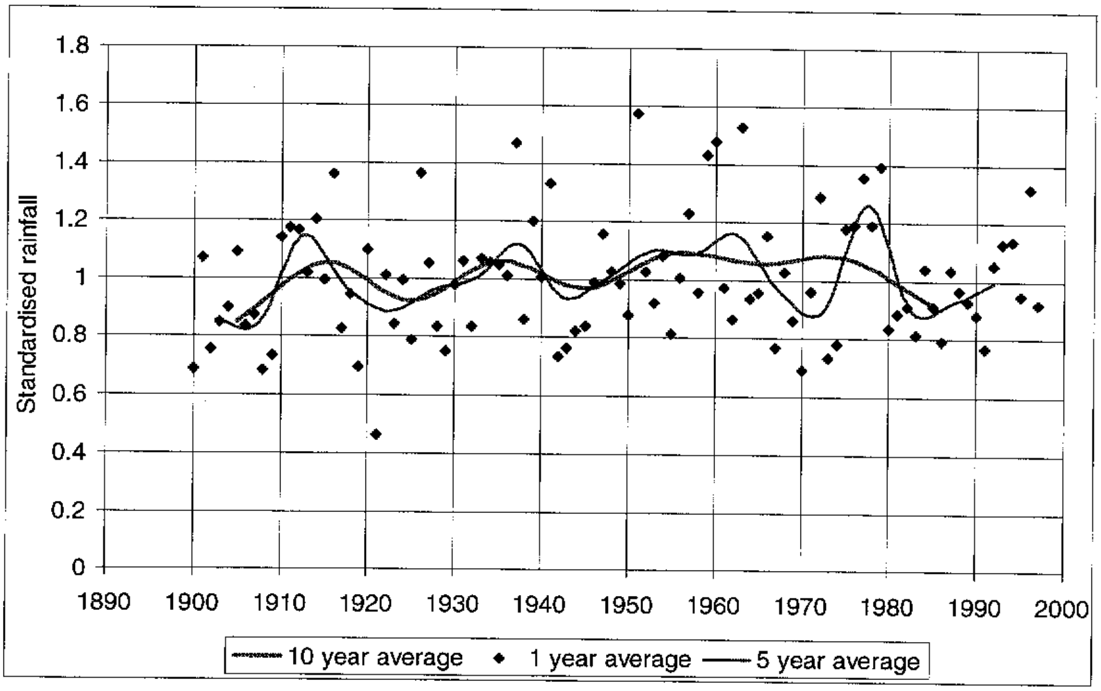


Figure 1: Trends in annual rainfall recorded at Monza

Consequently, it was necessary to develop methods for extending flow records so that a recent common period of record was available for all gauges. A two (2) stage approach was adopted with the first stage involving developing flow distribution curves (FDCs) for each station from actual flow records which were standardised by MF. The temporal homogeneity of the FDCs could then be examined and a curve appropriate for use with contemporary data identified.

The second stage involved the determination of a contemporary estimate of MF for each station. This involved using actual data records where possible and using a simple rainfall-runoff model to extend the records of stations which did not have contemporary data.

The estimate of MF could then be used in conjunction with the standardised flow distribution curve to produce estimates of Q95.

4.0 Results – Data appraisal

The process of examining the flow data collected for the Lambro catchment and undertaking data analysis revealed a number of problems existed.

1. The University of Milan had experienced difficulties during the original data collection process. Data for the catchment was held by a number of organisations. This hampered the task of identifying and collecting the data and also made it difficult to resolve inconsistencies identified in the data at a later date.

2. The flow and climatic data records were held in paper format and hence a considerable effort was required to convert these to digital format. The University of Milan was responsible for most of the data converting however, additional flow data and climatic data was required. Scanning of the data was not possible due to the poor quality of the original paper records and hence the additional data entry process was time consuming.

3. Detailed investigation of the raw flow records highlighted periods where individual flow gauges were behaving inconsistently to the majority of the other gauges. Attempts were made to determine the likely cause of the inconsistencies, however, a lack of data prevented some solutions being identified. A base data set was identified which was suitable for use in the study and excluded periods of dubious data.

4. The consistency of rainfall records were check by construction of double mass plots for gauges in the upper catchment compared to the good quality, long term records held for the Monza station in the lower portion of the catchment. It was found that the Asso and Cantu stations provided consistent rainfall records for the periods 1947 to 1991. Consequently, data from these stations was used in simple rainfall-runoff modelling undertaken during the latter phases of the project.

5. The rating curves used were derived from old current metering data. Flood events could be expected to significantly change the channel morphology at gauging stations and therefore the rating curves would need to be updated at regular intervals. Furthermore, rating curves are typically used to measure flood flows and may not be applicable to recording low flows. Redefinition of some rating curves was required to enable stage readings to be converted to low flow records.

6. The stage board at the Caslino gauging station was shifted at some time in the 1990's. However, details of the timing and magnitude of the shift was not able to be determined at the time of the study. This created considerable uncertainty in the flow estimates recorded at this gauge.

7. The influence of Lake Pusiano could not be fully investigated due to a lack of data. However, the available data indicated that the lake was not expected to significantly impact on the low flow hydrology of the river.

8. A simple water balance approach was used to confirm that the MF accreted in a consistent manner down the catchment. This process highlighted problems with the data obtained for the Caslino gauge that showed a break point occurring in 1990, suggesting the unrecorded shift in the stage board. A simple rainfall-runoff model was used to determine which portions of the data should be used for low flow analysis.

9. Accretion of runoff down the catchment highlighted the fact that a net import of water appeared to occur between the Biassono and Parco Lambro gauges. Although it was originally thought that the catchment north of the Parco Lambro gauge contained natural flow regimes more detailed investigations revealed that sewerage from the city of Monza and a portion of Milano's sewer discharges would impact on flows recorded at the Parco Lambro gauging station. It was therefore necessary to make an approximate adjustment to the flows to include this artificial influence. No detailed information regarding the exact nature of these discharges was available at the time of the study and therefore uncertainty existed in the adjustments that were adopted.

10. Base flow separation was performed in an effort to provide more detailed information regarding the catchment response to rainfall. The hydrographs at the Parco Lambro gauge appeared to be base flow dominated. However, the University of Milan confirmed that the interaction of groundwater with the river system was expected to be minimal at this point in the catchment. Further investigation revealed that a large proportion of the base flow component of the Parco Lambro gauge could be due to sewerage discharges from the city of Monza.

The data collection and quality control process highlighted a number of problems that could be considered indicative of problems associated with determined low flow statistics from relatively poor quality data records.

5.0 Results – Determination of Q95

Flow distribution curves (FDCs) for each station were developed from flow records where a continuous three (3) year period of actual flow data was available. All flows were standardised by the MF for the period of continuous data. This enabled the temporal consistency of FDCs at a station to be examined and a curve suitable for use with contemporary data to be identified. It was found that the FDCs were temporally consistent, as illustrated on Figure 2.

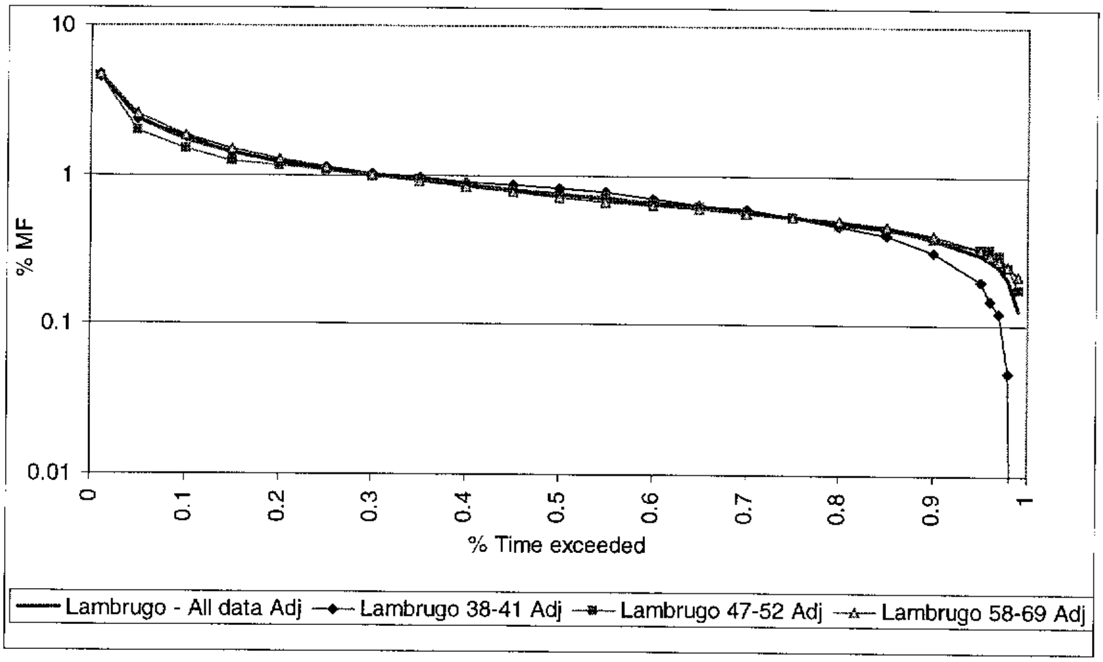


Figure 2: FDC for Lambrugo for three discrete time periods

Consequently, the final estimates of standardised Q95 were taken to be the pooled estimates determined from actual flow records and are summarised on Table 3.

Gauging Station	Standardised Q95 (%MF)
Caslino	23
Colombiao	10
Lambrugo	30
Biassono	19
Parco Lambro	34

Table 3: Final standardised Q95 estimates

6.0 Results – Determination of MF

Contemporary periods of good quality data were available for the Biassono and Parco Lambro gauges for the period 1980 to 1990. Therefore, it was considered appropriate to define this period as the period of common record for which the low flow statistics would be produced for all gauges. Actual flow records were used to produce the MF estimates for the Biassono and Parco Lambro stations. A portion of the recent flow records for the Caslino station was used to produce an estimate of MF. However, it was necessary to extend the flow records for the Lambrugo and Colombiao stations using a simple rainfall-runoff model, since these stations were not in operation for the period 1980 to 1990. The final estimates of MF for each of the stations are summarised on Table 4.

Gauge	Data Source	Mean Flow (cumecs)
Caslino	Observed data 1991 to 1994	1.73
Colombiao	Model results 1981 to 1991	0.64
Lambrugo	Model results 1981 to 1991	3.48
Biassono	Observed data 1984 to 1997	5.33
Parco Lambro	Observed data 1985 to 1994	12.01
Parco Lambro Adjusted	Observed data 1985 to 1994	9.51

Table 4: Final mean flow estimates

Table 4 also shows an adjustment of 2.5 cumecs applied to the MF at Parco Lambro. This represents the estimated impact of sewerage discharges from Monza and portions of the Milano sewer. Data regarding the exact nature of this artificial influence was not available at the time of this study.

7.0 Summary

The final low flow statistics determined for the five (5) stations within the Lambro catchment are summarised on Table 5 and Table 6. These Tables include an estimate of the minimum expected errors in the flow measurement from Young et. al. (1998) that represent the 68% confidence limits on the coefficient of variation for the flow statistics. The adjusted expected error was derived subjectively by consideration of the quality of the data used to produce the flow estimates.

Gauge	MF (cumecs)	Minimum expected error	Adjusted expected error
Caslino	1.73	11% of MF	21% of MF
Colombiao	0.64	6% of MF	16% of MF
Lambrugo	3.48	5% of MF	15% of MF
Biassono	5.33	5% of MF	5% of MF
Parco Lambro	12.01	5% of MF	10% of MF
Parco Lambro Adjusted	9.51	5% of MF	10% of MF

Table 5: Final Mean Flow estimates and expected errors

Gauge	Q95 as % of MF	Q95 (cumecs)	Minimum expected error	Adjusted expected error
Caslino	23	0.40	15% of Q95/MF	25% of Q95/MF
Colombiao	10	0.06	15% of Q95/MF	25% of Q95/MF
Lambrugo	30	1.04	10% of Q95/MF	20% of Q95/MF
Biassono	19	1.01	10% of Q95/MF	10% of Q95/MF
Parco Lambro	34	4.08	14% of Q95/MF	19% of Q95/MF
Parco Lambro Adjusted	14	1.62	14% of Q95/MF	19% of Q95/MF

Table 6: Final Q95 estimates and expected errors

These low flow statistics were interpolated over the river network of the Lambro catchment, see Exhibit (A) and Exhibit (B) for the distribution of MF and Q95, respectively.

8.0 Conclusions

This study highlighted the problems associated with the determination of flow statistics from relatively poor quality records. Difficulties were experienced by the University of Milan and by the Institute of Hydrology during data collection and collation phases. The process of converting paper records to a digital format was found to be time consuming and careful checking methods needed to be followed. Poorly documented information regarding rating curves and a lack of recent rating curve calibration data was considered to induce a significant source of uncertainty into the final flow estimates. Poor documentation of modifications to gauging stations caused considerable problems at the data interpretation stage of the study.

Methodologies were successfully developed to enable flow statistics to be derived from several sets of gauge data that lacked a common period of record. The generalised approach involved; examining climatic trends; developing temporally consistent flow distribution curve; and using a simple rainfall-runoff model to extend flow records and hence determine mean flow. This approach was successfully used in the Lambro catchment and has potential for use in other catchments where the GREAT-ER modelling system is to be applied.

A lack of information relating to artificial influences represented a potentially large source of error in the final flow estimates. Additionally, the locations of artificial influences need to be known to allow correct interpretation of flow data at any point on the river network. This also has important ramifications for the water quality model since significant changes in the flow regime may occur over very short distances due to the impact of an individual discharge/abstraction. This directly affects the dilution ratios in the river downstream of the discharge/abstraction point.

This study highlighted the importance of methodical and rigorous data appraisal procedures. Furthermore, the need for field inspections and dissemination of local knowledge was emphasised. The difficulties experience in the data collection and verification phases of the project are considered to be indicative of problems which would be experienced in regions were hydrometic data is of relatively poor quality.

The University of Milan was able to provide high quality GIS coverages of the river network and catchment boundaries that allowed the final flow distributions to be easily prepared. The University of Milan was able to liase successfully with the relevant local authorities, investigate alternative data sources, collect and collate data, relay inquiries to local authorities and provide important local knowledge. The co-operation of a local authority like the University of Milan was essential to the success of this study and highlights the necessity of local partnering to progress GREAT-ER throughout Europe.

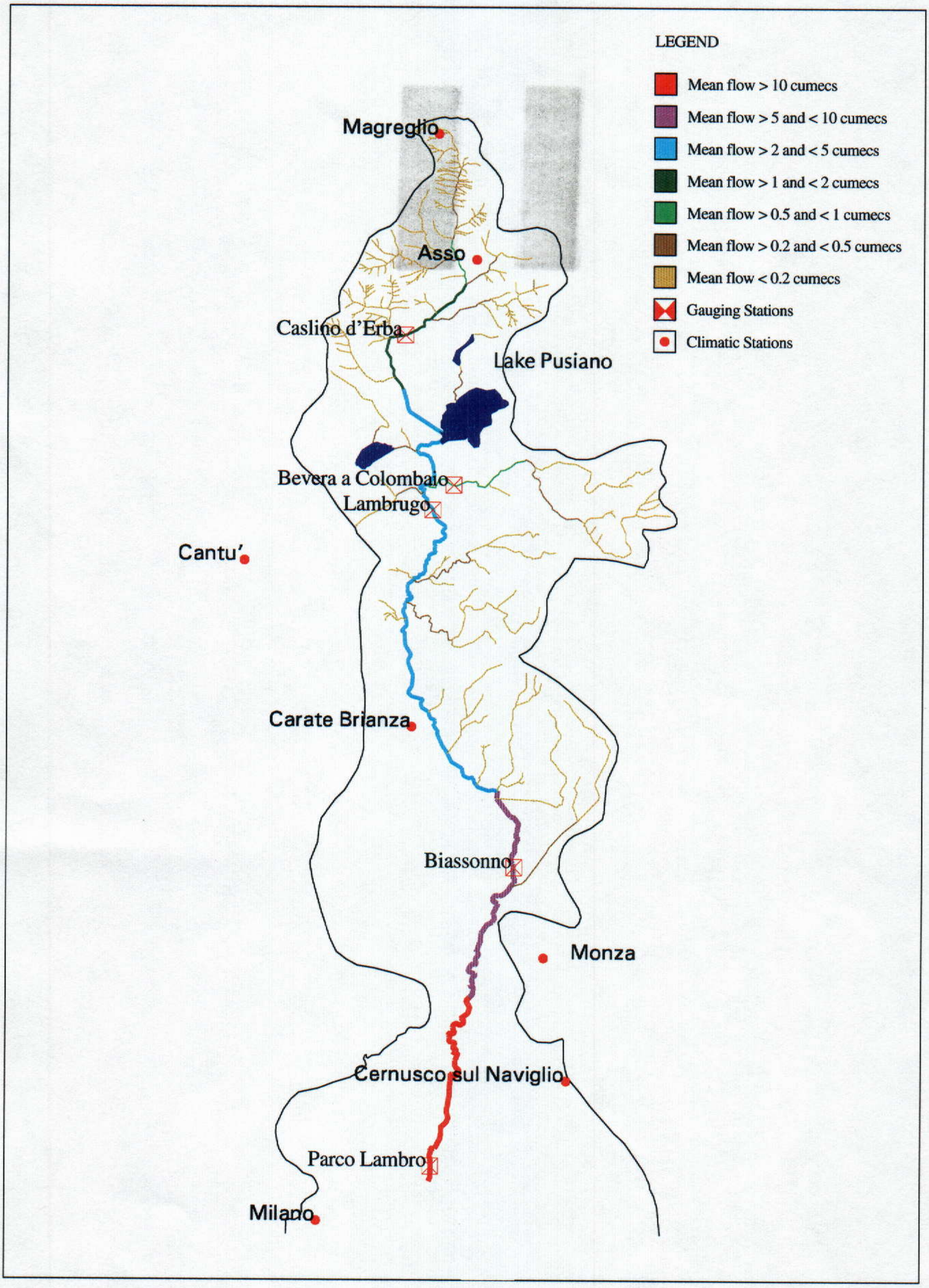


Exhibit (A) : Mean flow estimates for the Lambro catchment

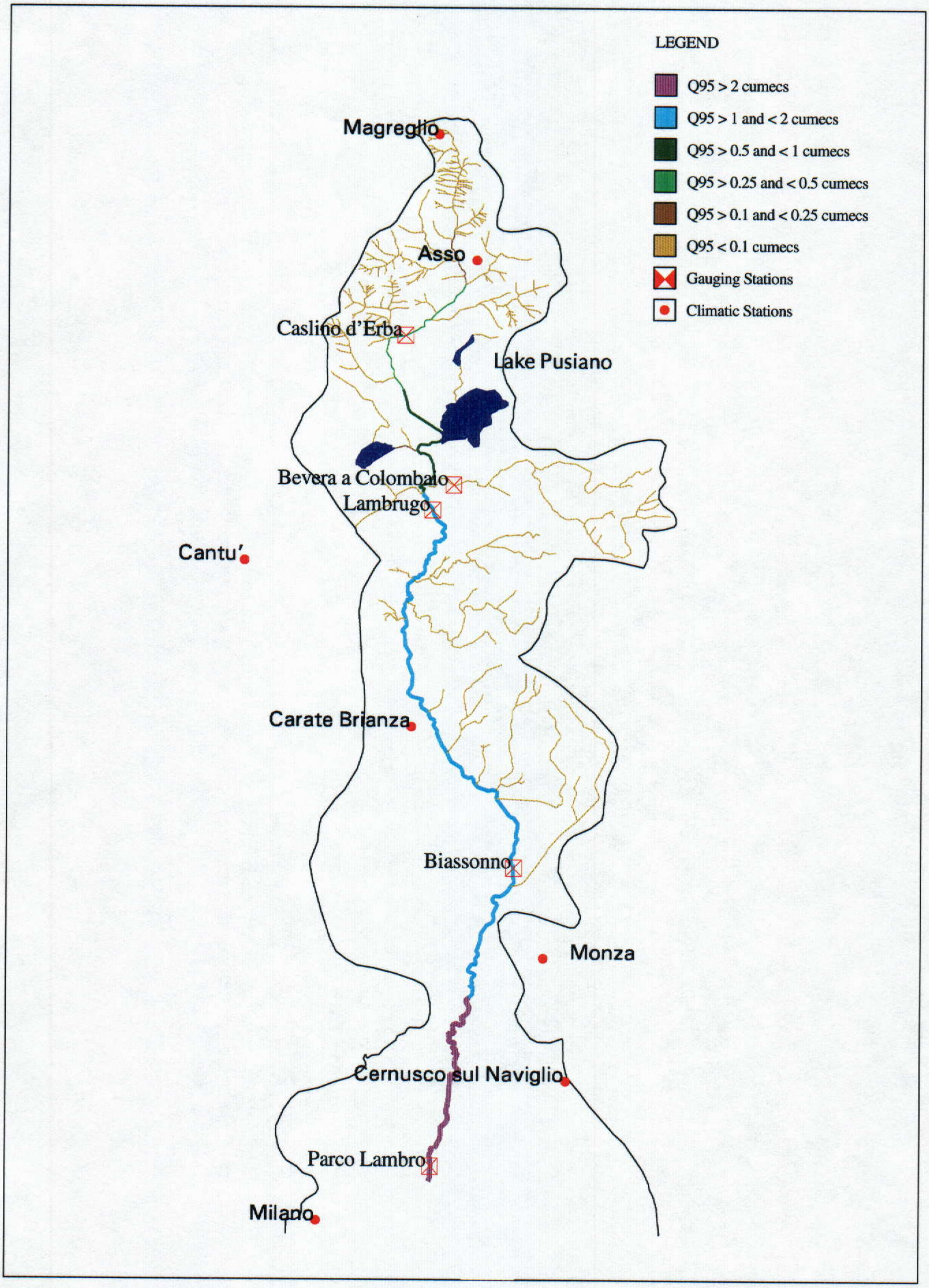


Exhibit (B) : Q95 estimates for the Lambro catchment