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Pre-feasibility estimation of flows on Buonamico River at St. Luca Hydro Scheme, Southern Calabria

A. Bullock and Kelly D. M.

November, 1989

Institute of Hydrology
Wallingford
Oxon
OX10 8BB
Tel: (0491) 38800
Telex: 849365 HYDROL G

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1. Introduction

This report develops a procedure for estimating flows with a given exceedance probability at an ungauged site on the Buonamico River at St. Luca Hydro Scheme, Southern Calabria, Italy. The catchment above St. Luca Hydro Scheme has a catchment area of 115.0 km^2, receives an estimated average annual rainfall of 1725mm and drains FAO soil unit Bd, (Dystric Cambisols) comprising weakly weathered acidic parent material. Pre-feasibility estimates of flows at St. Luca are required for assessing the suitability of the site for a hydropower scheme.

Mean flow at the ungauged site is estimated to be 3.8 cumecs from simple regional water balance and linear rainfall runoff models using data from 62 gauging stations throughout Calabria and Sicily. A pooled standardised flow duration curve is developed for FAO soil unit Bd, which characterises the flow variability of rivers overlying Dystric Cambisols in Southern Calabria. The pooled flow duration curve is calculated from 5 gauging stations with continuous daily mean flow data. Combination of the mean flow estimate and the standardised flow duration curve enables the estimation of rivers flows of given exceedance probabilities in absolute discharge units at the site of interest. The monthly distribution of flows is calculated from 5 gauging stations and expressed as both the proportion of flows which can typically be expected to occur in each month, and as mean monthly flows at St. Luca Hydro Scheme.

2. Estimation of mean flow

A simple water balance model was developed for the estimation of mean flow using average annual yield (AAY) and average annual rainfall (AAR) from 62 catchments in Calabria and Sicily. The catchments used are listed in Table 1. The period of record used for the derivation of the mean annual statistics is prior to 1970, except for those 5 catchments highlighted by asterisks for which more recent data were available.

For each catchment average annual actual evaporation losses were calculated as the difference between rainfall and flow. Figure 1 shows the regional relationship between average annual actual evaporation losses and average annual rainfall.

Table 1. Mean runoff and rainfall data for 62 catchments in Southern Calabria and Sicily

	AREA (sq.km.)	AAY (mm)	AAR (mm)	
RAGANELLO a Terzeria	143.0	319	1114	
MUCONE (Crati) a Luzzi	73.0	538	1164	
CRATI a Conca	1132.0	620	1260	
ESARO (Crati) a Cameli	55.4	887	1499	
ESARO (Crati) a La Musica	532.0	665	1469	
COSCILE (Crati) a Camerata	303.0	652	1249	
TRIONTO a Difesa	31.7	577	1253	
CARGA (Neto) a Torre Garga	43.0	686	1317	
LESE (Neto) a Schiena d'Asino	60.0	685	1382	
PONTICELLI a ponte SS 106	13.4	464	567	
ESARO DI CROTONE a S. Francesco	81.2	234	636	
TACINA a Rivioto	77.0	932	1492	
TACINA a Serrarossa	223.0	627	1161	
ALLI a Orso	46.0	852	1527	
MELITO (Corace) a Olivella	41.2	608	1256	
CORACE a Grascio	178.0	701	1406	
ANCINALE a Spadola	42.5	1314	1712	**
ANCINALE a Razzona	116.0	1024	1699	**
ALACO a Mommone	14.8	1199	1820	**
ALACO a Pirrella	38.0	1124	1748	**
ASSI a Botteria	52.8	653	1456	
ALLARO a ponte Mongiana	11.8	1060	1329	**
CARERI a Bosco	48.0	561	1698	
ANNUNZIATA a Straorino	8.1	799	1454	
CALABRO' (Petrac) a Puzzara	54.0	1303	1561	
DUVERSO (Petrace) a S Giorgia	28.7	949	1777	
VASI' (Petrace) a Scifa'	19.4	1519	1922	
PETRACE a Gonia	410.0	645	1492	
MESIMA a Sbarretta	424.0	371	1112	
METRAMO (Mesima) a Castagnara	16.5	1488	1816	
METRAMO (Mesima) a Carmine	233.0	618	1509	
AMATO a Marion	115.0	677	1422	
AMATO a Licciardi	435.0	514	1299	
SAVUTO a Ponte Savuto	141.0	834	1497	
LAO a Pie' di Borgo	279.0	1004	1569	
NOCE a La Calda	44.0	1186	1670	
NOCE a Le Fornaci	186.0	1145	1909	
S LEONARDO a Monumentale	521.5	198	714	
ELEUTERIO a Lupo	10.3	315	862	
VALLE DELL'ACQUA a Serena	21.7	207	788	
ORETO a Parco	75.6	505	1080	
NOCELLA a Zucco	56.6	252	951	
JATA a Taurro	163.8	224	786	
FASTAIA a La Chinea	32.5	176	660	
DELIA a Pozzillo	138.8	147	688	
BELICE DESTRO a Sparacia	116.5	257	750	
BELICE SINISTRO a Case Belate	324.5	213	748	
SENONE a Finocchiara	76.8	200	640	
BELICE a Belice	807.2	185	729	

PLATANI a Passofonduto	1237.0	146	664
IMERA MERIDIONALE O SALSO a Cinque Archi	545.3	132	696
IMERA MERIDIONALE O SALSO a Capodarso	611.0	152	693
IMERA MERIDIONALE O SALSO a Besero	995.1	113	652
IMERA MERIDIONALE O SALSO a Drasi	1782.1	81	547
DIRILLO a Dirillo	233.7	45	516
SIMETO a Biscari	696.0	384	896
SIMETO a Giarretta	1832.2	309	747
GIRGIA a Case Celso	24.9	229	705
DITTAINO a Bozzetta	79.2	227	731
CRISA a Case Carella	46.9	213	646
GORNALUNGA a Secreto	232.1	79	602
ALCANTARA a Moio	356.1	249	961

SOURCE DATI CARATTERISTICI DEI CORSI D'ACQUA ITALIANI, Pubbl. N. 17 del Servizio Idrigrafico, 5a Edizione, Poligrafico dello Stato, Roma 1980. ** denotes published data updated by subsequent records.

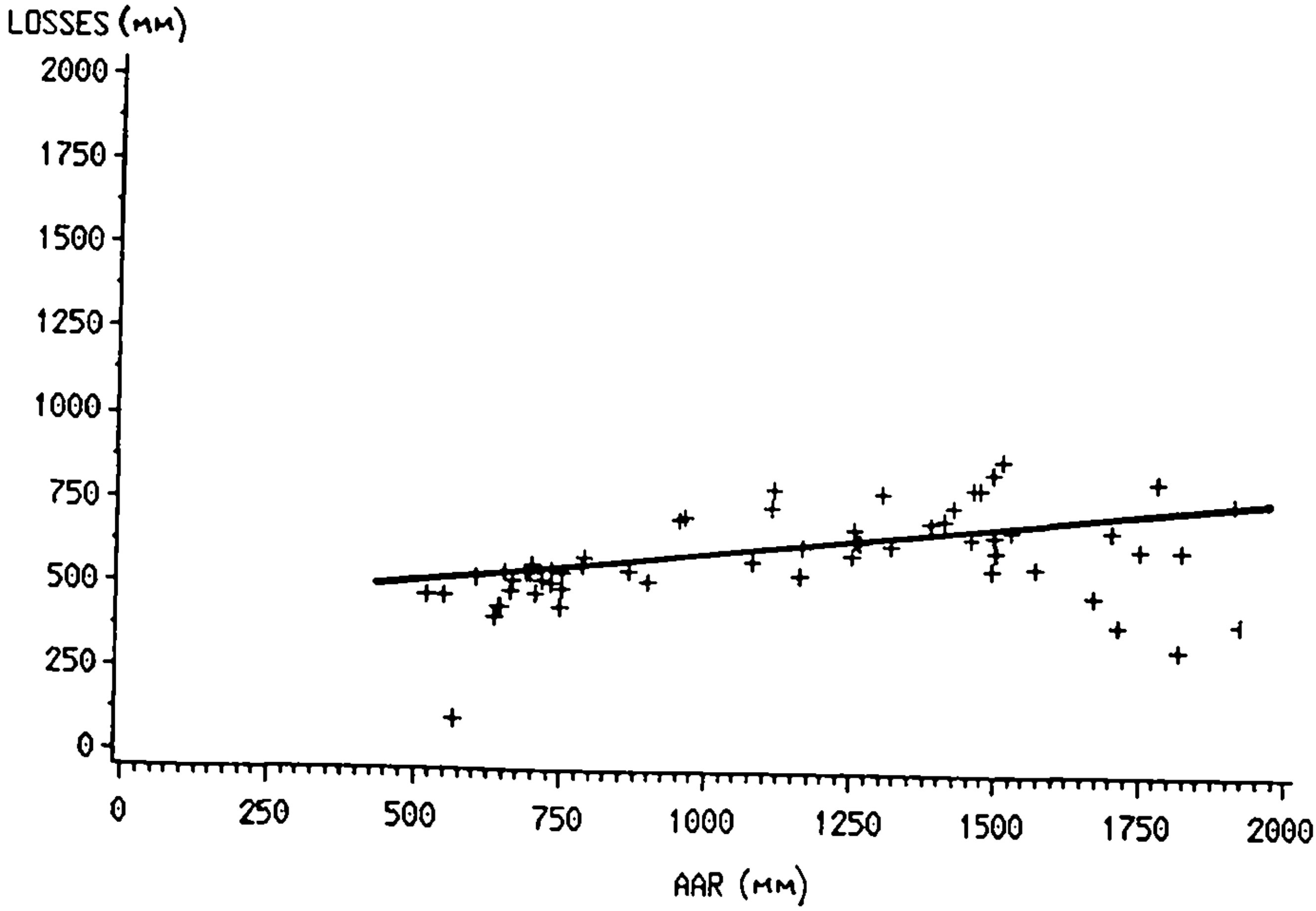

Figure 1 *Regional relationship between average annual evaporation losses and average annual rainfall for Calabria and Sicily based on 62 catchments.*

Figure 1 enables an appoximation to be made of actual evaporation losses at ungauged sites from a knowledge of catchment rainfall. The average annual rainfall for the Buonamico river at St. Luca Hydro Scheme is estimated to be 1725mm, calculated as the mean of average annual rainfall (1925-1970) at St. Luca (1299.5mm) and of average annual rainfall (1929-1970) at Polsi (2145.9mm). Interpolation of isohyets on a mean annual rainfall map of Southern Italy gives an approximate estimate of 1800mm for the Buonamico catchment above St. Luca. For a catchment receiving 1725mm actual evaporation losses are estimated from Figure 1 to be in the order of 650mm to 700mm. Average annual yield (AAY) at the site is calculated as the difference between rainfall and evaporation losses, giving an approximate value of AAY of between 1025mm and 1075mm at St. Luca Hydro Scheme.

A simple linear regression of AAY against AAR using the 62 catchments calculates the following equation.

$$AAY = 0.846\ (AAR - 483) \qquad R^2 = 0.85$$

$$s.e.e. = 153.7mm$$

Substituting on AAR value of 1725mm, this equation estimates AAY to be 1050mm, which is intermediate between the loss estimates.

This value of AAY may be converted to mean flow (in cumecs) using the following equation:

$$\text{Mean flow} = \frac{AAY * AREA}{31536}$$

where AAY is average annual yield (in mm), 1025mm in this case

AREA is catchment area (in sq. km.), $115km^2$ in this case

Using this conversion the mean flow on the Buonamico at St. Luca Hydro Scheme is estimated to be 3.8 cumecs.

3. Estimation of standardised flow duration curve

A standardised flow duration curve is developed for catchments draining the FAO soil unit Bd, which comprises Dystric Cambisols. The catchment above St. Luca is located entirely within this soil unit, and a standardised flow duration curve is developed which characterises flow regimes from adjacent catchments with similar soil properties.

Inspection of catchment boundaries and the Soil Map of the European Communities identified five catchments with continuous daily mean flow data which drain soil unit Bd. These catchments are listed in Table 2 with the period of flow data that was used in this study.

Table 2. Summary of daily flow data used in the development of a standardised flow duration curve for FAO soil unit Bd (Dystric Cambisils) in Southern Calabria

Gauging Station	Period of record used	Period of record available
ALACO at Pirrella	1970 1971	1970 - 1975 1979 198
ANCINALE at Razzona	1970 1971	1970 1982
ALACO at Mommone	1970 1971	1970 1980
ANCINALE at Spadola	1970 1971	1970 1980
ALLARO at Pone Mongiana	1970 1971	1970 - 1979

Not all available daily data were used in analysis because data were received in hardcopy form. For each of the five station, two years of flow data from January 1 1970 to December 31 1971 were loaded onto the HYDATA archiving and analysis package. The period 1970-1971 constitutes the only data period common amongst the available daily flow data.

In order to assess the representativeness of hydrological response during the selected 1970-1971 period, all available 13 years of daily data were loaded for ANCINALE at Razzona. Figure 2 presents calendar year flow duration curves for each of the 13 years, with the 1970 and 1971 years annotated. In each case, the annual flow duration curve is standardised by the 1970-1982 period of record mean flow at Razzona of 3.554 cumecs.

Annual flow duration curves at Razzona exhibit considerable consistency, with interannual variability between 0.2 and 20 times the long term mean flow. Neither 1970 nor 1971 are extreme in terms of the volume or distribution of hydrological response and each appears to adequately represent the available longer data period. Evidence from this comparison gives confidence to use of 1970-1971 data only at the other 4 gauging stations.

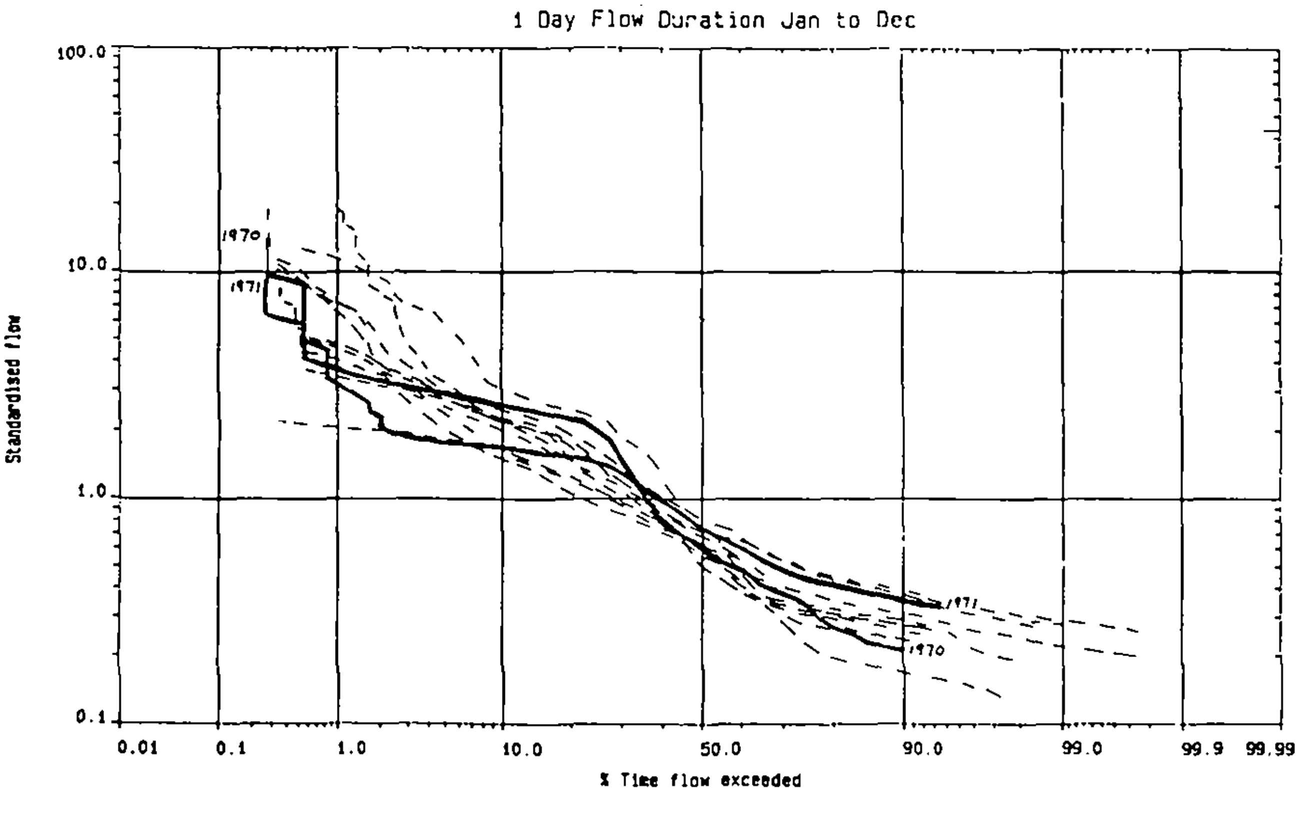

Figure 2. Calendar year 1 day flow duration curves for the River ANCINALE at Razzona for the period 1970 to 1982

Standardised flow durations curves for the period 1970-1971 for the five gauging stations draining FAO soil unit Bd are presented in Figure 3.

A	ALACO at Pirrella	(Mean flow =	1.25 cumecs)
B	ANCINALE at Razzona	(Mean flow	3.76 cumecs)
C	ALACO at Mammone	(Mean flow =	0.58 cumecs)
D	ANCINALE at Spadola	(Mean flow =	1.51 cumecs)
E	ALLARO at Pone Mongiana	(Mean flow	0.45 cumecs)

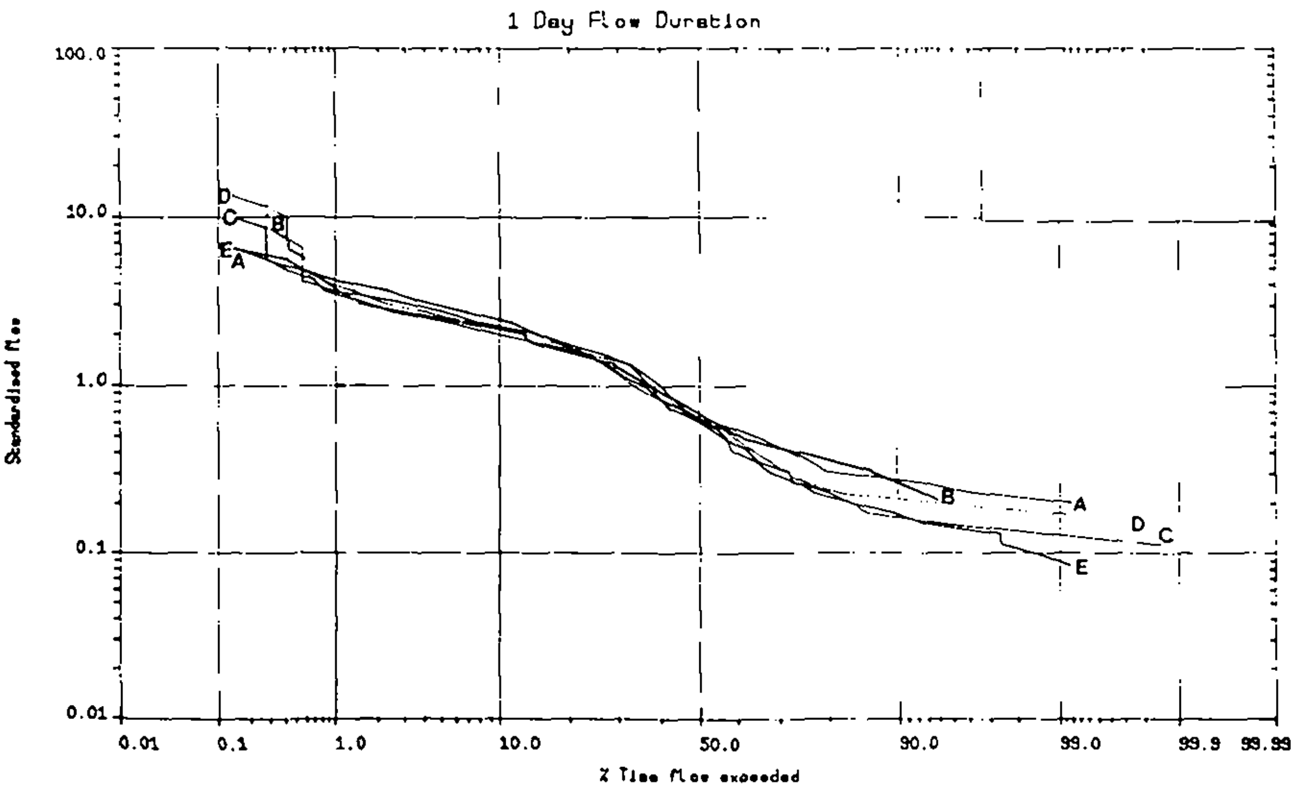

Figure 3. Standardised 1 day flow duration curves for 5 gauging stations draining FAO soil unit Bd (Dystric Cambisols) in Southern Calabria

Values of key exceedance percentiles expressed as a fraction of the mean flow at each gauging station are presented in Table 3, along with the calculated mean and standard deviation of these values.

Table 3. Catchment values (expressed as a fraction of mean flow) of key exceedance percentiles and the calculated mean and standard deviation for soil unit Bd

	Q95	Q90	Q75	Q50	Q25	Q10	Q5
ALACO at Pirrella	0.24	0.27	0.37	0.65	1.51	2.01	2.42
ANCINALE at Razzona	0.20	0.26	0.39	0.63	1.42	2.19	2.60
ALACO at Mammone	0.15	0.16	0.25	0.61	1.60	2.27	2.77
ANCINALE at Spadola	0.20	0.21	0.27	0.65	1.44	2.21	2.63
ALLARO at Pont Mongiana	0.14	0.17	0.26	0.63	1.45	2.47	2.97
Mean	0.19	0.21	0.31	0.63	1.48	2.23	2.68
Standard Deviation	0.04	0.05	0.07	0.02	0.07	0.17	0.21

The mean and standard deviation of key percentiles constitute a pooled standardised 1 day flow duration curve for FAO soil unit Bd in Southern Calabria. The pooled flow duration curve with associated error bands representing one standard deviation is presented graphically in Figure 4.

Conversion of exceedance percentiles to absolute discharge units (cumecs) is achieved by substitution of the mean flow into Figure 4. In this study, the mean flow of 3.8 cumecs on the Bunoamico at St. Luca Hydro Scheme should be substituted. For example, the flow which is estimated to be exceeded for 25% of time is 1.48 times the mean flow, notably 5.6 cumecs. Similarly, it can be estimated that a discharge of 1.0 cumecs (0.26 times the mean) will be exceeded for approximately 80% of time.

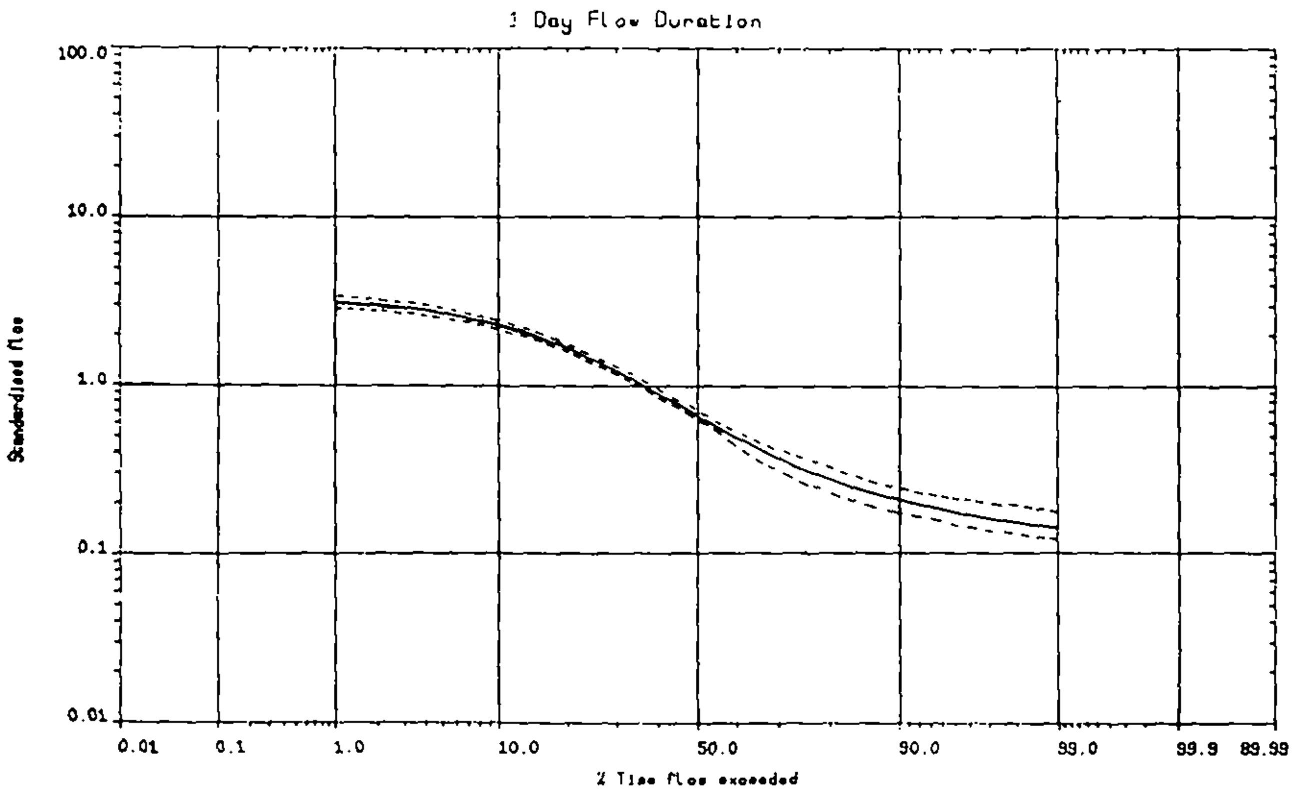

Figure 4. Pooled standardised 1 day flow duration curve for FAO soil unit Bd (Dystric Cambisols) in Southern Calabria

4. Estimation of mean monthly flows

Flow duration curves give no indication of the seasonal distribution of flows as the timing of flows is disregarded. Table 4 presents the proportion of mean flow occurring in each month for the five catchments draining FAO soil unit Bd, and calculates the mean and standard deviation of these monthly values.

Table 4. Fraction of flow occurring in each month at 5 gauging stations draining FAO soil unit Bd (Dystric Cambisols) and the calculated Mean and Standard deviation

	Pirrella	Razzona	Mammone	Spadola	Pont Mongiana	Mean	S.D.
JAN	0.14	0.16	0.16	0.16	0.16	0.16	0.01
FEB	0.13	0.15	0.16	0.16	0.15	0.15	0.01
MAR	0.12	0.15	0.15	0.14	0.15	0.14	0.01
APR	0.11	0.10	0.11	0.10	0.13	0.11	0.01
MAY	0.08	0.08	0.07	0.07	0.08	0.08	0.01
JUN	0.05	0.04	0.04	0.04	0.04	0.04	0.005
JUL	0.03	0.03	0.02	0.02	0.02	0.02	0.005
AUG	0.02	0.02	0.01	0.02	0.01	0.02	0.005
SEP	0.03	0.02	0.02	0.02	0.02	0.02	0.005
OCT	0.05	0.05	0.06	0.06	0.05	0.05	0.005
NOV	0.09	0.07	0.06	0.07	0.06	0.07	0.01
DEC	0.15	0.13	0.14	0.14	0.13	0.14	0.01

Combination of the mean flow estimate of 3.8 cumecs with these fractions allows preliminary estimates of mean monthly flows at St. Luca Hydro Scheme:

Mean Monthly flow (cumecs).

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
7.3	6.8	6.4	5.0	3.6	1.8	1.0	1.0	1.0	2.3	3.2	6.4

5. Estimation of Q_{max}

Rigorous estimation of Q_{max} at St. Luca Hydro Scheme cannot be achieved without undertaking either a regional flood frequency analysis or analysis of Probable Maximum Precipitation, both of which are beyond the scope of this pre-feasibility study.

For the five catchments on FAO soil type Bd in Southern Calabria for which daily flow data are available (see Table 2), the annual maximum mean daily flows were abstracted. For each station an index flood, Qbar was calculated as the arithmetic mean of the annual maximum flood series. These mean annual flood estimates were plotted against catchment area as shown in Figure 5 and a least-squares regression was fitted to these data. The derived relationship is:-

$$\text{Qbar} = 0.384 + 0.518\ \text{AREA} \qquad R^2 = 0.955$$

$$\text{s.e.e.} = 5.5\ \text{cumecs}$$

The fit is very good, although the data set is very restricted. However, an estimate of the mean annual flood for the Buonamico River at St. Luca Hydro Scheme may be produced from this equation, and with an area of 115 km^2, Qbar is estimated as 60 cumecs.

This Qbar estimate is for a mean daily flow, and the instantaneous peak would be very much greater. In general, for small catchments, we would expect the ratio of instantaneous peak to mean daily flow to be about 1.5 to 2 for small catchments in a region such as Calabria. Thus a better estimate of the instantaneous mean annual flood is assumed to be 100 cumecs.

For pre-feasibility purposes, an acceptable preliminary design flood may be the 500 year return period event. From Farquharson et al (1987), a flood frequency curve for catchments of less than 100 km^2 in Italy is presented in Table III. The 500 year flood is given there as 5.2 times Qbar, or 520 cumecs for the St Luca Hydro Scheme.

A flood frequency analysis was undertaken of the 5 stations on FAO Soil type Bd for which daily data were available. The mean ratio of the 500 year flood (Q_{500}) to Qbar for these individual stations is somewhat greater than that from Farquharson et al (1987). Thus a conservative preliminary estimate of the spillway design flood may well be closer to 700 or 800 cumecs.

A more thorough study of all available rainfall and flow data for the Calabria region would be necessary before the final design flood could be established.

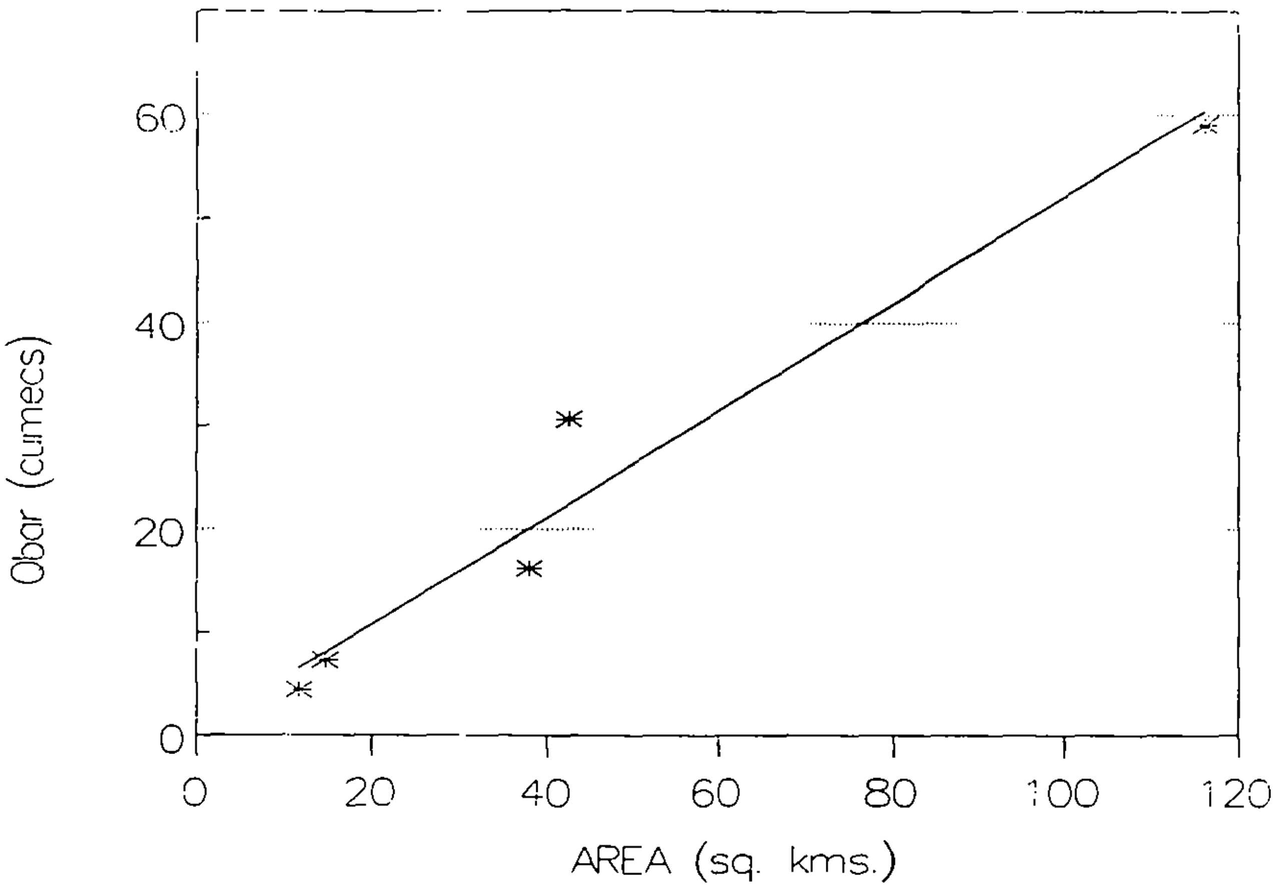

Figure 5 ***Regression relationship between mean daily flow Qbar and catchment area***

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