INSTITUTE of
HYDROLOGY

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Sir Alexander Gibb and Partners

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RESERVOIR YIELD ESTIMATES FOR BAIE LAZARE DAM, SEYCHELLES

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1. INTRODUCTION

Estimates of long term water demands for Mahe were prepared by Howard Humphreys and Partners in 1979, where the recommendation was made that the Baie Lazare catchment be developed to meet the forecast demands of Southern Mahe. At the time of the Howard Humphreys report, very few rainfall or runoff data were available for the proposed reservoir catchment. Subsequently, in 1982 the reservoir yield for the Baie Lazare catchment was updated by GITEC who were able to use rainfall and runoff data for a somewhat longer period.

Over recent years, the hydrological database of the Seychelles, and in particular Mahe, has been thoroughly reviewed by the Seychelles Water Authority with much of their work being undertaken or supervised by a British hydrologist, Eric Rooke, who left Mahe in February 1985. In view of this revision of the basic rainfall and flow data and because of the somewhat longer periods of record now available, this present study was undertaken to produce a full reappraisal of storage-yield for the proposed Baie Lazare dam.

The results presented in Section 4 of this report are believed to represent the best storage-yield estimates possible given the available data. However, because there are only eight years of runoff data on the Baie Lazare river and because the Val D'Endore rainfall record from within the catchment is of relatively poor quality, some uncertainty as to the true safe long term yield of the proposed dam remains. This uncertainty will remain until very much longer runoff records are available. In order to attempt to quantify this uncertainty in the storage-yield results, results of recent unpublished research undertaken by the Institute of Hydrology have been used. Thus in Section 4, where the reservoir storage capacity required to meet various yields is presented, the possible range of uncertainty in these estimates is disucssed. It should be noted that these quoted confidence limits on reservoir capacity are based on research in other parts of the world and have not been tested under conditions prevailing in the Seychelles. Nevertheless, the confidence limits presented on the final figure of this report are unlikely to be grossly inaccurate.

2. DATA AVAILABLE

The hydrometerological data available for the present studies were drawn from the Draft Hydrological Yearbook dated July 1985 produced by the Seychelles Water Authority. This compendium of rainfall, evaporation, climate, flow and groundwater data is believed to represent the most authoritive set of information presently available for Mahe. The data contained in these yearbooks comprise a significantly longer and better quality data set than was available for either the Howard Humphreys or GITEC reports.

2.1 RAINFALL DATA

Mahe has a resonable coverage of daily raingauges although the south and west of the island is rather less well represented. The Baie Lazare catchment has one raingauge at Val D'Endore which has daily records since August 1975 and an autographic recorder since March 1977. However, both records have significant gaps and few years are complete. In those months where both gauges were operational, the agreement between the gauges is reasonable, if not exactly good, with a correlation coefficient of $r = 0.937$. Despite there being some rather large descrepancies between the two records in individual months, it was reasonable to derive a composite record for Val D'Endore based mainly on the autographic recorder, infilled as necessary from the daily gauge. This composite record is shown in Table 1. The mean annual rainfall at Val D'Endore is estimated to be 1885 mm which is somewhat higher than the value of 1770 mm shown on the map of Mean Annual Rainfall given in the Seychelles Water Authority Yearbook.

There are a number of longer rainfall records on Mahe as shown on Figure 2, which is a bar chart showing rainfall data availability. Because the Val D'Endore record length is short, record extension by regression on other longer rainfall records was attempted. Monthly correlations for 1975-84 of Val D'Endore with Victoria (New Port), Grand Anse, Anse Royale Hospital, Anse Boileau and Anse Aux Pins showed that Val D'Endore was reasonably correlated with all of these stations. There was no strong reason for preferring any particular raingauge for record extension on purely statistical grounds and so the Victoria record was adopted because it has the longest record by far.

TABLE 1 MONTHLY RAINFALL AT VAL D'ENDORE

(Composite record from Autographic and Daily raingauges. Data from Seychelles Water Authority Year Book, July 1985)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1975								88.0	43.5	92.0	72.5	362.5	-
1976	294.0	382.5	134.5	103.5	39.5	51.0	70.5	154.0	130.0	64.5	14.5	331.5	1770
1977	286.5	195.0	280.9	219.6	31.2	53.6	88.8	78.2	25.2	400.7	165.9	314.8	2140
1978	245.6	106.5	149.6	222.9	92.7	42.3	56.2	27.2	-	147.9	533.3	367.9	-
1979	368.4	72.3	242.7	188.0	39.6	70.9	85.1	31.0	19.3	206.0	278.8	169.2	1602
1980	71.9	240.8	67.7	251.7	207.1	104.9	83.5	72.2	28.9	-	116.4	244.5	-
1981	239.8	39.4	395.6	56.0	199.8	68.1	36.3	43.6	20.4	126.2	307.9	412.0	1545
1982	-	-	127.6	-	141.5	69.8	63.0	80.1	172.1	47.2	241.5	249.4	-
1983	467.8	18.2	64.2	226.6	180.6	90.0	140.8	243.4	409.0	74.2	123.6	312.0	2350
1984	287.7	233.8	114.3	115.9	16.0	37.3	-	-	104.2	316.1	155.4	382.2	-
1985	161.5	119.4	359.8	228.4	200.6	25.8							
Mean	269.2	156.4	193.7	160.4	114.9	61.4	78.0	90.9	102.8	163.9	201.0	292.6	1881
St. Devn.	113.2	117.0	118.8	87.3	79.4	24.3	30.8	68.7	134.9	122.2	148.1	116.4	350

Note The Mean Annual rainfall of 1881 is for the 5 complete years only. It should be noted that the sum of the monthly mean rainfalls is 1885 mm.

Location of raingauges

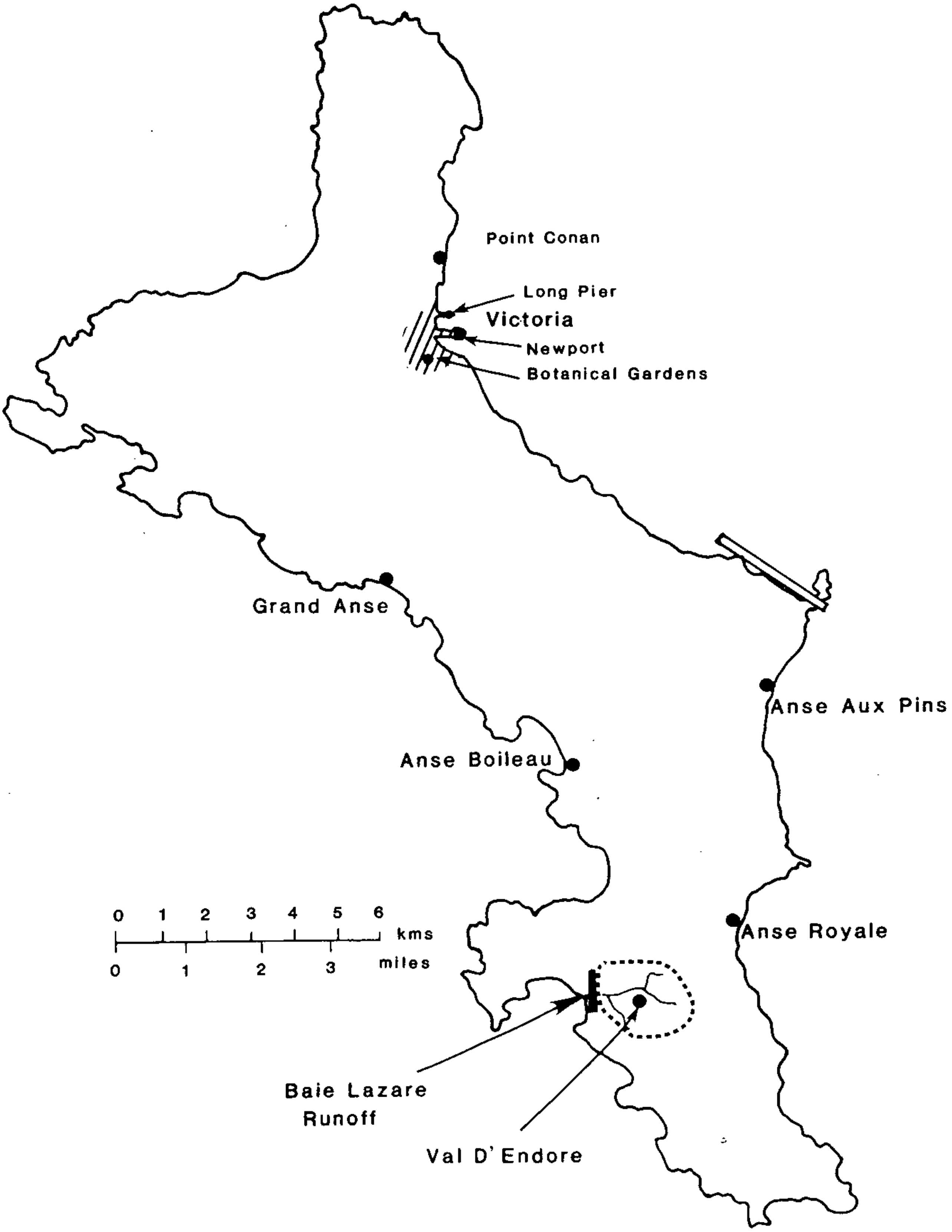

Figure 1

Rainfall data availability

(Only raingauges of major significance to the present study)

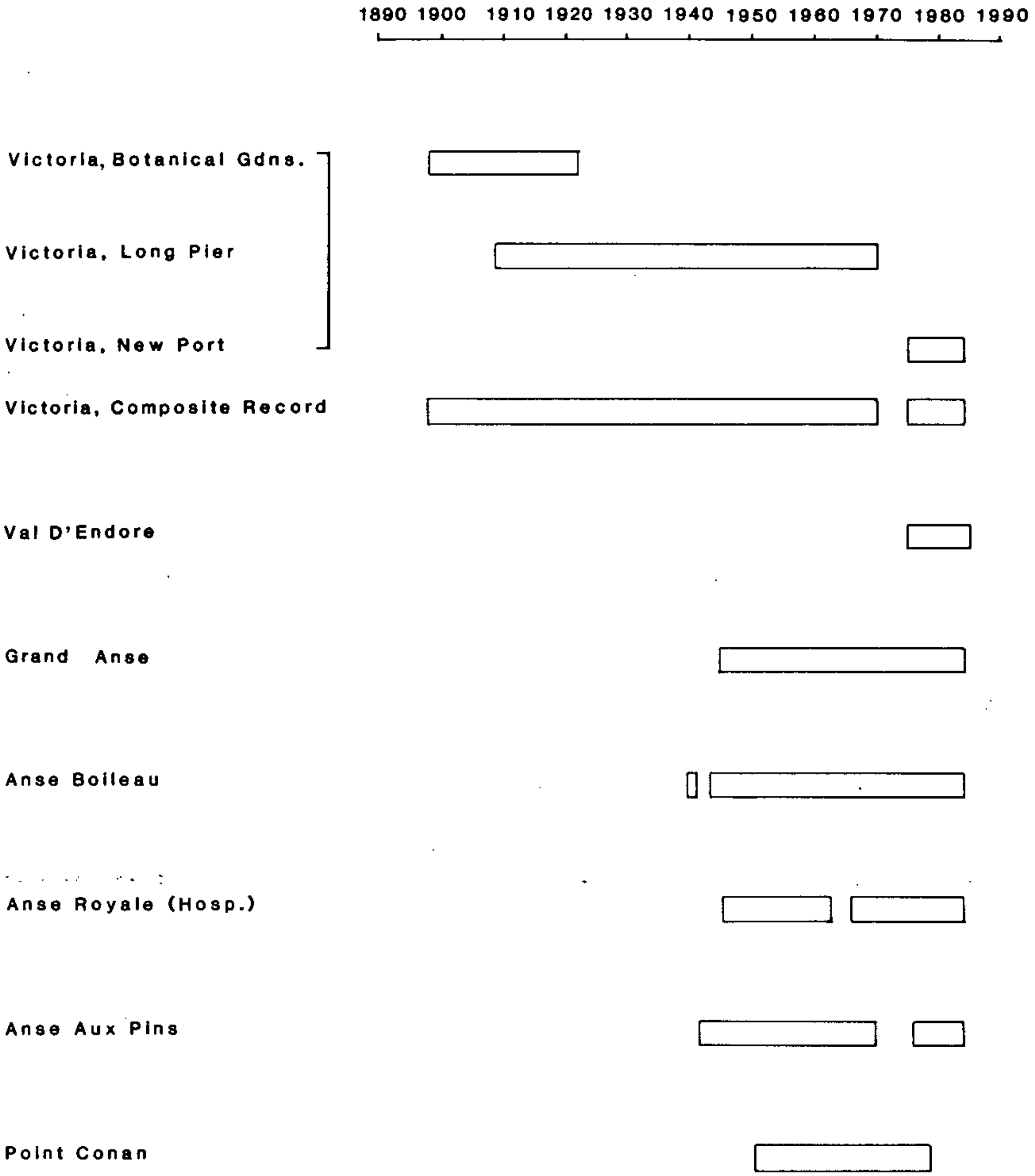

Figure 2

A composite rainfall record was derived for Victoria comprising the Botanical Gardens data from 1898 to 1908, Long Pier from 1909 to 1970 and the New Port from 1975 to 1984. No attempt was made to fill the gap in the Victoria record of 1971 to 1974 as the great length of the available observed rainfall record was thought to represent adequately long term rainfall variability.

Details of the Val D'Endore record extension are given in Section 3.1 of this report.

2.2 EVAPORATION DATA

A number of estimates of open water evaporation for Mahe have been made over the years and the annual totals of these estimates vary from 1670 to 2230 mm. The lowest estimate is contained in the GITEC report of 1982 and is for Penman open water evaporation, as are the annual totals of 1760 mm from the Seychelles Water Authority Yearbook and 1980 mm given by Howard Humphreys in their 1979 report. An annual total of 2230 mm is given by the Ministry of Transport and Tourism, Dept of Civil Aviation in their "Climate of the Seychelles". It is not clear how this figure was computed.

Calculation of evaporation using the Penman formula involves some empirical choices of parameters and so the variability in published annual totals is not altogether surprising. The total of 1760 mm given in the Seychelles Water Authority Yearbook is the most recent estimate available and has been computed by hydrologists based in the Seychelles rather than by short term consultants. The monthly Penman open water evaporation estimates computed by the Seychelles Water Authority have been adopted for this study. They are shown in Table 2.

TABLE 2 PENMAN OPEN WATER EVAPORATION (mms)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
121	125	131	115	161	177	188	193	192	141	111	105	1760

2.3 RUNOFF DATA

The Baie Lazare river has been gauged since July 1977 when a recorder was installed to monitor water level over the compound broad crested weir with its associated V-notch plate. Daily flows are available from the

Seasonal distribution of rainfall, evaporation and runoff

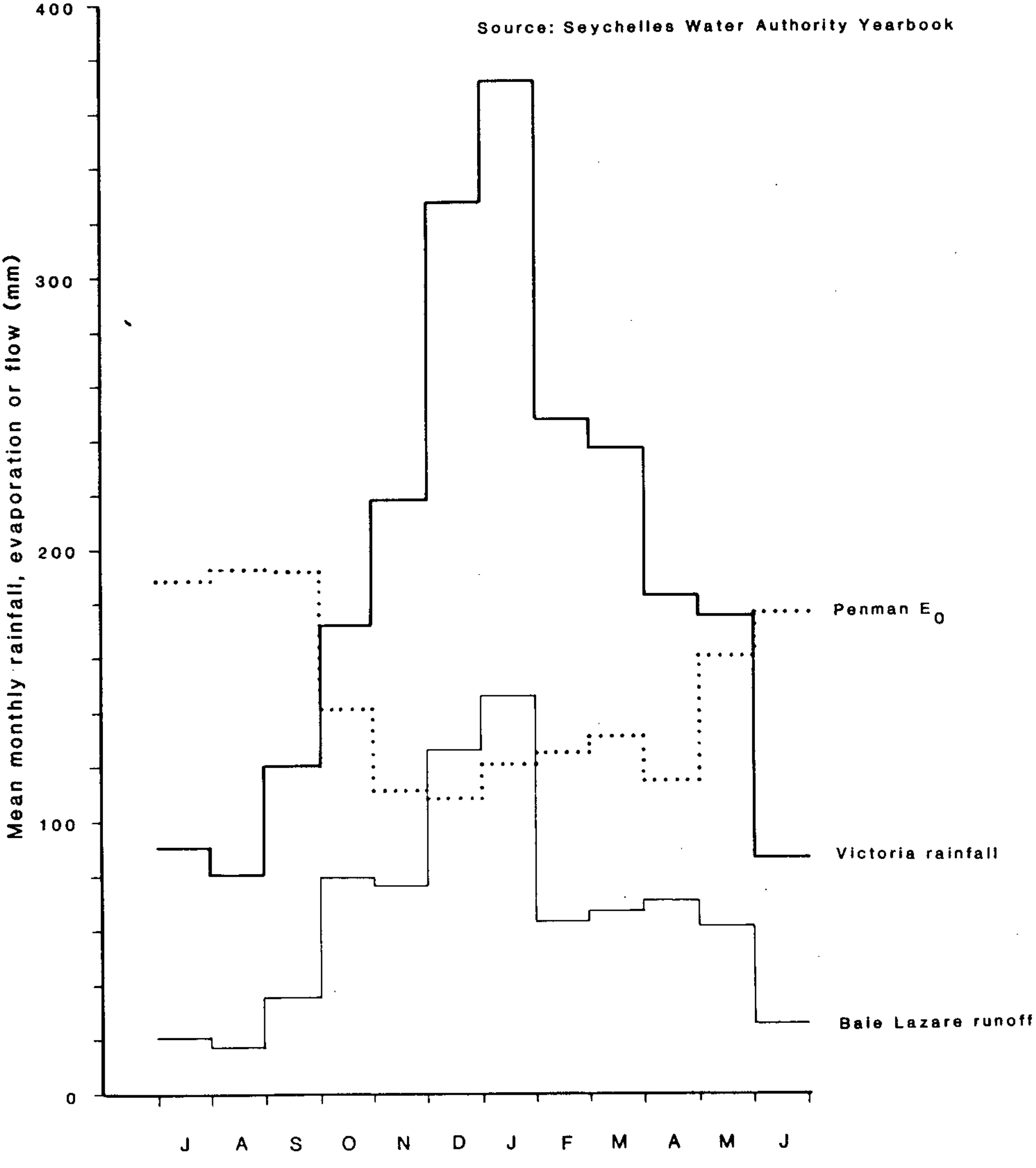

Figure 3

TABLE 3 MONTHLY RUNOFF AT BAIE LAZARE
(MM DEPTH OVER THE CATCHMENT)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1977							17	15	7	118	51	105	
1978	128	77	68	136	80	33	18	9	8	19	163	214	992
1979	223	93	109	90	36	20	18	11	5	13	56	59	733
1980	45	54	16	52	107	64	34	20	11	4	23	42	472
1981	64	28	99	53	62	27	15	10	4	11	77	205	657
1982	156	30	31	49	27	11	30	14	81	247	114	153	945
1983	295	65	53	55	78	26	29	44	155	127	44	99	1071
1984	157	100	60	42	15	12	6	17	15	89	85	130	728
1985	98	65	102	84	83	31							

Mean Annual Runoff of 8 water years (July to June)

⩦ 791 mm

Seychelles Water Authority Yearbook for the period July 1977 to July 1985. Although data from individual days are missing, monthly mean flows are given for the entire period of record in the Yearbook. These flows have been accepted as being reliable for the present studies as they cannot be checked adequately without access to the original records.

For the eight years recorded, the mean annual runoff is 791 mm which is 42 per cent of the average annual rainfall of 1885 mm. The runoff ranges from 467 mm in July 1980 to June 1981, and 500 mm for 1979/80 up to 1211 mm for 1982/83. Flows are lowest in the period June to September and December and January normally experience the highest flows in any year. This pattern exactly mirrors the mean monthly rainfall pattern as shown in Figure 3.

The recorded flows used as the basis for the present studies are given in Table 3. The proposed dam site is some distance downstream of the flow gauging station on the Baie Lazare river. However, the area downstream of the gauging station but upstream of the dam is only about 0.3 sq kms or about one eighth of the gauged portion of the dam catchment. Because of the uncertainties inherent in estimating the long term mean and variability from just eight years of flow record, no adjustment has been made to the flows given in Table 3. In Section 3.1, extension of the short period of recorded flows is discussed and it is suggested that the long term flow sequence generated as described in 3.1 provides a reasonable basis for reservoir design.

2.4 RESERVOIR AREA AND CAPACITY CHARACTERTISTICS

Reservoir area and capacity relationships were derived from 1:2500 scale contour maps with a contour interval of 5 metres. The resulting relationships are shown in Table 4.

TABLE 4 RESERVOIR ELEVATION/AREA/CAPACITY RELATIONSHIP

Water Elevation (m)	Reservoir Area (ha)	Reservoir Volume (Megalitres)
75	0.210	0
80	1.422	41
85	3.693	169
90	7.743	455
95	13.164	977
100	17.673	1748

Note Minimum draw-off level taken as 83 m

Hence Dead Storage = 100 Ml

3. RECORD EXTENSION

The short rainfall and flow records at Val D'Endore and Baie Lazare could be used directly to generate historic values independently of rainfall information from other parts of the island. However, because a fairly strong relationship exists between rainfall records at all sites, information over the historic period at other localities can be used to produce simulated flow and rainfall records of greater accuracy at Baie Lazare and Val D'Endore respectively.

A comparison with rainfall records at other sites suggests that rainfall data from Val D'Endore are not in general grossly inaccurate, although records for April 1979 and October 1982 are omitted from all analyses. Inspection of monthly correlations of rainfall records at all the sites over the period 1975-1984 shows that rainfall at Val D'Endore is roughly as well correlated with rainfall at Victoria as with rainfall at closer sites. This may be explained by a general climatic effect over the whole island, with independent superimposed differences at individual sites. Because of this, and because it has the longest period of historic data, only Victoria is used as a source of information for simulating historic flows and rainfall records at Baie Lazare and Val D'Endore.

Flow and rainfall record extension are treated separately. An alternative would be to simulate historic rainfall at Val D'Endore, and use these to simulate flow at Baie Lazare, using a rainfall runoff relationship estimated from the 1977-1985 data. There is some merit in doing this, but the two stage procedure is likely to give poorer simulation of flow due to the additional uncertainty in estimating two relationships rather than one.

3.1 RUNOFF RECORD EXTENSION

Taking first the extension of flow records, we chose a lagged regression relationship as the underlying structural model, given as

$$q_t = a_{j,1} q_{t-1} + \cdot\cdot + a_{j,k} q_{t-k} + b_{j,0} p_t + b_{j,1} p_{t-1} \cdot\cdot + b_{j,i} p_{t-i} \qquad (1)$$

Here subscript $j = 1, \cdot\cdot 12$ is introduced to allow for different parameters a,b for each month. The variables q_t, p_t denote flow and rainfall in month t at Baie Lazare and Victoria. Note that $t = j + (n-1)\times 12$ where n is the n^{th} year of data. Because the catchment is small and data are monthly, lags k and i are expected to be small. Fitting equation (1) as an unweighted regression suggested values of 1 and 0, leaving

$$q_t = a_j \, q_{t-1} + b_j \, q_t \tag{2}$$

$$\text{or} \quad \text{flow}(t) = a_j \, \text{flow}(t-1) + b_j \, \text{rainfall}(t) \tag{3}$$

Here the second subscript on a and b have been dropped since there is no ambiguity.

Because errors appear to be higher at higher flows, a transformed non-linear regression was used for estimation,

$$\log(\text{flow}(t)) = \log(a_j \text{flow}(t-1) + b_j \text{ rainfall}(t)) + e_{j,t} \tag{4}$$

Here $e_{j,t}$ is a Normally distributed random term with mean zero and variance $\sigma^2_{j,1}$. Separate fitting of equation (4) for each month suggested no significant difference between $a_1, a_2 \, .. \, a_{12}$ and $b_1, b_2 .. b_{12}$ except in February. A combined model

$$\log(\text{flow}(t)) = \log(a \text{ flow}(t-1) + b \text{ rainfall}(t)) + e_t \tag{5}$$

was fitted, with February rainfall reduced to .5 x recorded value. This value was thought suitable since February rainfall at Val D'Endore is about half that at Victoria. The difference in the b_j parameter for February is a reflection of this. Fitting the combined model of equation (5) gave estimates shown in Table 5.

TABLE 5 PARAMETERS OF RUNOFF EXTENSION MODEL

	Estimate	SE	Correlation matrix	
a	.30	.05	1	
b	.52	.06	- .64	1

$\sigma^2_1 = .23$

Clearly both a and b are significant, confirming the usefulness of rainfall at Victoria for flow simulation at Baie Lazare, in the absence of other related variables. For simulation, equation (5) is used with a sensible value chosen for flow (1), a and b chosen at random from a Normal probability density with mean and variance taken from Table 5, and e_t chosen with variance σ_1^2 estimated as 0.23.

3.2 RAINFALL RECORD EXTENSION

Rainfall simulations at Val D'Endore were based on a structural relationship

$$z_t = c_j + d_j p_t \tag{6}$$

where z_t is rainfall at Val D'Endore in month t, c_j and d_j, j=1,2..12 are parameters. Separate fitting of the regression relationship for ech month suggested that the parameters c_j were not significantly different from zero, leaving

$$\text{rainfall at Val D'Endore (t)} = d_j \text{ rainfall at Victoria (t)} \tag{7}$$

or $$\mathrm{RVD}(t) = d_j \, \mathrm{RVic}(t) \tag{8}$$

A logarithmic relationship

$$\log \mathrm{RVD}(t) = \log d_j + \log \mathrm{RVic}(t) + a_{j,t} \tag{9}$$

was initially used to estimate d_j for each month. Here $a_{j,t}$ is a Normally distributed error term having mean zero and variance $\sigma_{j,2}^2$. Estimates of d_j were generally about 1, but significantly different in December, January, February, June, July, August. To account for this, the following adjustments were made to Victoria rainfall, the new series being denoted RVic':

January : recorded value x .8
February : " " x .4
June : " " x 1.3
July : " " x 1.3
August : " " x 1.3
December : " " x .8

A single combined model

$$\log RVD(t) = \log d + \log RVic'(t) + a_t \qquad (10)$$

was then fitted using the adjusted data. Examination of the results of this fitting suggested that the logarithmic transformation was rather strong, and would give a tendency for occasional very large simulated rainfall values. To avoid this a weighted regression was introduced, with d estimated by minimizing

$$SS = \Sigma_t w \ (\log (RVD(t)) - \log(d) - \log RVic'(t))^2. \qquad (11)$$

Here the weight w_t is chosen as RVic'(t), and the variance of a_t, σ_2^2, estimated by SS/N-1, N being the number of months data used, 104.

Estimates of d and σ_2^2 are given in Table 6

TABLE 6 PARAMETERS OF RAINFALL EXTENSION MODEL

	Estimate	SE
d	0.95	.04

$\sigma_2^2 = 26.7$

Monthly rainfall simulations were computed using

$$\log RVD(t) = \log(d) + \log RVic'(t) + a_t/\sqrt{RVic'(t)} \qquad (12)$$

with d and a_t chosen at random from Normal (.95, 0.0016) and Normal (0,26.7) densities respectively.

4 RESERVOIR YIELD

4.1 CHOICE OF STORAGE-YIELD DESIGN PROCEDURE

The large number of available reservoir yield design procedures can be broadly classified into three groups. The first group, "critical period techniques", analyses events when the demand cannot be met by the inflows to the reservoir. The second is based on probability matrix methods and the third depends on the generation of sequences of stochastic flows.

There has been much discussion concerning the choice of reservoir yield design methods. For this study we decided to use several methods to compare the different results. This will provide more information on which to base the final solution and may also indicate the variability due to the uncertainties of the short inflow series available. Also it will show there is no unique solution for data that does not fully describe the population statistics. The critical period techniques include many methods such as Stall, Rippl etc. and from these we have chosen to use the Deficient Volumes method (Parks and Gustard, 1982) as it is particularly concerned with the drawdown of reservoir capacity during low inflow sequences.

The most flexible of the matrix methods is the Gould procedure (McMahon and Mein, 1978). This incorporates a monthly water balance and a surface area related evaporation. We have adopted this method as our second storage-yield analysis technique.

The procedures requiring stochastic flow generation seem inappropriate for this study as the 8 years of measured flows would not be sufficient to calibrate a generation model. The longer synthetic series could be used as a basis for generation but the data would have been generated through the use of two models and would have all the inherent errors that this implies. We have therefore not chosen a method from this category.

The third method we have used is the simple counting of number of years of failures in order to produce a failure rate estimate. This complements the deficient volumes analysis as one looks at the capacity required to sustain a yield during non-failure periods while the other estimates a failure measure strictly from the failure years. The following three sections describe each of the methods in detail.

(i) Method A: Deficient Volumes

This method is based on reservoir simulation using monthly inflows, demands and evaporation. An initial reservoir capacity and yield are chosen within the likely range of interest. A monthly water balance is carried out to obtain the draught on reservoir storage required to meet the selected demand. Figure 4 describes a typical summation of these draughts showing both the cases of spill and failure. The annual maximum draught is extracted from the monthly reservoir simulation and in the case of Figure 4 these are S1, S2, S3 and S4. S1, S2 and S3 are typical examples of the deficient volumes that the reservoir must supply from storage in order to meet the demand. S4 must be discarded as the reservoir has failed and the yield has not been met.

The non-failure deficient volumes from each year are ranked and plotted. As they are an annual maximum series the most applicable distribution is likely to be that of the log normal. Blom's plotting position was used where the non-exceedence probability (Fi) of the i^{th} smallest storage is given by

$$Fi = \frac{i - 0.375}{n + 0.25}$$

where n = total number of years of data available.

The results of plotting three ranked series of deficient volumes is shown in Figure 5 for three different sized reservoirs. All values to the left of the true storage probability line are failures and not included in the analysis.

Considering the smallest reservoir capacity, the ranked deficient volumes increase as the probability of failure increases until a plateau is reached where failures occur and the storage required is equal to the capacity of the reservoir. The selected demand will be provided by this reservoir capacity with a probability of failure, P_1, determined from the intersection of the curve and plateau. Thus the probability of failure is determined from the distribution of the non-failures. The practical solution is found by extending the distribution of non-failures and using the point at which it crosses the horizontal line representing the capacity of the reservoir.

Typical summation of monthly draught on reservoir storage

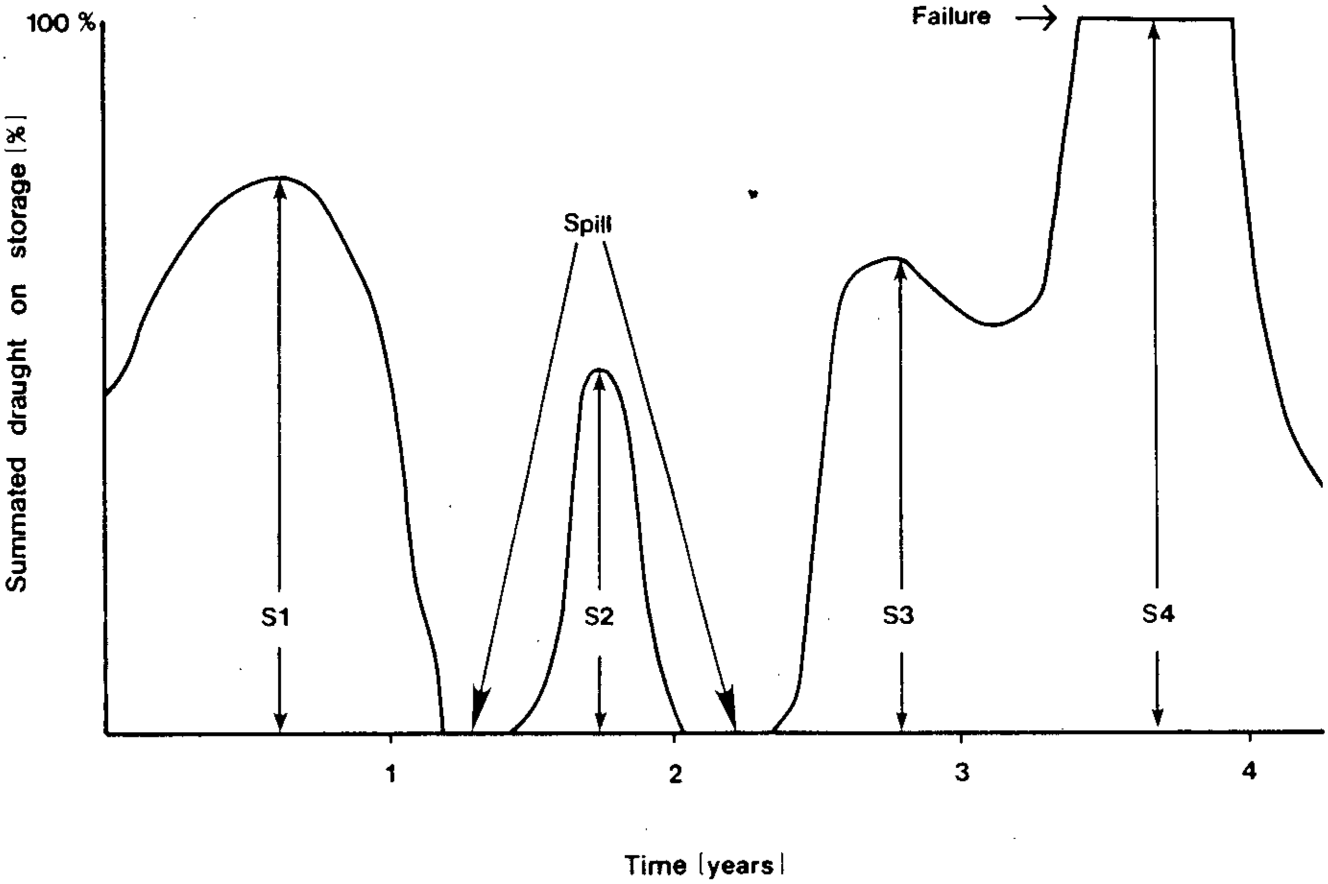

Figure 4

Explanation of deficient volume analysis

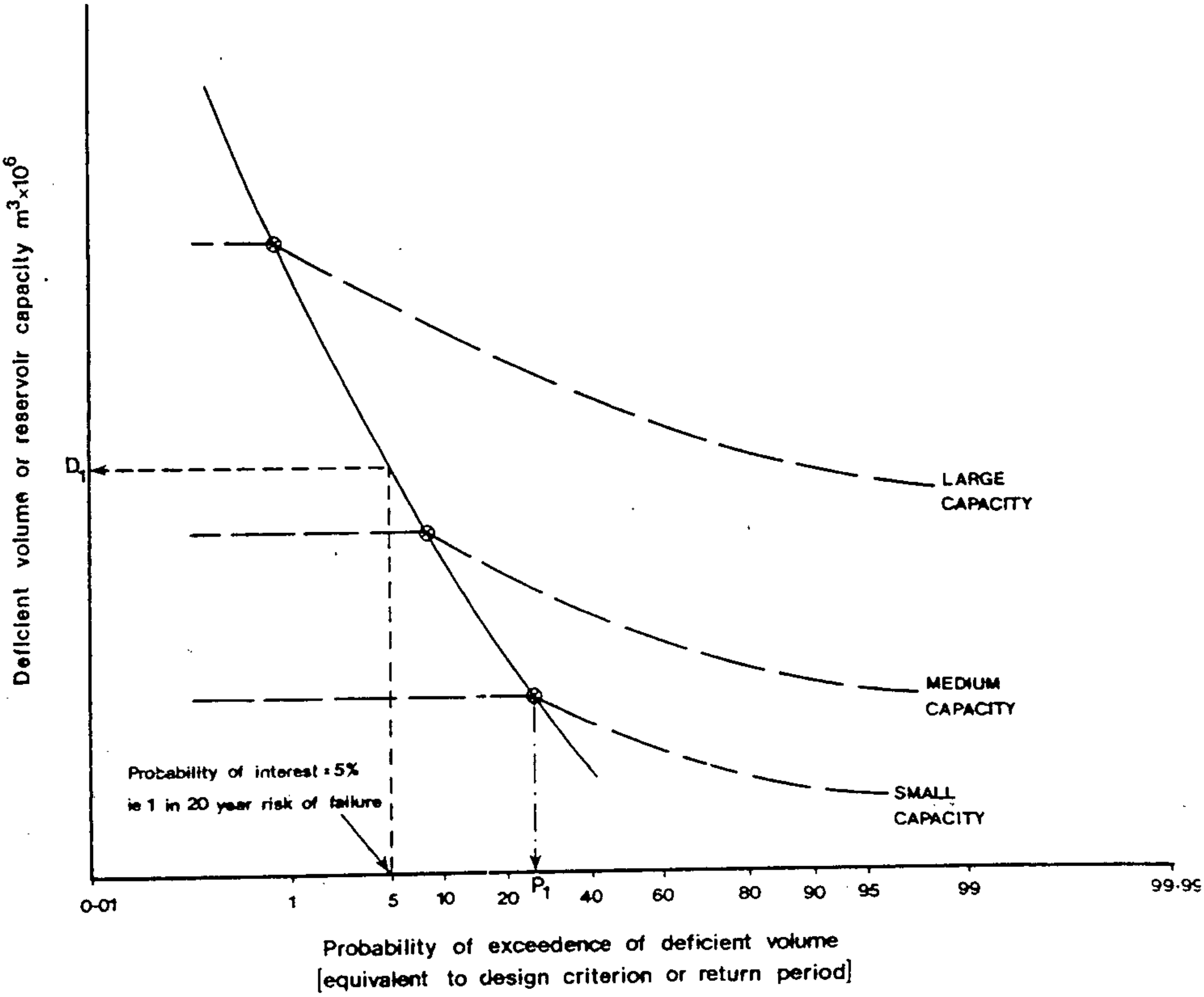

Figure 5

This method could be used to determine the resevoir capacity just capable of sustaining any yield for any specified probability of failure by successive simulation trials, but this iterative approach would be very time consuming. We have avoided this by simulating the behaviour of successively larger reservoir capacities and noting the probabilities of failure at the points of inflection on Figure 4. If a line of best fit is drawn through these points of inflection, the reservoir capacity, D1, necessary to sustain the chosen yield with any required probability of failure, may be determined.

The process is repeated for a range of demands, and a series of storage-probability curves are produced. These curves define the reservoir capacities necessary to sustain the range of demands with the corresponding return periods of failure.

It is important to select realistic starting contents of the reservoir for the simulation trials. The choice of appropriate starting contents is only significant during early years of the simulation until the resevoir spills for the first time; subsequently reservoir contents are then independent of the starting condition. It is unrealistic to start the simulation with the reservoir empty since we are looking for the long term yield that can be sustained by any reservoir capacity with a specified risk of failure. We determined the initial reservoir contents by running the simulation program with some arbitrary starting contents, say one third of the total capacity, and determined the mean end of year contents from this trial simulation. This mean was subsequently used as the initial contents for the final reservoir simulation trial for that yield and reservoir capacity combination. Trials with a range of initial starting contents showed this procedure to be very robust and we suggest that these objectively determined initial contents provide a sound basis for subsequent yield estimation.

From this information we can carry out trials to determine the yield available for any capacity of reservoir and a certain return period of failure.

(ii) **Method B: Gould**

The Gould method requires that the reservoir is divided into several

(N) states of equal storage value. Each year of the inflow data is treated separately and is routed through the reservoir, on a monthly basis, starting the reservoir in each of the N states and noting the state in which it finishes. When this procedure has been repeated for each year of data the results are collated in a transition matrix. This expresses the probability of ending in any of the N states, conditional on the starting state.

At the same time, the number of occasions in which the reservoir fails or spills is counted and noted with its corresponding starting state. Thus we can determine the probability of spilling, failing and ending in any particular state, conditional on the starting state. We need only determine the probability of being in each of the states at the start of a year, and then the joint probability of this and of failing will determine the steady state likelihood of failure.

The probability of being in any state at the start of a year is the same as being in any state at the end of the year and can be determined from the transition matrix and starting conditions of the reservoir. If the transition matrix, T, is multiplied by the initial vector of probabilities of starting contents, P, we will arrive at the vector of probabilities of starting contents at the second year.

That is

$$|P|_2 = |T| \times |P|_1$$

This process can be continued according to the scheme

$$|P|_{t+1} = |T| \times |P|_t$$

However, with time, the vector P_t reaches a steady state as the effect of the initial conditions at the beginning of the first year become negligible. Conceptually this is explained as follows. A reservoir's starting condition becomes less relevant to its state at any time t as t increases. The likely reservoir state at time t relates progressively more to the characteristics of the river flow sequence. Eventually the likelihood of starting a year in any state is totally dependent on the nature of the inflows and withdrawals. This is then the steady state situation.

Once the vector P_t reaches a steady state this describes the likelihood of being in any of the N states and this occurs when

$$|P|_{t+1} = |P|_t$$

We are now in a position to determine the probability of failure which is the sum of the products of the probability of the reservoir being in each particular zone and the probability of failure from starting in that zone.

This procedure is carried out, for each reservoir capacity, varying the demand, until the desired probability of failure is reached.

We can now produce results, from the same initial assumptions of reservoir size and return period of failure, for comparison with the deficient volume results.

For further information concerning matrix methods the reader is referred to McMahon and Mein (1978).

(iii) **Method C: Failure Rate**

This method is the most straightforward of the three. It requires one pass through the data once the starting contents have been determined. A monthly reservoir water balance is carried out and the number of annual failures (of any duration) is noted. This is then expressed as a percentage of the total number of years and the inverse of this provides a rough estimate of the return period of failure. In the past we have often used this method as a check on more sophisticated techniques. In this case it provides extra information to increase the confidence in our results with little extra effort.

The failure rate can easily be extracted from the information provided as output from the deficient volumes method. It therefore starts in the same month with the same starting contents as the deficient volumes. With these three methods we are in a position to look at the storage-yield relationship at the Baie Lazare damsite and to comment on the results from different methods.

4.2 RESULTS OF STORAGE-YIELD ANALYSES

Each of the above methods was used with the 78 year series of monthly flows, rainfalls and the mean monthly open water evaporations given in Table 2. The 78 year series of flows and rainfall comprised extended flow sequences for the period 1900 to 1970 inclusive, which were described in Section 3, plus the recorded flows for Baie Lazare and recorded rainfall for Val D'Endore for the period 1978 to 1984. Where Val D'Endore rainfall was missing, the record was in filled from Victoria using the regression model described in Section 3.2.

A number of possible reservoir capacities within the range 200 to 1800 Ml were studied and annual demands ranging from 400 to 1800 Ml abstracted from these possible reservoirs. The results of these analyses from the three methods are shown in Figures 6 to 8 where lines indicating 90 and 98 per cent reliability of supply are also shown.

Because there is no definitive method of storage-yield analysis we have combined the results from all three methods to provide an answer on which greater confidence can be placed. The Failure Rate method calculates probability of failure as an integer number of years during which a failure has occurred, and thus gives a less well defined relationship than the other methods. We have therefore given the Failure Rate method half the weight of the other two when combining them. This produces a central estimate of yield for each level of reliability. The results of the storage yield studies are given in Table 7 and shown in Figure 9.

There are undoubtedly uncertainties associated with the derived synthetic flow and rainfall sequences used as the basis of these storage-yield studies. Some discussion of the reliability of the derived synthetic series has been given in Section 3 of the present report.

In an attempt to quantify the possible confidence limits of the yield estimates given in Table 7 and shown on Figure 9, we have called upon some background research into reservoir storage-yield recently undertaken at the Institute of Hydrology but not yet published. We have estimated the 68 per cent confidence limits on the 98 reliable storage yield curve and this is shown as a shaded area on Figure 9. The confidence limits, as shown by this shaded area, define a region on the graph within which the true storage-yield relationship would occur with a likelihood of 68 per cent. It should be noted that the results of each of the three storage-yield methods studied fall well within the range of the confidence limits. It is also interesting to note that the 90 per cent reliability curve falls inside the area of uncertainty of the 98 per cent reliability curve.

Storage yield analysis for Baie Lazare dam

Method (a) Deficient volumes

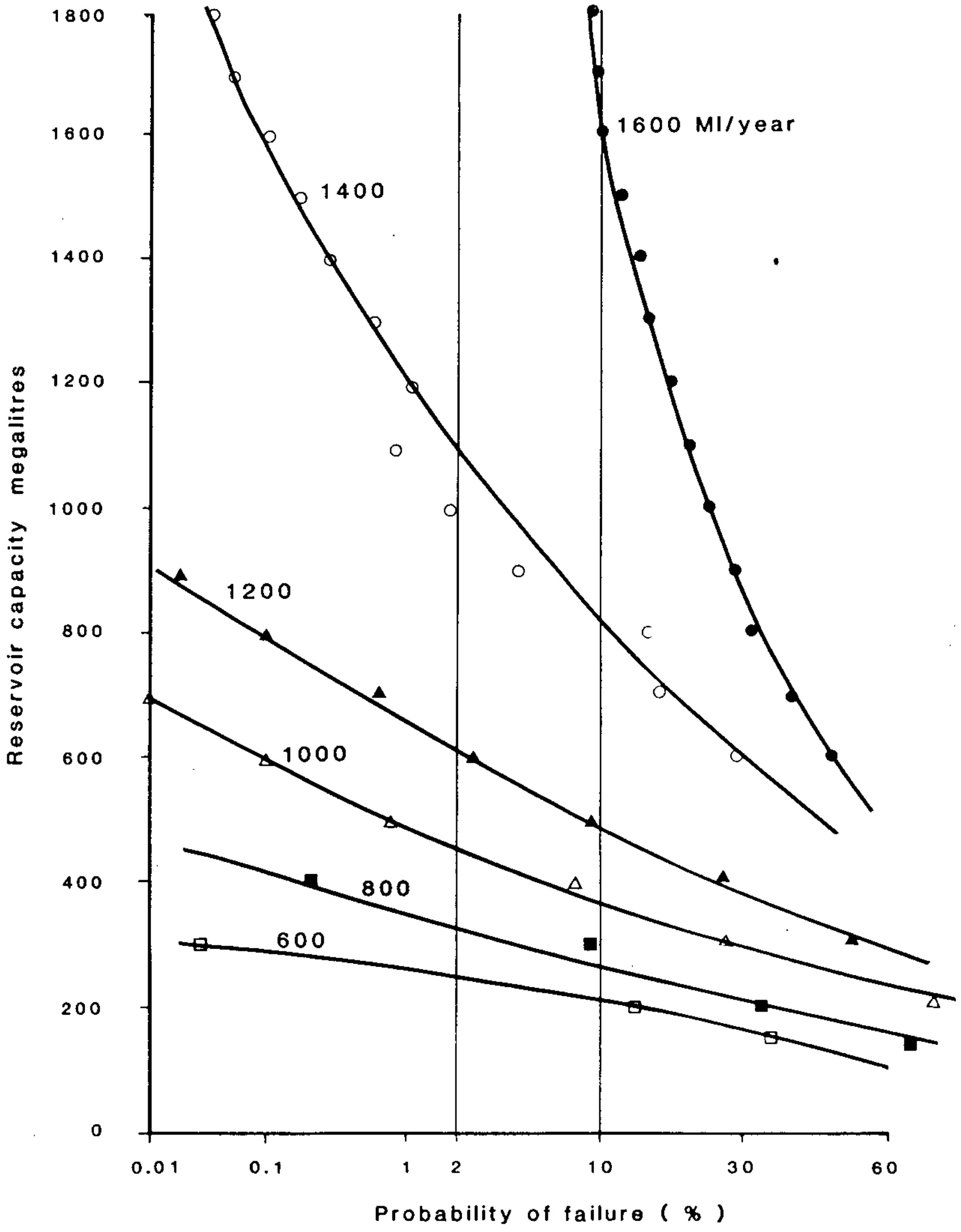

Figure 6

Storage yield analysis for Baie Lazare dam

Method (b) Gould

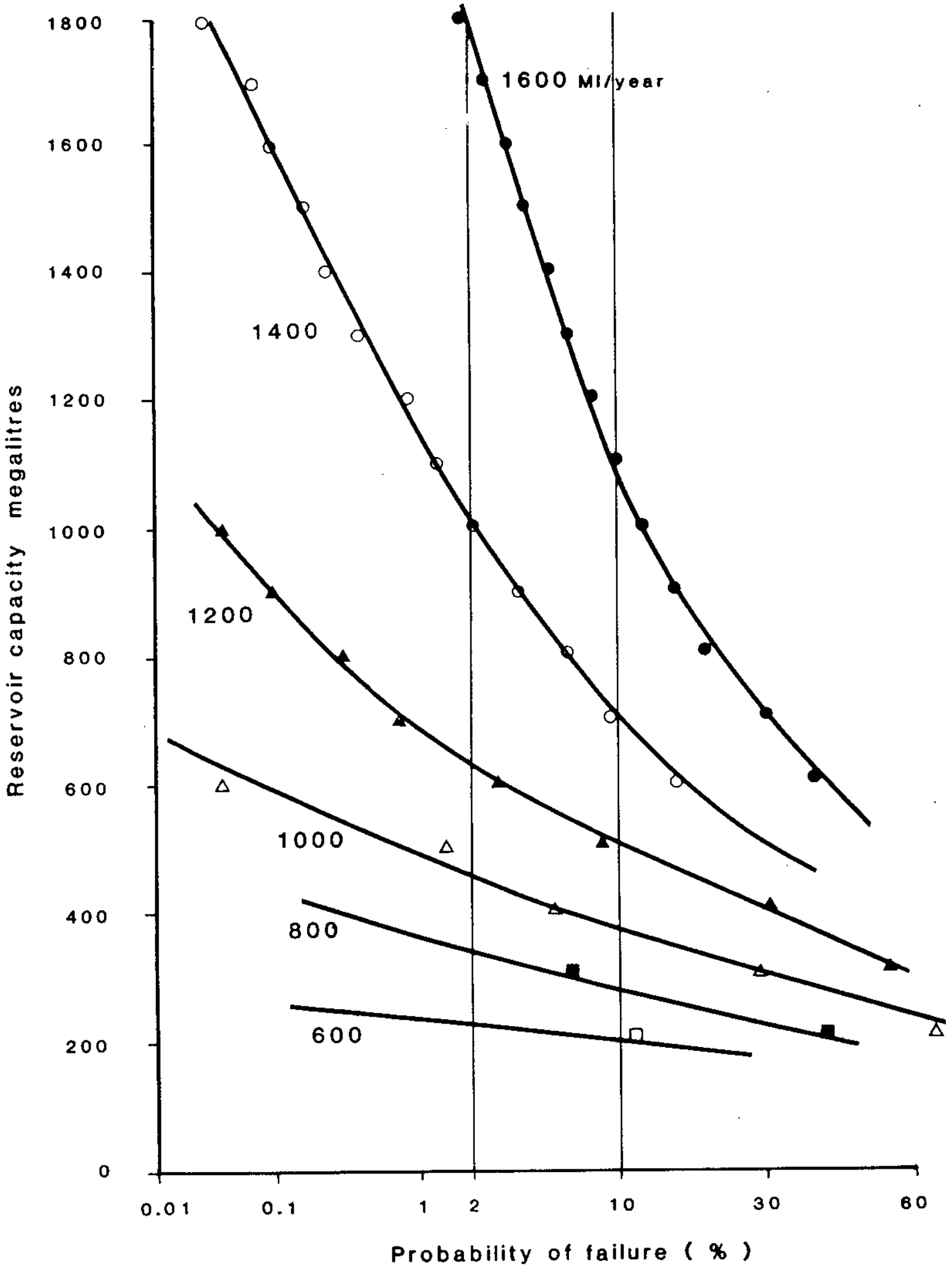

Figure 7

Storage yield analysis for Baie Lazare dam

Method (c) Counting failures

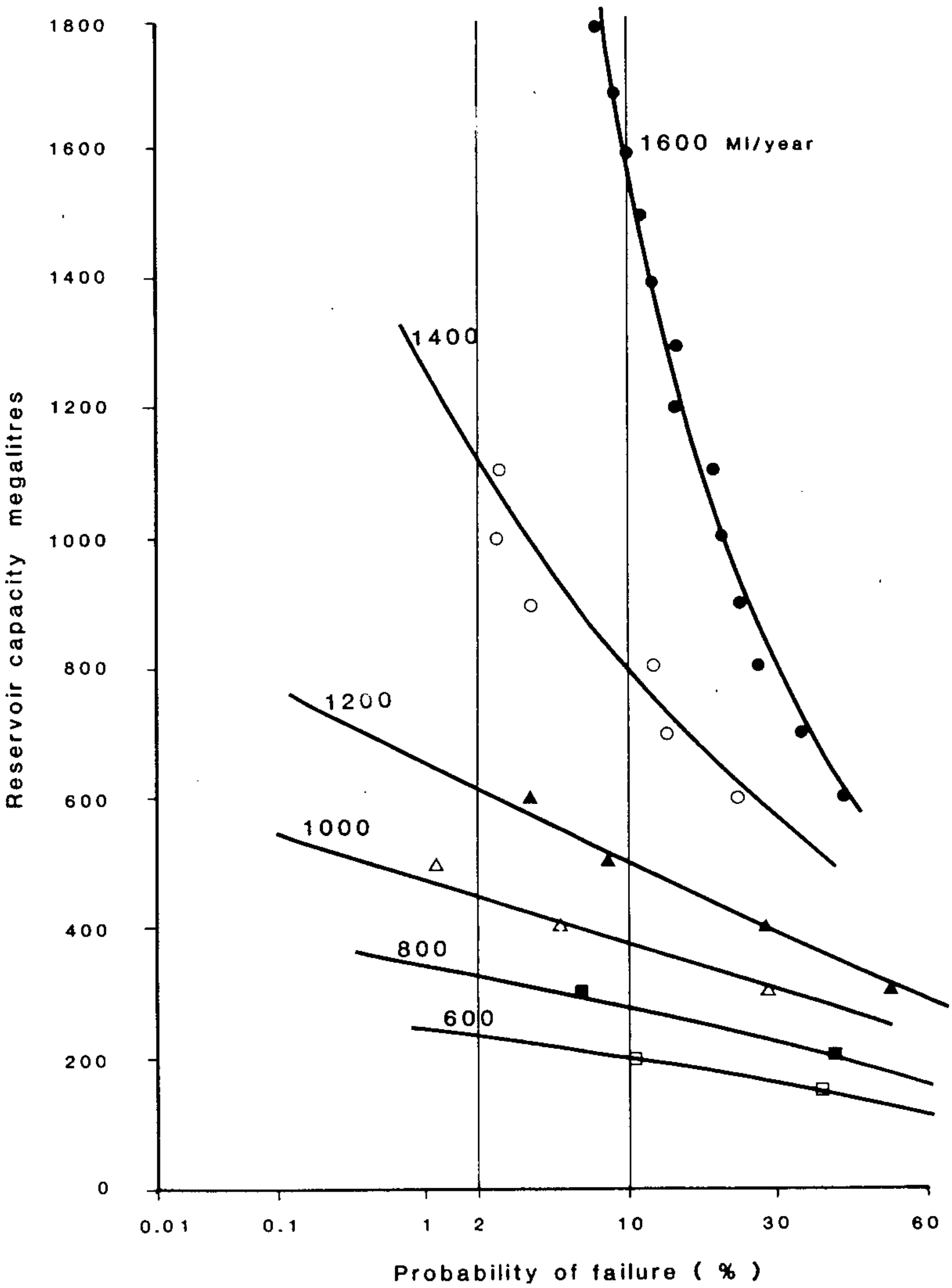

Figure 8

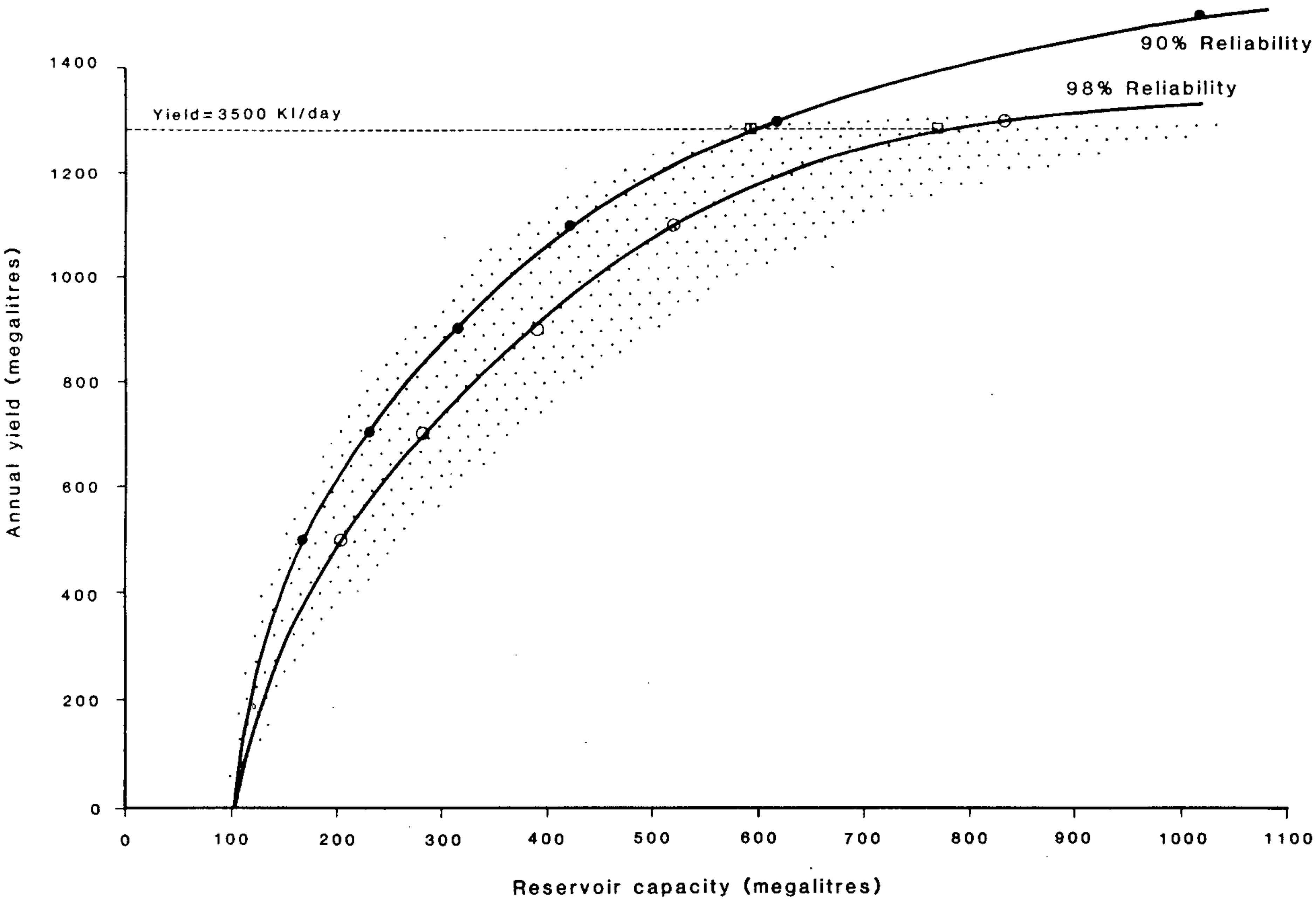
90% and 98% Reliable yields from Baie Lazare dam

Figure 9

TABLE 7 BAIE LAZARE DAM - RESULTS OF STORAGE-YIELD ANALYSIS

(i) 1 IN 50 YEAR RISK OF FAILURE (IE 98% RELIABILITY)

RESERVOIR CAPACITY REQUIRED TO MEET DEMAND - (M LITRES)

ANNUAL DEMAND	GOULD METHOD	DEFICIENT VOLUMES	COUNTING FAILURES	CENTRAL ESTIMATE
500	190	220	190	202
700	270	290	280	280
900	380	400	390	390
1100	520	520	520	520
1300	810	860	830	834
1280 (3500 Kl/day)	760	790	750	770

(ii) 1 IN 10 YEAR RISK OF FAILURE (IE 90% RELIABILITY)

RESERVOIR CAPACITY REQUIRED TO MEET DEMAND - (M LITRES)

ANNUAL DEMAND	GOULD METHOD	DEFICIENT VOLUMES	COUNTING FAILURES	CENTRAL ESTIMATE
500	160	170	170	166
700	230	230	240	232
900	310	320	320	316
1100	420	420	430	422
1300	590	650	620	620
1500	860	1140	1080	1016
1280	570	600	590	586

5. CONCLUSIONS AND RECOMMENDATIONS

The storage-yield results for the proposed Baie Lazare reservoir are based on the best data presently available. Some indication of the range of uncertainty of the results is given on Figure 9, although it should be noted that the shaded area between the 68 per cent confidence limits is based on research that has not been validated in the Seychelles.

These studies of the uncertainty of yield from any particular reservoir capacity should perhaps be carried out using data from the Seychelles. However, the results presented will not be grossly inaccurate and are indicative of the probable range of reliable yield for any reservoir capacity.

The effects of reservoir sedimentation and seepage from the reservoir have not been considered implicitly in the present study. Because the minimum drawoff level has been set at 83 m AOD, a relatively large dead storage of about 100 Ml would exist in the reservoir and sedimentation is unlikely to be a significant problem.

It should be noted that the computed yields presented in Table 7 and shown on Figure 9 comprise both water drawn from the reservoir into supply plus seepage losses. Thus estimated seepage losses must be subtracted from the computed yields to determine the water available for supply.

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Institute of Hydrology Wallingford Oxfordshire OX10 8BB UK
Telephone Wallingford (STD 0491) 38800 Telegrams Hycycle Wallingford Telex 849365 Hydrol G

The Institute of Hydrology is a component establishment of the Natural Environment Research Council