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STORAGE YIELD ANALYSIS

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1986-87

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ABSTRACT

The analysis of storage-reliability-yield relationship is important to provide preliminary design capacity or yield estimates for storage reservoirs governed by requirements over a period. Traditionally, Rippl's mass curve approach or its automated equivalent sequent peak algorithm have been used to obtain a single estimate of design capacity of reservoir with implied reliability as unity. In this report, simulation technique has been used to develop the storage-yield relationship for a single purpose-single reservoir taking reliability as a factor in capacity computation. Fibonacci method of unidimensional search has been employed to achieve the desired reliability. The developed program also performs reservoir operation computations. A test input and corresponding results have been given to demonstrate the methodology used in this report.

1.0 INTRODUCTION

The storage-reliability-yield study is essential to provide preliminary design capacity or yield estimates for storage reservoirs governed by requirements over a long span of time. It defines the relationship between inflow characteristics, reservoir capacity,controlled release and reliability.

The methods mostly used for performing storage-yield analysis can be broadly classified into (1) Sequential, and (2) nonsequential procedures. Sequential analysis makes use of historical (or synthetic) time series of inflows, which is routed through the reservoir system, accounting the necessary outflows, including water supply, evaporation seepage losses, minimum downstream releases and other operations. The most commonly used sequential procedure is the mass curve introduced by Rippl or its automated equivalent sequent peak algorithm. Simulation analysis is another sequential procedure, most common in use. Although non-sequential methods have been advocated for design purposes, these procedures have seen limited use in design application.

In this study, simulation method has been used for analysing storage-yield-reliability relationships. Reliability has been accounted as a factor for the computation of reservoir capacity or possible yield, with the help of optimization search technique using Fibonacci method.

1.1 Purpose of Storage-Yield Analysis

The storage required to meet a specified demand depends on three factors; the variability of inflow, the size and variability of the demand and the degree of reliability of this demand being met.

The storage-yield analysis is important in the design of reservoirs. Once the site for a reservoir is selected, the next important step is computation of capacity of reservoir and yield available during different periods. This analysis also includes reservoir operation computations and subsequently helps in development of rule curve.

1.2 Scope of the Program

The developed program is capable of performing storage-yield analysis for a single-purpose single reservoir. Two basic options available are-computation of capacity of reservoir to meet the specified demands and estimation of possible yield with a given reservoir capacity; both at specific reliability. Two more options are available for initial condition of reservoir. Using this option, the starting state of the reservoir may be set either empty or full. The program employs Fibonacci method (adopted from

Kuester & Mize, 1973), for one dimensional search to achieve the desired reliability. The program (APPENDIX-I) has been developed to make reservoir yield analysis for monthly data, which can be changed depending on availability of space in the system, by making necessary alterations in COMMON Statements.

2.0 DEFINITION OF TERMS

(a) Release

Release or draft is the amount of controlled outflow from a reservoir during a given time interval to serve useful purpose(s).

(b) Yield

This is the measure of output from a reservoir. For the reservoirs serving the demands like irrgation, water supply and navigation, it equals the amount of water released for this purpose while for those generating hydroelectric power, the yield is the amount of energy generated during the time interval.

(c) Reliability

Reliability of a reservoir is specified as the probability p of the reservoir being in the satisfactory state. Mathematically

$$p = \text{Prob}\ [X_t \in S] \qquad \ldots(1)$$

where X_t is the state of the system at time t and S is the domain of admissible states.

(d) Annual Reliability

Annual reliability is the probability that outflow will meet the demand within a year. Mathematically

$$R_a = (n-m)/n \qquad \ldots(2)$$

where m is number of failure years in the total number of n years.

(e) Time reliability

Time reliability is the portion of the total operation time during which the demand was fully met.

$$R_t = \frac{1}{T} \sum_{Y(\Delta t) \geq q} \Delta t \qquad \ldots(3)$$

where T is the period of operation, q is the target and Y is release.

(f) Volume Reliability

This is the measure of actually supplied portion of total volumetric demand during the period T, and is given by

$$R_v = 1 - \int_{y<q} (q-y)\, dt / \int_o^T q\, dt \qquad \ldots(4)$$

For constant target demand, the following relationship holds good among annual reliability, time reliability and volume reliability.

$$R_a \leq R_t \leq R_v \qquad \ldots(5)$$

The reason for this relationship among the various reliabilities is that most failure years include periods of non-failure operation and that during most failure periods, this release is not completely curtailed.

In the present report, the time reliability is used to measure the performance of reservoir and wherever the term reliability is used without any adjective, it signifies time reliability.

3.0 METHODOLOGY ADOPTED

The program applies the Fibonacci search technique for the computation of variable, reservoir capacity or annual yield, till desired reliability is achieved with permissible tolerances, supplied by the user.

At the beginning of iteration, the upper bound of the variable is computed as the average inflow volume in a year given by

$$Y_{upl} = \frac{\sum_{t=1}^{NMONTH} I_t}{NMONTH} . 12 \qquad \ldots(6)$$

where Y_{upl} = upper bound of variable Y

I_t = reservoir inflow in time 't'

NMONTH = total number of months

Lower bound of storage is taken as dead storage S_{min}, whereas for annual yield lower bound is taken as zero. With the desired accuracy, specified lower bound and calculated upper bound, the subroutine FIBN is called to perform one dimensional search to reach the optimum value of variable.

In Fibonacci search technique, objective function is required, which is defined by the subroutine FUNC, as absolute difference in reliabilities desired and achieved. The reliability achieved is computed after complete reservoir operation computations, based on mass balance equation, given by

$$S_{t+1} = S_t + I_t - R_t - E_t \qquad \ldots(7)$$

Subject to

$$S_{min} \leq S_t \leq C$$

where S_t = storage at the beginning of t^{th} interval,

S_{t+1} = storage at the end of t^{th} interval,

C = capacity of reservoir

R_t = release in interval 't'

E_t = evaporation loss in t^{th} interval

D_t = demand in interval 't'

The evaporation loss E_t is function of both S_t and S_{t+1}. Hence iterative method is applied using elevation-area-capacity table, till absolute difference between two successive relative evaporation losses (E_t/S_t) are less than DIFMAX, which is user supplied. At each time interval, attempt is made to satisfy the demand to the extent possible. If the available water in reservoir is less than S_{min}, no release is made and the storage is depleted by evaporation only and the reservoir is assumed to have failed during that particular month. If during any period, $S_t + I_t \geq C$, the extra water over the storage capacity after meeting the demands is spilled. If there is not enough water in the reservoir to meet the demand during any period, the demand is met to the extent possible and the month is treated as failure month.

The reliability achieved is computed as given by

$$AREL = 1.0 - \frac{IFAIL}{NMONTH} \qquad ...(8)$$

where AREL = reliability achieved,

IFAIL = number of failures i.e. number of times for which $R_t < D_t$

As stated above, objective function, used in Fibonacci search method is given by

$$OF = | AREL - RELI | \qquad ...(9)$$

where OF = objective function

RELI = reliability desired

The details of Fibonacci search method, which is a unidirectional search method for nonlinear optimization problems, can be found in texts such as Taha (1976) and Rao (1979). The choice of this method over other univariate nonlinear programming techniques is somewhat subjective.

4.0 DESCRIPTION OF PROGRAM

The program consists of main program and several subroutines as described below.

4.1 Main Program

The main program (SY.FOR) is written in VAX-11 FORTRAN language. It reads the input data from logical unit one. After performing echo-printing, it sets the upper limit of the variable to be computed and calls subroutine FIBN with the arguments depending on option chosen. Finally, it calls subroutine FUNC to perform reservoir - operation computations with final value of variable. The main program also prints detailed reservoir operation table in a separate file (SY1.OUT), if requested.

4.1.1 Subroutine FIBN

This subroutine performs one dimensional search using Fibonacci method with the objective function, equal to absolute difference of reliabilities desired and achieved, computed by the program subroutine FUNC.

4.1.2 Subroutine FUNC

Subroutine FUNC makes reservoir operation computations based on detailed sequential analysis and computes objective function with the achieved reliability obtained from the analysis. It makes use of subprogram FINT for linear interpolation in reservoir level and evaporation computations.

4.2 Program Implementation

The program has been developed and tested on VAX-11/780 Computer System with FORTRAN 77 compiler, using various options with Dharoi reservoir as test problem. The input data can be in any consistent system of units. The program is sufficiently generalised. The statements which may require change for implementation of this program on the other systems are the OPEN statement, READ statement and WRITE statements.

4.3 Description of Input Variables

Following is the list of important variables with description which are needed for preparing input file for this program.

Variable	Dimension	Description
ACC	-	Accuracy required in Fibonnacci search method
AINF	L^3/T	Monthly inflow to reservoir
ALP	-	Multiplying factors to convert annual yield to monthly yield
ANY	L^3	Annual yield
AR	L^2	Reservoir surface area in elevation-area-capacity table

CAP	L^3	Reservoir capacity in elevation-area-capacity table
DIFMAX	-	Allowable difference in evaporation computation for two successive iterations
EL	L	Reservoir water level in elevation-area-capacity table
EVAP	L	Monthly evaporation (in terms of depth of water) from reservoir
EVFAC	-	Conversion factor for evaporation computations
FAC	T	Multiplying factor for converting monthly inflow rate to monthly inflow volume
IFM	-	First month of the time series
IFY	-	First year of the time series
IOPT	-	Option number for storage/yield computation with given yield/storage
IPR	-	A flag which equals zero if detailed working table is not to be printed
KOPT	-	A flag to fix initial storage in the reservoir
NDT	-	Number of sets of elevation-area-capacity data for the reservoir
NMONTH	-	Total number of months of analysis
RELI	-	Reliability desired to meet the demand
SMAX	L^3	Maximum storage/storage capacity of the reservoir

SMIN	L^3	Dead storage of the reservoir
TITLE	-	Title of the problem

The program reads all variables except Title in free format. Title is read in alphanumeric format, with maximum character length of 70.

4.4 Description of Output

The results are written in a file 'OUT.DAT' which is logical unit two. In addition to the values of the variables, read from input file, required storage to meet the yield or yield achieved with the given reservoir capacity, at a specific reliability, as the case may be, number of failures to meet the demand and reliability achieved are written in the output file. A detailed working table, showing stepwise water balance computation is written in a separate file OUT1.DAT with logical unit 3, if requested i.e. IPR $\neq$ 0.

A listing of program alongwith sample input and output is given in appendices I ,II and III respectively.

4.5 Preparing Input Data

A typical input file will have following organisations :

Line No.	Variable(s)	Format
1	TITLE	A
2	NMONTH	Free
	IFM	Free
	IFY	Free
	FAC	Free
	SMIN	Free
	RELI	Free
	EVFAC	Free
	IOPT	Free
	KOPT	Free
	IPR	Free
3	ANY, OR SMAX	Free
4	ALP	Free
5	NDT	Free
6 to (5+NDT)	EL	Free
	AR	Free
	CAP	Free
(6+NDT)	EVAP	Free
(7+NDT)	DIFMAX	Free
	ACC	Free
(8+NDT) ONWARDS	AINF	Free

5.0 CONCLUSIONS

The program developed for storage yield analysis may be used with two different options regarding initial reservoir condition in addition to two basic options concerning objectives. Reliability has been considered a factor to determine reservoir capacity or possible yield. These facts support this program as useful in making analysis of storage-reliability-yield relationship and also in preliminary design of a single purpose single reservoir. The program may also be used for preliminary yield analysis of reservoirs generating hydroelectric power, if the yield can be given in terms of volume of water required.

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Appendix-I

```
C*****************************************************************************
C                 PROGRAM FOR STORAGE-YIELD ANALYSIS FOR A RESERVOIR
C
C    Available options --
C        iopt = 1 -- annual yield is known, storage is to be calculated
C        iopt = 2 -- storage is known, annual yield is to be calculated
C        kopt = 1 -- reservoir is assumed initially full.
C        kopt = 2 -- reservoir is assumed initially empty(smin)
C        ipr  = 0 -- detailed operation table is not to be printed
C*****************************************************************************
        common/ff/ alp(12),ainf(500),st(500),rel(500),ar(100),cap(100),el(100)
        common/fs/ evap(12),aevap(500),al(12),iyr(100)
        common/f2/ nmonth,reli,ifm,smin,arel,ifail,ndt,difmax,evfac,relmax,iter
        common/f3/ iopt,kopt,smax,any
        character*70 title
        open(unit=1,file='sy.dat',status='old')
        open(unit=2,file='sy.out',status='new')
        open(unit=3,file='sy1.out',status='new')
C*********************************************** Input block
        read(1,1) title
1       format(5X,a)
        read(1,*) nmonth,ifm,ify,fac,smin,reli,evfac,iopt,kopt,ipr
        if(iopt.eq.1) read(1,*) any
        if(iopt.eq.2) read(1,*) smax
        read(1,*) (alp(i),i=1,12)
        read(1,*) ndt
        do 28 i=1,ndt
28      read(1,*) el(i),ar(i),cap(i)
        read(1,*) (evap(i),i=1,12)
        read(1,*) difmax,acc
        read(1,*) (ainf(j),j=1,nmonth)
C*************************************    End of input
C*************************************    Echo printing
        write(2,1) title
        write(2,2) nmonth,ifm,ify
2       format(5x'No. of months = 'i4', First month ='i3', First yr ='i5/
        15x'The input data can be in any consistent system of units'/)
        write(2,5) fac,smin
5       format(5x'Multiplication factor for inflows = 'f14.4/
        15x'Dead storage                        = 'f14.4)
        if(iopt.eq.1) write(2,33) any
        if(iopt.eq.2) write(2,34) smax
33      format(/5x'Annual yield required ='f12.2/6X'storage is to be
        1 calculated (option 1 chosen)'/)
34      format(/5x'Maximum storage ='f14.2/6X'possible yield is to be
        2 calculated (option 2 chosen)'/)
        if(kopt.eq.1) write(2,35)
        if(kopt.eq.2) write(2,36)
35      format(5x'Reservoir is assumed initially full')
36      format(5x'Reservoir is assumed initially empty (Smin)')
```

```
      write(2,6) reli,evfac
6     format(/5x'Reliability required ='f5.2', Evap factor = 'f10.5)
      write(2,37) acc
37    format(/5x'Requireu accuracy in  Fibonacci search    = 'f10.5)
      write(2,3)
3     format(/5x'Monthly yield factors'/)
      write(2,29) (alp(i),i=1,12)
29    format(5X,12f9.5)
      write(2,4)
      write(2,22) (ainf(J),J=1,nmonth)
22    format(5x,8f10.2)
4     format(/5x'Monthly inflow data'/)
      write(2,7)
7     format(/10x'  Elevation - area - capacity - spill capacity table'/)
      write(2,14)
14    format(7x'S N'8X'Elevation'7X'Area'9X' Capacity'/)
      write(2,8)(i,el(i),ar(i),cap(i),i=1,ndt)
8     format(5x,i5,3x,f12.4,3x,f12.2,3x,f14.2)
      write(2,9) (evap(i),i=1,12)
9     format(/5x'Monthly evaporation data'/(5x,6(1x,f10.4)))
      write(2,13) difmax
13    format(/5x'Maximum difference in evaporation ='f10.6)
C************************************** End of echo print
      do 15 i=1,nmonth
      ainf(i)=ainf(i)*fac
      sum=sum+ainf(i)
15    continue
      supl=sum/(nmonth/150.)
      ylmin=smin
      if(iopt.eq.2) then
      supl=supl*1
      write(2,16)supl
      ylmin=0.0
      go to 269
      endif
      write(2,16)supl
16    format(5x'Assumed upper limit of the variable ='f14.2/)
269   continue
C     **************** One dimensional search using Fibonacci method
      if(iopt.eq.1) call fibn(acc,supl,stor,ylmin)
      if(iopt.eq.2) call fibn(acc,supl,any,ylmin)
      frl=fint(cap,el,stor,ndt)
      if(ipot.eq.1) write(2,270)stor,frl
270   format(5X,'Maximum storage ='f12.2',  Full reservoir level ='f12.2/)
      if(iopt.eq.1) write(2,31) stor
      if(iopt.eq.2) write(2,32) any
31    format(/5x'Required storage = 'e10.3)
32    format(/5x'Possible  yield  = 'f10.3)
      if(iopt.eq.1) call func(stor,of)
      if(iopt.eq.2) call func(any,of)
```

```
      write(2,23) ifail,arel
23    format(/5x'No. of  failures ='i4', Reliability achieved ='f7.4/)
      if(ipr.eq.0) stop
      write(3,17)
17    format(25x'Monthly Working Table'/21X'All figures in volume units
     1(10**3)')
      write(3,18)
18    format(' Month   St Stor     Inflow      Demand      Release
     1       Evap      End stor')
      im=ifm-1
      do 21 k=1,nmonth
      im=im+1
      if(im.gt.12) im=1
21    write(3,19) k,st(k)/1.e+03,ainf(k)/1.e+03,al(im)/1.e+03
     1,rel(k)/1.e+03,aevap(k)/1.e+03,st(k+1)/1.e+03
19    format(i4,f12.2,4f12.3,f12.2)
      stop
      end
      SUBROUTINE FIBN(ALPHA,B,X,A)
C     **********************************************************************
C     This subroutine performs one dimensional search using Fibonacci method
C     alpha = accuracy reqd., X = variable, A = Lower limit, B = Upper limit
C     **********************************************************************
      DIMENSION FIB(100)
      DEL=B-A
      FIB0=1
      FIB(1)=1
      FIB(2)=2
5     BB=1/ALPHA
      IF(BB.le.2.0) then
       TYPE *,'  ACCURACY NOT SUFFICIENT, changed to 0.01'
       ALPHA=0.01
       GO TO 5
      endif
      JJ=2
12    JJ=JJ+1
      FIB(JJ)=FIB(JJ-1)+FIB(JJ-2)
      CC=FIB(JJ)
      IF(CC.le.BB) go to 12
      I=0
      KK=JJ-2
      IK=JJ-2
      BL=B-A
      ALL=FIB(IK)*BL/FIB(JJ)
      W=A+ALL
      V=B-ALL
      CALL FUNC(W,T)
      CALL FUNC(V,U)
      JK=1
      IK=IK-1
```

```
      JJ=JJ-1
      DO 70 I=1,KK
      IF(U-T) 20,20,22
20    A=A+ALL
      BL=B-A
      W=V
      CALL FUNC(W,T)
      ALL=FIB(IK)*BL/FIB(JJ)
      V=B-ALL
      CALL FUNC(V,U)
      II=I+1
      IK=IK-1
      JJ=JJ-1
      IF(IK-1) 28,29,29
28    IK=1
29    CONTINUE
      GO TO 70
22    B=B-ALL
      BL=B-A
      V=W
      CALL FUNC(V,U)
      ALL=FIB(IK)*BL/FIB(JJ)
      W=A+ALL
      CALL FUNC(W,T)
      II=I+1
      IK=IK-1
      JJ=JJ-1
      IF(IK-1) 30,31,31
30    IK=1
31    CONTINUE
70    CONTINUE
      EPS=0.001*W
      DL=W+EPS
      CALL FUNC(DL,YL)
      IF(YL-T) 80,80,81
80    CALL FUNC(B,BF)
      X=(W+B)/2
      GO TO 87
81    CONTINUE
      X=(W+A)/2
87    ACC=(W-A)/DEL
      RETURN
      END
      FUNCTION FINT(A,B,AVAL,NN)
C     ********************************************
C     Function subprogramme for linear interpolation
C     ********************************************
      DIMENSION A(1),B(1)
      IF(AVAL.LT.A(1)) THEN
       FINT=B(1)
```

```
         RETURN
        ENDIF
        IF(AVAL.GT.A(NN)) THEN
         FINT=B(NN)
         RETURN
        ENDIF
        DO 10 I=2,NN
        IF(AVAL.EQ.A(I)) THEN
         FINT=B(I)
         RETURN
        ENDIF
        IF(A(I-1).LT.AVAL.AND.A(I).GT.AVAL) THEN
         FINT=B(I-1)+((B(I)-B(I-1))/(A(I)-A(I-1)))*(AVAL-A(I-1))
         RETURN
        ENDIF
10      CONTINUE
        END
        subroutine func(var,of)
C       ************************************************************************
C       The reservoir operation computations are performed in this subroutine
C       and the objective function for Fibonacci search is computed.
C       ************************************************************************
        common/ff/ alp(12),ainf(500),st(500),rel(500),ar(100),cap(100),el(100)
        common/fd/ evap(12),aevap(500),al(12)
        common/f2/ nmonth,reli,ifm,smin,arel,ifail,ndt,difmax,evfac,relmax,iter
        common/f3/ iopt,kopt,smax,any
        ii=0
12      if(iopt.eq.1) stor=var
        if(iopt.eq.2) then
         any=var
         stor=smax
        endif
        do 170 in=1,12
170     al(in)=any*alp(in)
        ifail=0
        if(kopt.eq.1) ST(1)=STOR
        if(kopt.eq.2) ST(1)=SMIN
        im=ifm-1
        do 10 i=1,nmonth
        iter=0
        im=im+1
        if(im.gt.12) im=1
        ast=st(i)
        aar=fint(cap,ar,ast,ndt)
        bar=aar
11      if(iter.eq.20) go to 19
        amean=(aar+bar)/2.0
        aevap(i)=amean*evap(im)*evfac
        st(i+1)=st(i)+ainf(i)-al(im)-aevap(i)
```

```
      rel(i)=al(im)
C     Check for maintains minimum storage
      if(st(i+1).lt.smin) then
       if(aevap(i).gt.st(i)+ainf(i)) aevap(i)=st(i)+ainf(i)
       st(i+1)=smin
       rel1=st(i)+ainf(i)-aevap(i)-st(i+1)
       rel(i)=amax1(rel1,0.0)
       st(i+1)=st(i)+ainf(i)-rel(i)-aevap(i)
      endif
C     Check for maximum storage
      if(st(i+1).gt.stor) then
       st(i+1)=stor
       rel(i)=st(i)+ainf(i)-aevap(i)-st(i+1)
      endif
      bst=st(i+1)
      bar=fint(cap,ar,bst,ndt)
      bevap=bar*evap(im)*evfac
      diff=abs(aevap(i)-bevap)/stor
      if(diff.gt.difmax) then
       iter=iter+1
       go to 11
      endif
19    if(rel(i).lt.al(im)) ifail=ifail+1
10    continue
      ii=ii+1
      bfail=ifail
      arel=1.0-bfail/Nmonth
      of=((arel-reli)*100)**2+VAR/10**7
      return
      end
```

Appendix-II

STORAGE DETERMINATION : DHAROI RESERVOIR

400 6 1935 72576.0 11928738.0 0.80 0.0633 1 2 1

20.0E+07 6969.6 28179.28 6969.6 27519.08 6969.6

0.0914 .0914 0.0914 0.0914 0.0914 0.09 0.06 0.06 0.057 0.093 0.0914 0.0914

15

163.07	0.00	0.00
164.59	1282042.00	155739.19
166.12	3158688.00	4890316.50
167.64	4724131.00	9681510.00
170.69	8043519.00	29078526.00
173.74	11928738.00	58898952.00
176.78	18524820.00	103209096.00
179.83	32189010.00	180845280.00
182.88	50640460.00	304598208.00
185.93	73357976.00	497228928.00
188.98	100133520.00	763140736.00
189.59	105621296.00	829421952.00
190.50	113313672.00	926854336.00
192.02	125047304.00	1108152704.00
193.55	137672832.00	1309173760.00

5.5 5.5 7.5 9.5 12.00 4.25 6.00 6.00 6.00 3.00 6.00 6.00

0.001 0.0001

333	2684	500	2818	436	133	64	46	25	8	4	3
495	155	386	337	124	32	5	0	0	0	0	0
103	6136	997	1671	376	130	89	78	62	47	34	30
1804	1284	808	206	59	30	40	0	54	52	49	47
15	321	760	1140	57	47	45	47	43	47	28	21
1287	582	607	135	65	19	0	0	0	0	0	0
678	7077	11981	709	151	71	52	53	34	15	6	19
37	11528	5485	6872	323	167	32	24	8	3	2	45
797	18460	6800	2752	399	55	32	26	14	6	3	74
990	9858	4209	14017	440	181	1688	103	71	32	17	8
333	14653	8524	1784	320	118	71	32	18	8	4	3
33	864	6406	2491	223	91	21	18	12	6	5	11
9	370	4346	3389	123	34	47	52	42	15	6	3
5	404	264	164	74	32	11	3	3	3	2	2
24	812	910	274	69	9	5	5	4	3	2	6
4	5280	2141	16503	1673	484	253	185	101	44	20	7
80	2052	1922	219	40	23	24	10	8	4	3	3
5	372	1767	576	209	77	57	66	27	12	6	3
77	218	133	810	309	101	69	53	34	57	26	14
768	5573	1871	9021	2072	288	193	153	116	82	59	43
292	151	4565	12256	1080	439	248	140	82	33	0	0
383	7246	8111	5278	5233	470	225	217	170	124	81	64
918	2251	1502	370	68	30	20	9	8	5	4	2
27	3245	321	929	429	135	64	23	15	10	6	4
4	781	2583	12335	1373	692	303	181	160	135	86	63
0	1715	3298	789	282	125	122	51	35	20	11	5
68	1608	789	11994	1094	621	347	203	377	77	41	18

7	2953	2589	1748	450	139	77	43	50	18	11	8
145	958	3185	4138	586	211	140	81	59	37	21	17
134	1720	5400	1347	406	177	121	112	69	31	21	13
10	1720	1191	346	2614	31	25	17	13	11	9	5
661	1518	339	705	39	11	8	8	8	7	92	20
186	4887	2518	3497	654	206	247	98	61	31	17	12
8	3471	1367	330	135	42	29	19	16	13	8	4
65	1133	886	502	33	9	5	4	53	5	2	11
635	186	4852	6069	1132	439	254	63	37	16	8	4
49	2887	1377	1794	145	42	30	17	14	7	4	0
279	1271	838	198	14	9	8	7	7	5	6	2
34	1987	13377	27688	2833	744	324	184	121	64	35	93
1981	611	1933	290	259	35	14	318	203	207	157	100
156	3567	5489	6956	1836	313	124	81	76	22	11	17

Appendix-III

STORAGE DETERMINATION : DHAROI RESERVOIR
No. of months = 400, First month = 6, First yr = 1935
The input data can be in any consistent system of units

Multiplication factor for inflows 72576.0000
Dead storage 11928738.0000

Annual yield required =200000000.00
storage is to be calculated (option 1 chosen)

Reservoir is assumed initially empty (Smin)

Reliability required = 0.80, Evap factor = 0.06330

Required accuracy in Fibonacci search 0.00010

Monthly yield factors

0.09140 0.09140 0.09140 0.09140 0.09140 0.09000 0.06000
0.06000 0.05700 0.09300 0.09140 0.09140

Monthly inflow data

333.00	2604.00	500.00	2818.00	636.00	133.00	64.00	46.00
25.00	8.00	4.00	3.00	495.00	155.00	386.00	337.00
124.00	32.00	5.00	0.00	0.00	0.00	0.00	0.00
103.00	6136.00	997.00	1671.00	376.00	130.00	89.00	78.00
62.00	47.00	34.00	30.00	1804.00	1284.00	808.00	206.00
59.00	30.00	40.00	0.00	54.00	52.00	49.00	47.00
15.00	321.00	760.00	1160.00	57.00	47.00	45.00	47.00
43.00	47.00	28.00	21.00	1287.00	582.00	607.00	135.00
65.00	19.00	0.00	0.00	0.00	0.00	0.00	0.00
678.00	7077.00	11981.00	709.00	151.00	71.00	53.00	53.00
34.00	15.00	6.00	19.00	37.00	11528.00	3485.00	6872.00
323.00	167.00	32.00	24.00	8.00	3.00	2.00	45.00
797.00	18460.00	6800.00	2752.00	399.00	55.00	32.00	36.00
14.00	6.00	3.00	74.00	990.00	9858.00	4209.00	14017.00
440.00	181.00	1688.00	103.00	71.00	32.00	17.00	3.00

Intermediate Lines of output deleted

10.00	1720.00	1191.00	346.00	2614.00	31.00	25.00	17.00
13.00	11.00	9.00	5.00	661.00	1518.00	339.00	705.00
39.00	11.00	8.00	8.00	8.00	7.00	92.00	20.00
186.00	4887.00	2518.00	3497.00	654.00	206.00	247.00	98.00
61.00	31.00	17.00	12.00	8.00	3471.00	367.00	330.00

Elevation - area - capacity - spill capacity table

S N	Elevation	Area	Capacity
1	163.0700	0.00	0.00
2	164.5900	1282042.00	155739.19
3	166.1200	3158688.00	4890316.50
4	167.6400	4724131.00	9681510.00
5	170.6900	8043519.00	29078528.00
6	173.7400	11928738.00	58898952.00
7	176.7800	18524820.00	103209096.00
8	179.8300	32189010.00	180845280.00
9	182.8800	50640460.00	304598208.00
10	185.9300	73357976.00	497228928.00
11	188.9800	100133520.00	763140736.00
12	189.5900	105621296.00	829421952.00
13	190.5000	113313672.00	926854336.00
14	192.0200	125047304.00	1108152704.00
15	193.5500	137672832.00	1309173760.00

Monthly evaporation data

5.5000	5.5000	7.5000	9.5000	12.0000	4.2500
6.0000	6.0000	6.0000	3.0000	6.0000	6.0000

Maximum difference in evaporation - 0.001000
Assumed upper limit of the variable =1068250726 4.00

Required storage = 0.139E+09

No. of failures = 81, Reliability achieved = 0.7975

Monthly Working Table

All figures in volume units(10**3)

Month	St Stor	Inflow	Demand	Release	Evap	End sto.
1	11928.74	24167.809	18000.000	18000.000	1484.707	16611.84
2	16611.84	194793.984	12000.000	66419.375	5841.283	139145.17
3	139145.17	36288.000	12000.000	26850.096	9437.905	139145.17
4	139145.17	204519.172	11400.000	195081.266	9437.905	139145.17
5	139145.17	31643.137	18600.000	26924.176	4718.953	139145.17
6	139145.17	9652.608	18280.000	18280.000	8853.638	121664.13
7	121664.13	4644.864	18280.000	18280.000	7574.675	100454.33
8	100454.33	3338.496	18280.000	18280.000	5769.950	79742.88
9	79742.88	1814.400	18280.000	18280.000	4686.140	58591.13
10	58591.13	580.608	18280.000	18280.000	4943.843	35947.89
11	35947.89	290.304	18280.000	18280.000	4312.014	13646.19
12	13646.19	217.728	18280.000	0.000	3866.655	9997.26
13	9997.26	35925.121	18000.000	18000.000	1659.855	26262.52
14	26262.52	11249.280	12000.000	12000.000	2754.177	22757.63
15	22757.63	28014.336	12000.000	12000.000	3014.757	35757.21
16	35757.21	24458.111	11400.000	11400.000	3618.950	45196.37
17	45196.37	8999.424	18600.000	18600.000	1783.649	33812.15
18	33812.15	2322.432	18280.000	18280.000	2718.938	15135.64
19	15135.64	362.880	18280.000	1525.285	2044.499	11928.74
20	11928.74	0.000	18280.000	0.000	1778.593	10150.14
21	10150.14	0.000	18280.000	0.000	1590.188	8559.96
22	8559.96	0.000	18280.000	0.000	1908.356	6651.60
23	6651.60	0.000	18280.000	0.000	2039.365	4612.24
24	4612.24	0.000	18280.000	0.000	2012.630	2599.61
25	2599.61	7475.328	18000.000	0.000	915.269	9159.67
26	9159.67	445326.344	12000.000	309757.188	5583.687	139145.17
27	139145.17	72358.273	12000.000	62920.367	9437.905	139145.17
28	139145.17	121274.492	11400.000	111836.594	9437.905	139145.17
29	139145.17	27288.576	18600.000	22569.615	4718.953	139145.17
30	139145.17	9434.880	18280.000	18280.000	8846.596	121453.45
31	121453.45	6459.264	18280.000	18280.000	7611.916	102020.80
32	102020.80	5660.928	18280.000	18280.000	5907.745	83493.99
33	83493.99	4499.712	18280.000	18280.000	4942.493	64771.21
34	64771.21	3411.072	18280.000	18280.000	5424.664	44477.63
35	44477.63	2467.584	18280.000	18280.000	5153.766	23511.44
36	23511.44	2177.280	18280.000	9126.604	4633.380	11928.74
37	11928.74	130927.102	18000.000	18000.000	3606.108	121249.73
38	121249.73	93187.586	12000.000	66452.367	8839.787	139145.17
39	139145.17	58641.406	12000.000	49203.504	9437.905	139145.17
40	139145.17	14950.656	11400.000	11400.000	9247.500	133448.33
41	133448.33	4281.984	18600.000	18600.000	4218.771	114911.55
42	114911.55	2177.280	18280.000	18280.000	7101.710	91707.12
43	91707.12	2903.040	18280.000	18280.000	5787.147	70543.02
44	70543.02	0.000	18280.000	18280.000	4208.769	48054.25
45	48054.25	3919.104	18280.000	18280.000	3261.411	30431.94
46	30431.94	3773.952	18280.000	18280.000	3196.393	12729.50

47	12729.50	3556.224	18280.000	1202.470	3154.520	11928.74
48	11928.74	3411.072	18280.000	0.000	3880.566	11459.24
49	11459.24	1088.640	18000.000	0.000	1352.752	11195.13
50	11195.13	23296.896	12000.000	12000.000	2188.598	20303.43
51	20303.43	55157.762	12000.000	12000.000	3536.559	59924.63
52	59924.63	82736.641	11400.000	11400.000	6531.413	124729.87
53	124729.87	4136.832	18600.000	18600.000	3929.778	106336.92
54	106336.92	3411.072	18280.000	18280.000	6621.187	84846.80
55	84846.80	3265.920	18280.000	18280.000	5419.920	64412.81
56	64412.81	3411.072	18280.000	18280.000	3993.137	45550.74
57	45550.74	3120.768	18280.000	18280.000	3120.104	27271.41
58	27271.41	3411.072	18280.000	15705.144	3048.599	11928.74
59	11928.74	2032.128	18280.000	0.000	3072.115	10888.75
60	10888.75	1524.096	18280.000	0.000	3563.632	8849.21
61	8849.21	93405.313	18000.000	18000.000	2657.932	81596.60
62	81596.60	42239.230	12000.000	12000.000	6495.983	105339.85
63	105339.85	44053.633	12000.000	12000.000	7982.682	129410.80
64	129410.80	9797.760	11400.000	11400.000	8451.188	119357.39
65	119357.39	4717.440	18600.000	18600.000	3766.513	101708.32
66	101708.32	1378.944	18280.000	18280.000	6295.147	78512.12
67	78512.12	0.000	18280.000	18280.000	4994.392	55237.73
68	55237.73	0.000	18280.000	18280.000	3493.111	33464.62
69	33464.62	0.000	18280.000	18280.000	2414.025	12770.59
70	12770.59	0.000	18280.000	0.000	2392.448	10378.14
71	10378.14	0.000	18280.000	0.000	2681.688	7696.46
72	7696.46	0.000	18280.000	0.000	2754.030	4942.43
73	4942.43	49206.527	18000.000	18000.000	1604.912	34544.04
74	34544.04	513620.344	12000.000	402637.625	6381.643	139145.17
75	139145.17	869533.063	12000.000	860095.188	9437.905	139145.17
76	139145.17	51456.383	11400.000	42018.480	9437.905	139145.17
77	139145.17	10958.976	18600.000	18600.000	4515.794	126988.35
78	126988.35	5152.896	18280.000	18280.000	7921.757	105939.48
79	105939.48	3773.952	18280.000	18280.000	6607.319	84826.12
80	84826.12	3846.528	18280.000	18280.000	4993.289	65399.36
81	65399.36	2467.584	18280.000	18280.000	4019.090	45567.86
82	45567.86	1088.640	18280.000	18280.000	4132.248	24244.25
83	24244.25	435.456	18280.000	9045.168	3705.799	11928.74
84	11928.74	1378.944	18280.000	0.000	3702.939	9604.74
85	9604.74	2685.312	18000.000	0.000	1264.161	11025.89
86	11025.89	836656.125	12000.000	702877.125	5659.754	139145.17
87	139145.17	398079.375	12000.000	388641.438	9437.905	139145.17
88	139145.17	498742.281	11400.000	489304.375	9437.905	139145.17
89	139145.17	23442.049	18600.000	18723.088	4718.953	139145.17
90	139145.17	12120.192	18280.000	18280.000	8933.445	124051.91
91	124051.91	2322.432	18280.000	18280.000	7654.083	100440.27
92	100440.27	1741.824	18280.000	18280.000	5728.909	78173.18
93	78173.18	580.608	18280.000	18280.000	4584.193	55889.59
94	55889.59	217.728	18280.000	18280.000	4770.869	33056.45
95	33056.45	145.152	18280.000	17162.492	4110.374	11928.74
96	11928.74	3265.920	18280.000	0.000	3880.566	11314.09
97	11314.09	57843.070	18000.000	18000.000	2105.031	49052.14
98	49052.14	1339753.000	12000.000	1242919.250	6740.595	139145.17
99	139145.17	493516.813	12000.000	484078.906	9437.905	139145.17

100	139145.17	199729.156	11400.000	190291.250	9437.905	139145.17
101	139145.17	28957.824	18600.000	24238.863	4718.953	139145.17
102	139145.17	3991.680	18280.000	18280.000	8670.552	116186.30
103	116186.30	2322.432	18280.000	18280.000	7182.180	93046.55
104	93046.55	1886.976	18280.000	18280.000	5359.066	71294.46

Intermediate lines of output deleted

380	70643.16	580.608	18280.000	18280.000	4226.403	48717.36
381	48717.36	580.608	18280.000	18280.000	3207.967	27810.01
382	27810.01	508.032	18280.000	13318.822	3070.478	11928.74
383	11928.74	6676.992	18280.000	3604.878	3072.115	11928.74
384	11928.74	1451.520	18280.000	0.000	3711.946	9668.31
385	9668.31	13499.136	18000.000	9968.962	1269.749	11928.74
386	11928.74	354678.906	12000.000	221773.391	5689.094	139145.17
387	139145.17	182746.375	12000.000	173308.469	9437.905	139145.17
388	139145.17	253798.266	11400.000	244360.375	9437.905	139145.17
389	139145.17	47464.703	18600.000	42745.742	4718.953	139145.17
390	139145.17	14950.656	18280.000	18280.000	9024.988	126790.84
391	126790.84	17926.271	18280.000	18280.000	8322.098	118115.02
392	118115.02	7112.448	18280.000	18280.000	6826.087	100121.38
393	100121.38	4427.136	18280.000	18280.000	5780.627	80487.90
394	80487.90	2249.856	18280.000	18280.000	6400.021	58057.73
395	58057.73	1233.792	18280.000	18280.000	6196.911	34814.61
396	34814.61	870.912	18280.000	18280.000	5291.118	12114.41
397	12114.41	580.608	18000.000	0.000	1382.915	11312.10
398	11312.10	251911.297	12000.000	118409.172	5669.055	139145.17
399	139145.17	99211.391	12000.000	89773.484	9437.905	139145.17
400	139145.17	23950.080	11400.000	14512.176	9437.905	139145.17