DFLOW USER'S MANUAL

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

The purpose of this user's manual is to describe the operation of a computer program called DFLOW. This program computes various types of statistically-based river flows that are used in water quality modeling studies and waste load allocations.

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ABSTRACT

DFLOW is a computer program for estimating design stream flows for use in water quality studies. This manual describes the use of the program on both the EPA's IBM mainframe system and on a personal computer (PC). The mainframe version of DFLOW can extract a river's daily flow record from EPA's STORET system and convert it into a format suitable for downloading to a PC. Both the mainframe and PC versions can compute aquatic life design flows based on either continuous duration or annual extreme value flow statistics and a human health design flow equal to a river's harmonic mean flow. The manual also describes the computational methods employed by DFLOW.

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1. INTRODUCTION

DFLOW is a computer program for estimating design flows for use in water quality studies. A design flow is a river flow with a specified frequency of not being exceeded, as determined from historical daily flow records. The mainframe version of DFLOW can extract daily flow records from the US Environmental Protection Agency's (EPA's) STORET data base and then compute design flows from these records. It also provides a facility to convert extracted flow files into a format that can be downloaded to a personal computer (PC). A PC version of DFLOW is available to compute design flows for flow records downloaded from STORET or obtained from other sources .

DFLOW implements EPA guidance on design flows for protection of aquatic life (U.S. Environmental Protection Agency, 1986) and for protection of human health. It computes three different types of design flows in accordance with this guidance. The <u>biologic-ally-based</u> and <u>extreme value-based</u> design flows are used in conjunction with aquatic life water quality criteria. The biologically-based design flow limits the frequency of all flow events within the period of record that are below the design flow. The extreme value design flow limits the frequency of years containing flows below the design flow. It corresponds to the traditional definition of design flow (e.g., the 7-day, ten year (7Q10) low flow). A third type of design flow, the <u>human health</u> design flow, applies to water quality criteria for protection of human health under lifetime exposure. It is computed as the harmonic mean of the daily flow record.

DFLOW runs interactively on either the EPA mainframe or on a DOS-compatible PC. The user should be prepared to supply DFLOW with the following kinds of information:

* the number of the US Geological Survey (USGS) stream gage whose daily flow record is to be extracted from STORET and the state where it is located (mainframe version only), or a data file containing a record of daily flow values (PC version only)
* the type of design flow to be computed (biologically -based, extreme value, or human health),
* the portion of the record to be analyzed (optional),
* defining parameters for extreme value design flows and for biologically-based design flows (if default values are not chosen).

More detailed descriptions of the defining parameters for the biologically-based and extreme value design flows are provided in the material that follows.

2. OPERATING INSTRUCTIONS

These instructions apply to the mainframe version of DFLOW. Operation of the PC version is described in Appendix A. DFLOW can be accessed through EPA's National Computing Center's IBM 3090 mainframe by users with an authorized STORET account. After entering the STORET environment under the TSO operating system, the DFLOW program can be invoked by entering the command:

WQAB DFLOW

An opening message screen provides information about the current program version number, latest bug fixes, and a user support phone number. After reading this screen and pressing the Enter key, the following main menu of choices will appear:

```
                 D F L O W   M A I N   M E N U
=================================================================
ENTER THE NUMBER OF THE PROCEDURE YOU WISH TO EXECUTE:

      1 - RETRIEVE FLOW DATA FROM STORET

      2 - CONVERT FLOW DATA FOR DOWNLOADING

      3 - COMPUTE DESIGN FLOWS

      4 - EXIT THE PROGRAM

OPTION ==>
```

The first choice is used to retrieve a record of daily flow data for a specific USGS flow gage from STORET. Options 2 and 3 cannot be used unless a flow record is first extracted from STORET. The second option is used to convert a flow record that has been retrieved from STORET into a file format that can be downloaded onto a PC. Users who work exclusively on the mainframe will not need to invoke this option. The third option executes the design flow estimation procedures of DFLOW, while the last option terminates the program and returns the user to the operating system.

Figure 1 illustrates a sample flow retrieval (option 1). There are three items of information that the user is prompted to supply: the name of the river (8 or less characters), an 8-digit USGS flow gage number, and the 2-character postal abbreviation of the state in which the gage is located. The river name can be any label that the user wants to assign to the river -- it need not be the actual name of the river. After these three items are entered, DFLOW submits a batch job to the STORET system to retrieve daily flow data for the designated flow gage. The time required to complete the retrieval depends on how heavily the mainframe is being used. Normally, it should take no more than a few minutes. When ready to proceed, the user presses the Enter key to bring up the main DFLOW menu once again. If the retrieval was successful, the retrieved flow data will be placed in a dataset named "river".FLOW (where "river" is the user-supplied river name) in the user's catalog.

An example of using option 2 of DFLOW for converting a STORET flow file into one suitable for downloading to a PC is shown in Figure 2. The user first supplies the name of a river for which a STORET flow retrieval was made previously using DFLOW's option 1. An error message results if a flow dataset for the named river cannot be found in the user's catalog. The user then designates whether the entire period of record or only a portion of the record should be converted. Upon completion of the conversion process, DFLOW alerts the user that the converted flow data resides in a dataset named "river".DOWNLOAD, where "river" is the user-supplied river name. The actual process of downloading the flow data onto a PC would be done outside of the DFLOW program, using a mainframe-to-PC file transfer procedure.

```
          D F L O W   M A I N   M E N U
===================================================

ENTER THE NUMBER OF THE PROCEDURE YOU WISH TO EXECUTE:

      1 - RETRIEVE FLOW DATA FROM STORET

      2 - CONVERT FLOW DATA FOR DOWNLOADING

      3 - COMPUTE DESIGN FLOWS

      4 - EXIT THE PROGRAM

OPTION ==> 1

NAME OF RIVER (8 OR LESS CHARACTERS) ==> quinnip
8-DIGIT USGS FLOW GAGE NUMBER        ==> 01196500
2-CHARACTER STATE ABBREVIATION       ==> ct

  JOB MRF      (JOB07164) SUBMITTED
SUBMIT COMPLETED
RETRIEVED FLOW DATA WILL BE STORED IN DATASET 'QUINNIP.FLOW'.

YOU MIGHT WANT TO WAIT NOW FOR FLOW RETRIEVAL JOB TO FINISH.

PRESS <ENTER> KEY WHEN READY TO CONTINUE ...

10.04.22 JOB07164 $HASP165 MRF64    ENDED AT NCCIBM1 CN(00)
```

Figure 1. Sample STORET Flow Retrieval

DFLOW's third main menu option, the computation of design flows, is illustrated in Figures 3 through 5. The user first supplies the name of a river for which flow data had been previously retrieved. An error message results if a flow dataset for the river cannot be found in the user's catalog. The user then selects the type of design flow to be calculated from a menu of the following choices: biologically-based, extreme value, or human health.

Figure 3 portrays selection of a biologically-based design flow computation. The user specifies whether the design flow is for acute (CMC) or chronic (CCC) water quality criteria and then whether default parameter settings apply or not. The parameters for a biologically-based design flow are as follows:

```
          D F L O W   M A I N   M E N U
===================================================

ENTER THE NUMBER OF THE PROCEDURE YOU WISH TO EXECUTE:

      1 - RETRIEVE FLOW DATA FROM STORET

      2 - CONVERT FLOW DATA FOR DOWNLOADING

      3 - COMPUTE DESIGN FLOWS

      4 - EXIT THE PROGRAM

OPTION ==> 2

NAME OF RIVER TO CONVERT (8 OR LESS CHARACTERS)  ==> quinnip


FLOW FILE CONVERSION FOR USGS GAGE 01196500
(QUINNIPIAC R AT WALLINGFORD, CT          )

HOW MUCH OF THE FLOW RECORD SHOULD BE CONVERTED:

   1 - THE ENTIRE AVAILABLE RECORD
   2 - ONLY A PORTION OF THE RECORD
?
1

 18993 DAYS OF FLOW RECORD CONVERTED.

CONVERTED FLOW DATA RESIDES IN DATASET 'QUINNIP.DOWNLOAD'.

 PRESS <ENTER> KEY TO CONTINUE ...
```

Figure 2. Sample Flow File Conversion

```
         D F L O W   M A I N   M E N U
==================================================

ENTER THE NUMBER OF THE PROCEDURE YOU WISH TO EXECUTE:

      1 - RETRIEVE FLOW DATA FROM STORET

      2 - CONVERT FLOW DATA FOR DOWNLOADING

      3 - COMPUTE DESIGN FLOWS

      4 - EXIT THE PROGRAM

OPTION ==> 3

NAME OF RIVER TO ANALYZE (8 OR LESS CHARACTERS)  ==> quinnip


DESIGN FLOWS FOR USGS GAGE 01196500
QUINNIPIAC R AT WALLINGFORD, CT
=================================================================

ENTER THE NUMBER OF THE DESIGN FLOW YOU WISH TO CALCULATE:

   1 - AQUATIC LIFE, BIOLOGICALLY-BASED
   2 - AQUATIC LIFE, EXTREME VALUE
   3 - HUMAN HEALTH, HARMONIC MEAN
   4 - RETURN TO MAIN MENU
?
1

WHICH TYPE OF WATER QUALITY CRITERION APPLIES:

   1 - CRITERION MAXIMUM CONCENTRATION (ACUTE)
   2 - CRITERION CONTINUOUS CONCENTRATION (CHRONIC)
?
2

SHOULD DEFAULT SETTINGS BE USED FOR THE BIO-BASED DESIGN FLOW PARAMETERS
(AS DESCRIBED IN US EPA TECHNICAL GUIDANCE MANUAL ON DESIGN FLOWS):

   1 - YES
   2 - NO
?
1

HOW DO YOU WANT TO ANALYZE THE AVAILABLE FLOW RECORD:

   1 - ANALYZE THE ENTIRE AVAILABLE RECORD
   2 - ANALYZE ONLY A PORTION OF THE RECORD
?
2

WHAT IS THE FIRST YEAR OF THE FLOW RECORD TO BE ANALYZED
?
1900

WHAT IS THE LAST YEAR  OF THE FLOW RECORD TO BE ANALYZED
?
1977
```

Figure 3. Sample Biologically-Based Design Flow

```
DESIGN FLOWS FOR USGS GAGE 01196500
QUINNIPIAC R AT WALLINGFORD, CT
-------------------------------------------------------------------------
PERIOD OF RECORD ANALYZED                    : 1931 TO 1977
ALLOWED NUMBER OF EXCURSIONS                 :          15.68
BIO-BASED CCC (CHRONIC) DESIGN FLOW          :          25.35 CFS

PRESS <ENTER> KEY TO CONTINUE ...

ENTER A FLOW (CFS) FOR WHICH YOU WANT AN
EXCURSION TABLE (OR 0 FOR NO TABLE)
?
25.35

WATER QUALITY EXCURSIONS FOR 1931-1977 AT DESIGN FLOW OF    25.35 CFS
--------------------------------------------------------------------------
|       CLUSTER PERIOD           |            EXCURSION PERIODS           |
--------------------------------------------------------------------------
|                     NUMBER OF  |                  DURATION    AVERAGE % |
|  START DATE        EXCURSIONS  |  START DATE       (DAYS)    EXCURSION * |
--------------------------------------------------------------------------
|  OCT  2, 1931         3.25     |  OCT  2, 1931       4           3.1    |
|                                |  NOV 11, 1931       5           1.4    |
|                                |  NOV 26, 1931       4          16.0    |
--------------------------------------------------------------------------
|  OCT 13, 1932         1.50     |  OCT 13, 1932       6           8.3    |
--------------------------------------------------------------------------
|  AUG 14, 1936         2.25     |  AUG 14, 1936       9          41.8    |
--------------------------------------------------------------------------
|  OCT 22, 1965         1.75     |  OCT 22, 1965       7          13.2    |
--------------------------------------------------------------------------
|  AUG  5, 1966         5.00     |  AUG  5, 1966      12           4.9    |
|                                |  AUG 19, 1966      25          31.7    |
--------------------------------------------------------------------------
|  AUG 12, 1970         1.75     |  AUG 12, 1970       7          21.4    |
--------------------------------------------------------------------------
|        TOTAL         15.50     |                                        |
--------------------------------------------------------------------------
* PERCENTAGE BY WHICH A CRITERION CONCENTRATION WOULD BE EXCEEDED.
PRESS <ENTER> KEY TO CONTINUE ...

ENTER A FLOW (CFS) FOR WHICH YOU WANT AN
EXCURSION TABLE (OR 0 FOR NO TABLE)
?
0
```

Figure 3. Continued

Number of days in a flow averaging period - a number between 1 and 30; default values are 1 day for acute water quality criteria and 4 days for chronic criteria.

Average number of years between excursions - the length of time, on average, between occurrences of m-day average flows below the design flow, where m is the flow averaging period specified above; default value is 3 years.

<u>Length of excursion clustering period</u> - the length of time used to cluster excursions (i.e., occurrences of m-day average flows below the design flow) together; default value is 120 days.

<u>Maximum number of excursions counted per cluster</u> - a ceiling placed on the number of design flow excursions that are actually counted within a clustering period; default value is 5.

As an example of how these parameters determine a design flow, consider a situation with 30 years of flow record where a design flow for chronic water quality criteria is being calculated. Under the default parameter values, a design flow would be chosen so that the total number of past occurrences of non-overlapping 4-day average flows below this flow is as close to, but no greater than, 30/3 or 10, excluding those that exceed 5 within any 120 day period.

If default parameter values are not used, the user is prompted to enter values for each one. Then the user has the option of using the entire flow record in the analysis or only a portion of the record. For the latter case, the user is prompted for the first and last years to be analyzed. A response of 1900 for the first year causes DFLOW to use the first available year in the retrieved streamflow record. A response of 1999 for the last year allows DFLOW to consider flows up to last year available in the flow record.

The output from DFLOW for a biologically-based design flow, as shown in Figure 3, lists the period of record analyzed, the allowed number of excursions below the design flow over this period, and the value of the computed design flow. After this, the user is prompted for a design flow from which a water quality excursion table is constructed. This table shows when a water quality criterion for a hypothetical toxicant would have been exceeded during the historical period of record. These criterion excursions occur when river flows are below the design flow. A sample excursion table is shown in Figure 3. The right hand side of the table lists individual excursion periods (consecutive days where each m-day average flow is below the design flow) and their average magnitude (the average percent difference between each m-day average flow in the period and the design flow). The left hand side of the table divides up the individual excursions periods into clusters and counts up the number of discrete excursions (the total duration of excursion days divided by the averaging period) within each cluster. Note that under the default excursion parameters used in this example, no more than 5 excursions are counted within any 120-day cluster period. The process of DFLOW requesting a design flow and then producing an excursion table continues until the user responds with a flow of 0. The program then returns to the menu of design flow choices.

Figure 4 illustrates the computation of an extreme value design flow. The user is prompted to supply values for the flow averaging period and the return period. The flow averaging period (call it m) has the same meaning as in the biologically-based design flow. However the return period now represents the number of years, on average, between occurrences of years with one or more m-day average flows below the design flow. For example, a return period of 10 years means that, on average, one of every ten years will have flow events that are below the design flow value. Note that in contrast to the biologically-based design flow, no information is conveyed on how many such flow events occur within each such year or over the total period of record.

After specifying the averaging and return periods, the user can opt to use the entire flow record or some designated portion as explained above. The output of the calculation shows the actual period of record analyzed and the resulting extreme value design flow. The program then returns to the design flow menu.

```
DESIGN FLOWS FOR USGS GAGE 01196500
QUINNIPIAC R AT WALLINGFORD, CT
================================================================

ENTER THE NUMBER OF THE DESIGN FLOW YOU WISH TO CALCULATE:

    1 - AQUATIC LIFE, BIOLOGICALLY-BASED
    2 - AQUATIC LIFE, EXTREME VALUE
    3 - HUMAN HEALTH, HARMONIC MEAN
    4 - RETURN TO MAIN MENU
?
2

ENTER VALUES FOR THE FOLLOWING PARAMETERS (TYPICAL VALUES ARE
SHOWN IN PARENTHESES):

FLOW AVERAGING PERIOD (7 DAYS)
?
7

RETURN PERIOD ON YEARS WITH EXCURSIONS (10 YEARS)
?
10

HOW DO YOU WANT TO ANALYZE THE AVAILABLE FLOW RECORD:

    1 - ANALYZE THE ENTIRE AVAILABLE RECORD
    2 - ANALYZE ONLY A PORTION OF THE RECORD
?
2

WHAT IS THE FIRST YEAR OF THE FLOW RECORD TO BE ANALYZED
?
1900

WHAT IS THE LAST YEAR  OF THE FLOW RECORD TO BE ANALYZED
?
1977

DESIGN FLOWS FOR USGS GAGE 01196500
QUINNIPIAC R AT WALLINGFORD, CT
----------------------------------------------------------------
PERIOD OF RECORD ANALYZED              : 1931 TO 1977
 7-Q-10 DESIGN FLOW                    :        32.41 CFS

PRESS <ENTER> KEY TO CONTINUE ...
```

Figure 4. Sample Extreme Value Design Flow

Figure 5 illustrates computation of a human health design flow, i.e., a harmonic mean flow. Once again the user has the option of specifying that only some portion of the flow record be analyzed. After this, the resulting harmonic mean flow is displayed, then the user is returned to the design flow menu.

```
DESIGN FLOWS FOR USGS GAGE 01196500
QUINNIPIAC R AT WALLINGFORD, CT
================================================================

ENTER THE NUMBER OF THE DESIGN FLOW YOU WISH TO CALCULATE:

    1 - AQUATIC LIFE, BIOLOGICALLY-BASED
    2 - AQUATIC LIFE, EXTREME VALUE
    3 - HUMAN HEALTH, HARMONIC MEAN
    4 - RETURN TO MAIN MENU
?
3

HOW DO YOU WANT TO ANALYZE THE AVAILABLE FLOW RECORD:

    1 - ANALYZE THE ENTIRE AVAILABLE RECORD
    2 - ANALYZE ONLY A PORTION OF THE RECORD
?
1


DESIGN FLOWS FOR USGS GAGE 01196500
QUINNIPIAC R AT WALLINGFORD, CT
----------------------------------------------------------------
PERIOD OF RECORD ANALYZED                : 1931 TO 1988
HUMAN HEALTH (HARMONIC MEAN) DESIGN FLOW :      113.69 CFS

PRESS <ENTER> KEY TO CONTINUE ...
```

Figure 5. Sample Human Health Design Flow

NOTE: The harmonic mean of a sample of values is the reciprocal of the mean of the reciprocals of the individual values within the sample.

The last choice on the design flow menu returns the user to the main DFLOW menu. Prior to returning to the main menu, DFLOW asks the user if the output from the design flow computations should be saved in a dataset (see Figure 6). If the user answers yes, then the output is placed in a dataset named "river".LOG (where "river" is the name of the river supplied previously by the user). After the DFLOW session is over, this dataset can be printed out by the user so that a hardcopy record of the computations is available. (There are several ways to print a dataset from a TSO session on the NCC IBM mainframe. Consult the NCC Users Guide or, if using remote telecommunication via a PC, the users manual for your PC communications software.) The "LOG" dataset for the examples shown in Figures 3 through 5 is displayed in Figure 7.

```
DESIGN FLOWS FOR USGS GAGE 01196500
QUINNIPIAC R AT WALLINGFORD, CT
======================================================================

ENTER THE NUMBER OF THE DESIGN FLOW YOU WISH TO CALCULATE:

   1 - AQUATIC LIFE, BIOLOGICALLY-BASED
   2 - AQUATIC LIFE, EXTREME VALUE
   3 - HUMAN HEALTH, HARMONIC MEAN
   4 - RETURN TO MAIN MENU
?
4

DO YOU WISH TO SAVE THE OUTPUT FOR THIS RIVER IN A DATASET:

   1 - YES
   2 - NO
?
1

OUTPUT CAN BE FOUND IN DATASET 'QUINNIP.LOG'.

 PRESS <ENTER> KEY TO CONTINUE ...


           D F L O W   M A I N   M E N U
=======================================================

ENTER THE NUMBER OF THE PROCEDURE YOU WISH TO EXECUTE:

      1 - RETRIEVE FLOW DATA FROM STORET

      2 - CONVERT FLOW DATA FOR DOWNLOADING

      3 - COMPUTE DESIGN FLOWS

      4 - EXIT THE PROGRAM

OPTION ==> 4

READY
```

Figure 6. Sample Exit From DFLOW

BIO-BASED DESIGN FLOW PARAMETERS

LENGTH OF FLOW AVERAGING PERIOD	:	4 DAYS
AVERAGE INTERVAL BETWEEN EXCURSIONS	:	3.0 YEARS
LENGTH OF EXCURSION CLUSTERING PERIOD	:	120.0 DAYS
MAX. NUMBER OF EXCURSIONS PER CLUSTER	:	5.0

DESIGN FLOWS FOR USGS GAGE 01196500
QUINNIPIAC R AT WALLINGFORD, CT

PERIOD OF RECORD ANALYZED	:	1931 TO 1977
ALLOWED NUMBER OF EXCURSIONS	:	15.68
BIO-BASED CCC (CHRONIC) DESIGN FLOW	:	25.35 CFS

WATER QUALITY EXCURSIONS FOR 1931-1977 AT DESIGN FLOW OF 25.35 CFS

CLUSTER PERIOD		EXCURSION PERIODS		
START DATE	NUMBER OF EXCURSIONS	START DATE	DURATION (DAYS)	AVERAGE % EXCURSION *
OCT 2, 1931	3.25	OCT 2, 1931	4	3.1
		NOV 11, 1931	5	1.4
		NOV 26, 1931	4	16.0
OCT 13, 1932	1.50	OCT 13, 1932	6	8.3
AUG 14, 1936	2.25	AUG 14, 1936	9	41.8
OCT 22, 1965	1.75	OCT 22, 1965	7	13.2
AUG 5, 1966	5.00	AUG 5, 1966	12	4.9
		AUG 19, 1966	25	31.7
AUG 12, 1970	1.75	AUG 12, 1970	7	21.4
TOTAL	15.50			

* PERCENTAGE BY WHICH A CRITERION CONCENTRATION WOULD BE EXCEEDED.

DESIGN FLOWS FOR USGS GAGE 01196500
QUINNIPIAC R AT WALLINGFORD, CT

PERIOD OF RECORD ANALYZED	:	1931 TO 1977
7-Q-10 DESIGN FLOW	:	32.41 CFS

DESIGN FLOWS FOR USGS GAGE 01196500
QUINNIPIAC R AT WALLINGFORD, CT

PERIOD OF RECORD ANALYZED	:	1931 TO 1988
HUMAN HEALTH (HARMONIC MEAN) DESIGN FLOW	:	113.69 CFS

Figure 7. Sample DFLOW Session Log

3. COMPUTATIONAL PROCEDURES

This section describes the computational steps employed by DFLOW for each of the three types of design flows considered. It begins with the extreme value design flow, since this type of design flow also serves as a starting point in computing the biologically-based design flow.

Extreme Value Design Flow

The extreme value design flow is computed from the sample of lowest m-day average flows for each year of record, where "m" is the user-supplied flow averaging period. Established practice uses arithmetic averaging to calculate these m-day average flows. A log Pearson Type III probability distribution is fitted to the sample of annual minimum m-day flows. The design flow is the value from the distribution whose probability of not being exceeded is 1/R, where R is the user-supplied return period. The procedure is modified slightly to accommodate situations where some annual low flows are zero.

Step 1. Initialize each element of a vector X of daily flow values to UNKNOWN (i.e., a very large number such as $1x10^{20}$).

Step 2. Read in daily flow values from the retrieved STORET flow file into X, where X(1) corresponds to the first day of record. (Note: February 29th of leap years is ignored.)

Step 3. Create m-day running arithmetic averages from the daily flows in X, and replace the daily flows of X with these values. The running average of X(i), X(i+1), ..., X(i+m-1) is placed in X(i).

Step 4. Find the lowest m-day running average value for each water year recorded in X (where a water year begins on April 1) and store the resulting values in vector Y. Let NY denote the number of entries in Y.

Step 5. Let N be the number of non-zero entries in Y. Assume that these Y-values are a sample drawn from a log Pearson Type III probability distribution. The design flow, DFLOW, is the value from this distribution whose probability of not being exceeded is 1/R, where R is the user-supplied return period. Use the following procedure to find DFLOW:

Step 5a. Find the mean (U), standard deviation (S), and skewness coefficient (G) of the natural logarithms of the non-zero entries in Y.

Step 5b. Let F0 be the fraction of entries in Y that are zero:

$$F0 = (NY - N)/NY$$

Let P be the cumulative probability corresponding to the user-supplied return period of R years, adjusted for the presence of zero-flow years:

$$P = (1/R - F0)/(1 - F0).$$

In other words, if F0 is the probability of having a year with zero stream flow, and 1/R is the allowed probability of a year with an excursion below the design flow, then P is the corresponding excursion probability in years with non-zero flows.

Step 5c. Let Z be the standard normal deviate corresponding to cumulative probability P. Z can be computed using the following formula (Joiner and Rosenblatt, 1971):

$$Z = 4.91(P^{.14} - (1-P)^{.14})$$

Step 5d. Compute the gamma deviate, K, corresponding to the standard normal deviate Z and skewness G using the Wilson-Hilferty transformation (Loucks et al., 1981):

$$K = (2/G)([1 + G*Z/6 - G^2/36]^3 - 1)$$

Step 5e. Compute DFLOW as exp(U + K*S).

Biologically-Based Design Flow

A descriptive definition of the biologically-based design flow is presented in U.S. Environmental Protection Agency (1986). It is computed by starting with a trial design flow, then counting how often this flow is not exceeded by m-day average flows in the historical record. (In contrast with the traditional method of computing extreme value design flows, the m-day flow averages are harmonic means, not arithmetic ones. The reason why is explained in Rossman (1990)). This count is compared to the allowed number of such occurrences, and the trial design flow is adjusted accordingly. The specific computational steps involved are as follows:

Step 1. Initialize each element of a vector X of daily flow values to UNKNOWN (i.e., a very large number such as $1x10^{20}$).

Step 2. Read in daily flow values from the retrieved STORET flow file into X, where X(1) corresponds to the first day of record. (Note: February 29th of leap years is ignored.)

Step 3. Create m-day running harmonic averages from the daily flows in X, and replace the daily flows of X with these values. The running average of X(i), X(i+1), ..., X(i+m-1) is placed in X(i) and is computed as follows:

> Define B(j) as 1/X(i+j-1) if X(i+j-1) > 0, and 0 otherwise, for j = 1 to m. Let DSUM be the sum of B(j) for j = 1 to m and m0 be the number of B(j) values that equal 0. Then replace X(i) with X(i) = (m-m0)/DSUM*(m-m0)/m.

Note that this procedure takes into account the possibility of zero flows when forming a harmonic average.

Step 4. Compute an extreme value m-day average trial design flow (DFLOW) using the biologically-based average number of years between flow excursions (R) as the return period.

Step 5. Compute the allowed number of flow excursions, A, (i.e., the number of distinct m-day average flows allowed to be below the design flow) over the NDAYS of streamflow record: A = NDAYS/365/R.

Step 6. Use the procedure described below to compute the number of biologically-based flow excursions resulting under the trial design flow DFLOW. Because the trial flow was computed as an extreme value flow, the resulting number of biologically-based excursions will most likely be larger than the allowed number, A. If it is not, then keep increasing the trial design flow by some fixed increment until the resulting number of excursions exceeds A.

Step 7. Use the Method of False Position (Carnahan et al., 1969) to successively refine the estimate of the biologically-based design flow as follows:

Step 4a. Set lower and upper bounds on the design flow with their corresponding excursion counts:

FL = 0;   XL = 0.

FU = DFLOW; XU = number of excursions under DFLOW.

Step 4b. Check on convergence of the bounds. If FU - FL is within 0.5% of FL, then end with DFLOW = FU. If XL is within 0.005 of A, then end with DFLOW = FL. If XU is within 0.005 of A, then end with DFLOW = FU. Otherwise proceed to the next step.

Step 4c. Interpolate between the bounds to find a new trial design flow, FT:

FT = FL + (FU - FL)*(A - XL)/(XU - XL)

and compute the number of excursions (XT) occurring for this flow (see procedure described below).

Step 4d. Update the bounds based on the value of XT:
If XT <= A, then set FL = FT and XL = XT. Otherwise set FU = FT and XU = XT. Then return to the convergence check of Step 4b.

The process used to count the number of flow excursions for a given design flow proceeds in two phases. The first phase identifies all excursion periods in the period of record. An excursion period is a sequence of consecutive days where each day belongs to an m-day running average flow that is below the given design flow. Recall that "m" is the flow averaging period set by the user. Phase two groups these excursion periods into excursion clusters and counts up the total number of excursions occurring within all clusters. An excursion cluster consists of all excursion periods falling within a prescribed length of time from the start of the first period in the cluster (120 days is the default cluster length). The number of excursions counted per cluster is subject to an upper limit whose default value is 5.

Before describing the detailed procedures for each of these phases a simple numerical example will be used to illustrate the method. Suppose that the design flow under consideration is 100 cfs and that the period of record yields a sequence of 4-day running average flows as follows:

Day	4-Day Avg. Flow, cfs	Day	4-Day Avg. Flow, cfs
1	34	513	
2	65	to	< 100
3	25	545	
4-12	> 100	546	
13	57	to	> 100
14	34	end	
15	26		
16-512	> 100		

The first flow excursion period for this record consists of the 4-day averages occurring on days 1, 2 and 3. Thus the period extends from day 1 to day 6 (days 4, 5 and 6 belong to the averaging period that begins on day 3). There are two other excursion periods consisting of days 13 to 18 and 513 to 548. Under the default clustering parameters, there are 2 excursion clusters; cluster 1 contains periods 1 and 2, and cluster 2 contains period 3. The number of excursions in each cluster is as follows:

Cluster	Period	Start Day	Length, Days	# Excursions in Period	# Excursions in Cluster
1	1	4	6	6/4 = 1.5	3.0
	2	13	6	6/4 = 1.5	
2	3	513	36	36/4 = 9.0	5.0

Note that the number of excursions in each period equals the period length divided by the averaging period. The nominal number of excursions in cluster 2 is 9, and since this exceeds the limit of 5, only 5 are counted. The total number of excursions for the design flow of 100 cfs in this example is 3 + 5 = 8.

The detailed procedure for counting biologically-based flow excursions under a specified design flow is as follows:

PHASE 1

Define P1(i) = day which begins excursion period i,

P2(i) = day which ends excursion period i,

XP(i) = number of excursions in period i,

XKL_{max} = maximum cluster length (e.g., 120 days).

t = current day of record.

Step 1. Set i = 0, P2(0) = 0, and t = 1.

Step 2. If the m-day running average beginning on day t is greater or equal to the specified design flow then proceed to Step 5.

Step 3. If the current day t is more than a day beyond the end of the current excursion period (t > P2(i) + 1), or if the length of the current excursion period equals XKL_{max} then begin a new excursion period by setting:

i = i + 1

P1(i) = t

P2(i) = m - 1

XP(i) = 0.

Step 4. Update the ending day of the current excursion period and the excursion count for this period:

P2(i) = P2(i) + 1

XP(i) = (P2(i) - P1(i)) / m.

Step 5. Proceed to the next day of record (t = t + 1). If not at the end of the record then return to Step 2. Otherwise proceed to phase 2.

PHASE 2

Define i = current excursion period,

k = current excursion cluster,

$K1$ = day of record which begins cluster k,

$XK(K)$ = number of excursions in cluster k,

XK_{max} = maximum number of excursions counted per cluster (e.g., 5),

Step 1. Set $i = 1$, $k = 0$, and $K1$ = a large negative number.

Step 2. If the length of the current cluster is greater than the maximum length (i.e., $P2(i) - K1 > XKL_{max}$) then begin a new cluster with excursion period i, i.e.,

$$k = k + 1$$

$$K1 = P1(k)$$

$$XK(k) = 0.$$

Step 3. Update the excursion count for the current cluster,

$$XK(k) = \text{minimum}\{XK(k) + XP(i),\ XK_{max}\}.$$

Step 4. Proceed to the next excursion period ($i = i + 1$) and return to Step 2. If no more excursion periods remain, then total up the number of excursions in each cluster ($XK(1) + XK(2) + \ldots + XK(k)$) to determine the total number of excursions.

Human Health Design Flow

The overall harmonic mean daily flow can serve as a design flow for human health water criteria that are based on lifetime exposures. (See Rossman (1990) for justifying the use of the harmonic mean.) Computation of the harmonic mean flow begins by reading daily flow values into a vector X. Then the following steps are followed:

Step 1. Set NDAYS = 0, NZEROS = 0, DSUM = 0 and t = 1.

Step 2. If X(t) equals UNKNOWN, then go to Step 5. Otherwise set NDAYS = NDAYS + 1.

Step 3. If X(t) equals 0, then set NZEROS = NZEROS + 1 and got to step 5.

Step 4. Set DSUM = DSUM + 1/X(t).

Step 5. Set t = t + 1. If the end of the record has not been reached then return to Step 2.

Step 6. Compute the design flow HMEAN as

HMEAN = (NDAYS - NZEROS) / DSUM * DR

where DR = (NDAYS - NZEROS) / NDAYS.

Note that this procedure takes into account the possibility of days with zero flow. The final estimate of the harmonic mean is a weighted average of the harmonic mean of the non-zero flows and zero. The weight attached to the harmonic mean of the non-zero flows is simply the fraction of the total days of record that have non-zero flows.

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01196500
 32 01 01        38.00
 32 01 02       121.00
 32 01 03       174.00
 32 01 04       142.00
 32 01 05       107.00
 32 01 06       110.00
 32 01 07       281.00
 32 01 08       270.00
 32 01 09       190.00
 32 01 10       147.00
 32 01 11       155.00
 32 01 12       155.00
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Figure 8. Initial Portion of a PC Flow File

To execute the program, the following command is used:

DFLOW

The user is then prompted to enter the name of the streamflow file (1 to 8 characters, **without the .FLO extension**). If the flow file cannot be found or accessed, an error message results and the program terminates. Otherwise, it uses the same menus, data prompts, and output displays as the mainframe version. Upon exiting the program, a log of the computations is saved in a file whose prefix is the same as the streamflow file and has an extension of .LOG. This file can be printed to produce a hardcopy of the calculations.