

PROGRAM USER GUIDE FOR RORA

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INTRODUCTION

This manual describes the use of the computer program RORA for analysis of streamflow records using data in a particular format (example: Figure 1). This format was not available at the time the program was developed but is now available from USGS web sites. This manual does not include complete explanation of the computer program; the reader is referred to Rutledge (1998, pages 17-32).

The program estimates ground-water recharge using the recession-curve-displacement method. Also known as the Rorabaugh Method (Rorabaugh, 1964; Daniel, 1976), the method is based on the change in total potential ground-water discharge that is caused by each recharge event. Results of the program were compared with results of the manual application of the Rorabaugh Method (Rutledge and Daniel, 1994).

The RORA program is intended for analyzing a ground-water-flow system that is characterized by diffuse areal recharge to the water table and ground-water discharge to a stream. The method is appropriate if all or most ground water in the basin discharges to the stream and if a streamflow-gaging station at the downstream end of the basin measures all or most outflow. Regulation and diversion of streamflow should be negligible. For more information about the application of the method the reader is referred to Rutledge (1998, pages 2-3) and Rutledge (2000, pages 10-11)

Note –

The RORA program was first adapted for reading web data in 2002. In 2007, adaptations were made in the code to accommodate changes in the way USGS web data handle gaps in streamflow record. This newer version of the program was posted on the RORA web site in January 2007. The newer version can read data in the new or old format.

```

# ----- WARNING -----
# The data you have obtained from this automated U.S. Geological Survey database
# have not received Director's approval and as such are provisional and subject to
# revision. The data are released on the condition that neither the USGS nor the
# United States Government may be held liable for any damages resulting from its use.
# Additional info: http://waterdata.usgs.gov/nwis/help/?provisional
#
# File-format description: http://waterdata.usgs.gov/nwis/?tab_delimited_format_info
# Automated-retrieval info: http://waterdata.usgs.gov/nwis/?automated_retrieval_info
#
# Contact: gs-w_support_nwisweb@usgs.gov
# retrieved: 2007-01-08 12:44:58 EST
#
# Data for the following site(s) are contained in this file
# USGS 02038850 HOLIDAY CREEK NEAR ANDERSONVILLE, VA
# -----
#
# Data provided for site 02038850
# DD parameter statistic Description
# 02 00060 00003 Discharge, cubic feet per second (Mean)
#
# Data-value qualification codes included in this output:
# A Approved for publication -- Processing and review completed.
#
agency_cd site_no datetime 02_00060_00003 02_00060_00003_cd
5s 15s 16s 14s 14s
USGS 02038850 1966-04-27 5.6 A
USGS 02038850 1966-04-28 7.0 A
USGS 02038850 1966-04-29 4.8 A
USGS 02038850 1966-04-30 4.2 A
USGS 02038850 1966-05-01 4.2 A
USGS 02038850 1966-05-02 2.3 A
USGS 02038850 1966-05-03 1.1 A
USGS 02038850 1966-05-04 6.1 A
USGS 02038850 1966-05-05 4.9 A
USGS 02038850 1966-05-06 4.3 A
USGS 02038850 1966-05-07 3.7 A
USGS 02038850 1966-05-08 3.5 A
USGS 02038850 1966-05-09 3.2 A
USGS 02038850 1966-05-10 2.9 A
USGS 02038850 1966-05-11 2.9 A
USGS 02038850 1966-05-12 2.9 A
USGS 02038850 1966-05-13 2.9 A
USGS 02038850 1966-05-14 3.8 A
USGS 02038850 1966-05-15 3.2 A
USGS 02038850 1966-05-16 2.8 A
USGS 02038850 1966-05-17 2.6 A
USGS 02038850 1966-05-18 2.5 A
USGS 02038850 1966-05-19 5.8 A
USGS 02038850 1966-05-20 3.6 A
USGS 02038850 1966-05-21 2.8 A
USGS 02038850 1966-05-22 2.5 A
USGS 02038850 1966-05-23 2.3 A
USGS 02038850 1966-05-24 2.3 A
USGS 02038850 1966-05-25 4.5 A
USGS 02038850 1966-05-26 3.6 A
USGS 02038850 1966-05-27 2.9 A
USGS 02038850 1966-05-28 4.2 A
USGS 02038850 1966-05-29 2.9 A
USGS 02038850 1966-05-30 2.4 A
USGS 02038850 1966-05-31 3.6 A
USGS 02038850 1966-06-01 2.8 A
USGS 02038850 1966-06-02 2.4 A
USGS 02038850 1966-06-03 2.2 A
USGS 02038850 1966-06-04 2.0 A
USGS 02038850 1966-06-05 1.8 A
USGS 02038850 1966-06-06 1.7 A
USGS 02038850 1966-06-07 1.7 A
USGS 02038850 1966-06-08 1.7 A
USGS 02038850 1966-06-09 1.5 A
USGS 02038850 1966-06-10 1.5 A
USGS 02038850 1966-06-11 2.1 A
USGS 02038850 1966-06-12 1.5 A
USGS 02038850 1966-06-13 1.4 A
USGS 02038850 1966-06-14 1.4 A
USGS 02038850 1966-06-15 1.3 A
USGS 02038850 1966-06-16 1.2 A

```

Figure 1. Example streamflow data file obtained from a USGS web site. (This is truncated from the data file Holiday.txt, which is available with this manual.)

PREPARING TO USE THE PROGRAM

This section describes data files that the program user may need to obtain or prepare prior to executing the program. The first-time user experimenting with the data files included with this report may skip this section and proceed to the instructions for running the program (page 7). The section about the SCREEN program (page 4) may be helpful to the first-time user.

OBTAINING STREAMFLOW DATA FILES

A streamflow data file can be obtained from the following USGS web site: http://waterdata.usgs.gov/nwis/dv/?referred_module=sw. From this site, the user is first asked to “Choose Site Selection Criteria”. For example, if the site of interest is Holiday Creek near Andersonville, Virginia, yet the site identification number is not known, the user might check the boxes for *State* and *Site Name* and then hit the “Submit” button. At the subsequent “Select sites that meet all of the following criteria” page, the user would then enter *Holiday* under site name, select the state of Virginia from the state list, check the “Streamflow, ft³/s” box in the “Water Level/Flow Parameters” group of the Available parameters list, and then issue the request using the “Submit” button near the very bottom of the page. The subsequent page will be a list of all sites found that meet the specified criteria. Clicking on the site number will display a page including graph(s) of the previous 365 days of data. The final step to obtain a file of streamflow data is to check the “00060 Discharge (Mean)” item under the Available parameters heading, choose “Tab-separated” from the Output format list, enter the Begin and End dates of interest, and then hit GO. Once the data are displayed in your browser select “Save as” from the file pull-down menu of your browser and designate the directory where the data are to be written on the user’s computer, and specify a file name. On some systems this might require copying and pasting into Notepad. File names should be in the format *xxxxx.txt*, where *xxxxx* is an abbreviated station name. In this case the file name might be designated as *Holiday.txt*. (Note: the length of the file name, including *.txt*, should be 12 characters or less.) Designate file type should be “Text File (.txt)”. An example streamflow data file, obtained as described above, is illustrated in figure 1.

A few comments about data files obtained from a USGS web site. Beginning in 2006, some files may include text qualifiers about streamflow data. These qualifiers, which may be evident in recent data (2006+), can appear immediately after a streamflow quantity and in some cases the qualifier may be located in the place of the streamflow quantity. The program may not execute properly due to these text qualifiers. For this reason the program user may need to edit streamflow data files, scanning for these qualifiers, and removing them if they exist.

In some applications, the program user may choose to generate a data file from a source other than a USGS web site. In this case, a few items about file format may be helpful: (1) Most of the header information (fig. 1) is not read by the program, and may not be necessary in a user-generated file. (2) The program starts reading data, two lines after it detects the string “agency” in the first five spaces of a line. (3) The columns of

information in each data line are tab-separated in a data file from a USGS web site (these could be substituted with single blank spaces in a user-generated data file).

As noted on the first page, efforts have taken place to maintain the functionality of the program using data in a particular format. Nonetheless, there may be some cases in which the program user will need to modify format statements in the code and re-compile the program. The fortran source code is available on the program web site.

THE “SCREEN” PROGRAM

Before analyzing a streamflow data file the user may execute the SCREEN program to display the period of record. To demonstrate, execute the program by double-clicking the application in windows or by entering the command “screen” in the MS-DOS command window. Designate the streamflow data file *Indian.txt*. The output file *screenout.txt* should look like figure 2. This illustrates data are available from October 1958 to September 1968 and from October 1970 to September 1986.

```
THIS IS OUTPUT OF THE SCREEN PROGRAM,
VERSION OF JANUARY 2007

READING FILE NAMED Indian.txt
FIRST YEAR IN RECORD = 1958
LAST YEAR IN RECORD = 1986
      MONTH
YEAR  J F M A M J J A S O N D
1958  X X X X X X X X . . .
1959  . . . . . . . . . . .
1960  . . . . . . . . . . .
1961  . . . . . . . . . . .
1962  . . . . . . . . . . .
1963  . . . . . . . . . . .
1964  . . . . . . . . . . .
1965  . . . . . . . . . . .
1966  . . . . . . . . . . .
1967  . . . . . . . . . . .
1968  . . . . . . . . X X X
1969  X X X X X X X X X X X
1970  X X X X X X X X . . .
1971  . . . . . . . . . . .
1972  . . . . . . . . . . .
1973  . . . . . . . . . . .
1974  . . . . . . . . . . .
1975  . . . . . . . . . . .
1976  . . . . . . . . . . .
1977  . . . . . . . . . . .
1978  . . . . . . . . . . .
1979  . . . . . . . . . . .
1980  . . . . . . . . . . .
1981  . . . . . . . . . . .
1982  . . . . . . . . . . .
1983  . . . . . . . . . . .
1984  . . . . . . . . . . .
1985  . . . . . . . . . . .
1986  . . . . . . . X X X

COMPLETE RECORD = .      INCOMPLETE = X
```

Figure 2. Example graphical display of a streamflow record, showing periods of complete record and periods of incomplete record. (This display is generated onto a file by the program SCREEN, and on the monitor by RORA. Streamflow data file is *Indian.txt*.)

DRAINAGE AREA

The RORA program derives estimates of ground-water recharge that are expressed in units of length (inches) and in units of specific discharge (inches per year). In order to make such calculations the program needs the drainage area of the streamflow station. There should be one line written to the file *station.txt* for each streamflow data file (figure 3). Each line must include the name of the streamflow data file and the drainage area. The file *station.txt* includes entries for the streamflow data files that are included with this report, and may be used as a guide for the format of additional entries.

A few items about the format of *station.txt*. The file should have 10 header lines which are not read by the program. Beginning with line 11, each line should include streamflow file name (such as *Indian.txt*) and the drainage area of that station. The program is formatted to read these two fields as A12, 1F8.0. All drainage areas below are given with two decimal spaces after the decimal point, in which case the programmed format is ignored, and the two decimal places are read. When new lines are added to *station.txt*, no tabbing should be used. The program is sensitive to the case of the letters in the name of the streamflow file. For example one of the example data files included is "*Indian.txt*". The case of letters in file *station.txt* (figure 3) is the same, including the capital I. The program user should be aware of this when executing the program (next page).

The drainage area might be obtained from USGS databases, web sites, or data books, or the program user may determine it from topographic maps or other sources. Typically, it is the surface drainage area of the streamflow gaging station. In some applications, the hydrologist may have information to indicate the ground-water contributing area is significantly different from the surface drainage area. In this case the former might be designated in file *station.txt*.

File "station.txt"

This file is read by programs PREP, RECESS, RORA, and PART, to obtain the drainage area. Note: This file should have ten header lines. The streamflow file name should be 12 characters or less.

```
-----  
Name of          Drainage  
streamflow      area      The space below, after drainage area, is  
file            (Square  for optional information that is not read  
                miles)  by the programs. This is free-form.  
-----  
Indian.txt      8.88      02371200  Indian Creek near Troy Alabama  
Holiday.txt     8.53      02038850  Holiday Cr near Andersonville, VA  
Sewee.txt       117.00    01057000  Sewee Creek near Decatur, TN  
LitAndro.txt   73.50     01057000  Lt Androscoggin R nr S.Paris, ME  
BigHill.txt     37.00     01057000  Big Hill Cr near Cherryvale KS
```

Figure 3. Example file "station.txt", including the drainage area for each of the data files that are included with the program.

THE RECESSION INDEX

The program requires an estimate of the recession index. There are many methods for obtaining this variable; the basic procedure is to draw a straight line through data that represent linear recession on the semilog hydrograph (figure 4) then designate the recession index as the slope in days per log cycle. According to the Rorabaugh model of ground-water discharge to a stream, the recession will appear linear on such a graph when the ground-water-head profile has become stable (Rorabaugh, 1964).

The matching strip method has been used in a number of studies (Snyder, 1939; Toebes and Strang, 1964; Nathan and McMahon, 1990). The method is described by Bevens (1986). A method employed by Knisel (1963) involves plotting the streamflow on one day during a period of recession against the flow on a day later in that same period, and repetition of this process for numerous data pairs throughout the period of record. This method could be used, followed by unit conversions to obtain the recession index.

More discussion of the recession index is given by Rutledge (2000, pages 14-18). Another publication includes information about alternative methods for deriving this variable, including methods that employ ground-water-level information (Rutledge, 2003).

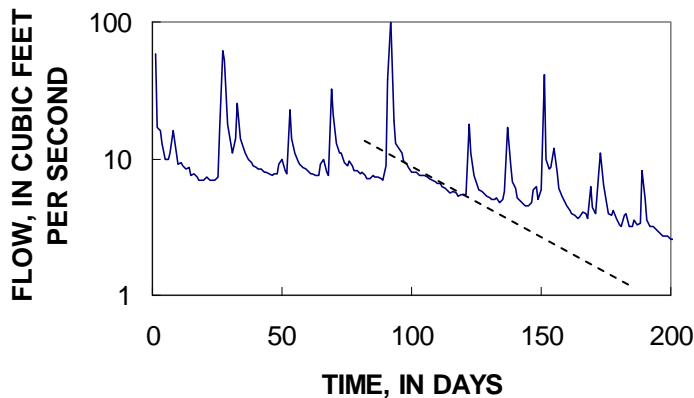


Figure 4. The basic procedure for determining the recession index is to draw a straight line through streamflow data during periods that show linear recession on the semilog hydrograph. (In this example, data are considered from day 100 to 118, julian dates of 1976. Streamflow record is Holiday Creek near Andersonville, Virginia.)

The program user can designate the recession index in the file *index.txt*. The file is included with entries for five streamflow data files (fig. 5). The format of these entries should be used as a guide for additional entries. The RORA program gives the user the option of reading the recession index from *index.txt*, or manual entry of the value during program execution.

A few items about the format of *index.txt*. The file should have 10 header lines which are not read by the program. Beginning with line 11, each line should include streamflow file name (such as *Indian.txt*) and the recession index. The program is formatted to read these two fields as A12, 1F8.2. When new lines are added to *index.txt*, no tabbing should be used. The program is sensitive to the case of the letters in the name of the streamflow file. For example one of the example data files included is “Indian.txt”. The case of letters in *index.txt* is the same, including the capital I.

```
File "index.txt" -- The recession index is entered on this file
manually or by running the RECESS program. This file "index.txt"
can be read by the PREP program (before running PULSE) and it can
be read by RORA. Note -- this file should have ten header lines.
```

```
-----
```

Name of streamflow file	Recession index (days per log cycle)
Indian.txt	100.00
Holiday.txt	80.00
Sewee.txt	65.00
LitAndro.txt	60.00
BigHill.txt	32.00

Figure 5. Example file “index.txt”, including the recession index for each of the data files that are included with the program.

RUNNING THE PROGRAM

This section gives specific instructions for running RORA for the five streamflow data files that are included with this report. The station information files *station.txt* and *index.txt*, which are provided with this report, have entries for these stations. The file *rorasum.txt* has header information for summary results of the RORA program. As provided with this report, the file does not include results, but each time the program is executed a new line will be written to the end of this file.

The program can be executed by double-clicking the RORA application in Windows Explorer, or by opening the MS-DOS window and entering the command "rora". In the first trial run, enter *Indian.txt* as the streamflow data file, then designate the starting year as 1971 and the ending year as 1980. When asked for the recession index, answer with the letter y indicating the program is to obtain it from file *index.txt*. Answer again with the letter y that the requirement of antecedent recession should be its default value. As a test of the program the user should repeat the process for the other four stations *Holiday.txt*, *Sewee.txt*, *LitAndro.txt*, and *BigHill.txt*. (Reminder – the case of all letters in file names must agree with the case in file *station.txt* (figure 3).) The program will ask an additional question for *BigHill.txt* because it includes days of zero flow. Answer y that flow on these days is to be designated 0.01 cubic foot per second.

After the program is executed five times as described above, the output file *rorasum.txt* should be identical to figure 6. Each time the program was run, a new line was written to the end of this file. The other output files *roraqrt.txt*, *roramom.txt*, *roraWY.txt*, and *rorapek.txt* are created the first time the program is executed, then over-written each time the program is executed again. To save the results in these files the user will need to copy or rename each to a separate file after each program run. As noted in the documentation report (Rutledge, 1998), results of the RORA program should be reported at the time scale of the quarter year (or season) or a larger time scale. Results on the basis of the month might be useful in some applications although the program user should be aware of potential problems (Rutledge, 2000, pages 29-31). Seasonal results might be obtained by summation of monthly totals from file *roramom.txt*.

File "rorasum.txt" Program version - Jan 2007

Each time the RORA program is run, a new line is written to the end of this file.

File name	Drainage area (Sq. miles)	Period	Requirement of antecedent recession (days)	Number of peaks detected	Recession index (Days/LogQ)	Recharge (in/yr)
Indian.txt	8.88	1971-1980	2	507	100.0	17.097
Holiday.txt	8.53	1971-1980	2	521	80.0	12.210
Sewee.txt	117.00	1971-1980	3	380	65.0	16.676
LitAndro.txt	73.50	1971-1980	3	342	60.0	20.751
BigHill.txt	37.00	1971-1980	3	293	32.0	2.455

Figure 6. Example results of the RORA program (written to file *rorasum.txt*) from test runs described in this report. (Other results are written to other files described in the report.)

The program generates a graphical display of the completeness of the record (figure 2). Results of the program will be most useful if the time period is one in which the record is complete for all calendar years. In the case of the record illustrated in figure 2, this would be 1959 to 1967 (or a subset of these years) or 1971 to 1985 (or a subset of these years). If there is a gap within the period specified, the program will not make calculations. (For example if the period specified was 1961 to 1980.) The program will make calculations in some cases of missing record if the days missing are only at the beginning or the ending of the period specified. Although some output is generated, in this case long-term results will not be written to *rorasum.txt*. To demonstrate, the program user can execute RORA, specifying *Indian.txt* as the streamflow file, and specifying the time period 1970 to 1980. In this case, a line is written to *rorasum.txt* indicating incomplete record, but partial results are written to *roraqrt.txt* (below) and *roramom.txt*, *roraqek.txt*, and *roraWY.txt*. The number “-99.99” indicates no result.

```

STREAMFLOW FILE =                Indian.txt
RECESSION INDEX (DAYS/LOG CYCLE) = 100.000000
REQUIREMENT OF ANTEC. RECESSION = 2
PROGRAM VERSION = JANUARY 2007

```

QUARTER-YEAR RECHARGE IN INCHES:

	JAN- MAR	APR- JUNE	JULY- SEPT	OCT- DEC	YEAR TOTAL
1970	-99.99	-99.99	-99.99	4.37	-99.99
1971	14.90	-0.16	2.58	4.27	21.59
1972	6.97	1.57	-0.01	7.13	15.67
1973	12.52	2.24	1.34	2.88	18.98
1974	6.90	2.85	0.96	3.87	14.58
1975	9.98	2.13	4.47	6.85	23.42
1976	9.90	5.70	1.54	5.35	22.49
1977	8.56	-1.07	1.43	2.86	11.78
1978	6.08	2.13	0.90	1.54	10.64
1979	7.62	3.51	2.81	4.03	17.98
1980	8.45	3.26	0.37	1.97	14.04

Because calculations for each recharge event require streamflow data before and after the event, there can be errors near the beginning and the end of the period of interest. These errors can include nondetection of a recharge event. In some applications the program might be executed for a period that begins prior to the period of interest and ends after the period of interest, then results for the period can be extracted from output files such as *roraqrt.txt*.

Specific instructions are provided in this manual for verifying that the program is executing correctly. When the program is applied using streamflow data from other basins, the user will need to obtain the recession index (see earlier section and references). Experiments might be conducted to show the sensitivity of the estimate of recharge to variation in the recession index (Example: Rutledge, 2000, page 18). If the hydrologist is concerned about errors caused by direct surface runoff, the requirement of antecedent might be increased above the default value. This can affect the program’s ability to detect recharge events, thus inducing other errors (Rutledge, 2000, pages 26-28).

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