

MODULE – 4: Reservoir Routing

The passage of flood hydrograph through a reservoir is an unsteady flow phenomenon. The equation of continuity is used in all hydrologic routing methods as primary equation. The reservoirs can be either controlled or uncontrolled. The controlled reservoirs have spillway with gates operated for making releases at the desired rates. The uncontrolled reservoirs are those whose spillway is not controlled by the gate operation. Reservoir routing requires the relationship between the reservoir elevation, storage and discharge to be known. This relationship is a function of the topography of reservoir site and the characteristics of the outlet facility. Several methods for routing a flood wave through a reservoir have been developed, namely: Mass Curve Method, Modified Puls Method, Goodrich Method, Coefficient Method, Steinberg Method, and Wisler-Brater Method.

This module carries out the routing analysis for a proposed reservoir with specified storage and release characteristics using the Modified Puls method. Metric system of units has been adopted and the desirable units of requisite data are specified in the column header.

4.1 Data Checks

Some of the checks performed by the module include:

- a) Initial storage capacity should be higher than the storage capacity at Dead Storage Level. Otherwise, the module invokes the message and aborts.
- b) E-A-C-RC (Elevation-Area-Capacity-Release Capacity) table of reservoir is checked. If the area (or capacity) at any reservoir level decreases with rising elevation or vice versa, the program aborts and flags the line number in the E-A-C-RC table for correction.
- c) The capacity at each level of E-A-C-RC table above the lowest level is checked by using the prismoidal formula. If the difference in the computed and specified capacity is greater than 10%, a message is flagged at the screen and in the result file after the presentation of E-A-C-RC table in the Input Data section. The program does not abort in this case.

4.2. Input Data Description

Inflow time series is specified in a tabular form. The file extension for input files is **.rri** and file extension for output files is **.rro** and for graphical file is **.rrg**. Various items that are input to the program are described below:

Title of the analysis

Specify the title of the data file containing general details of the analysis for remembrance at a later date (not more than 100 characters).

Number of values in inflow series

Specify the number of values in inflow flood hydrograph. Using this number, the form for inflow entry will automatically generate the specified number of empty cell rows corresponding to different time steps (hours) of inflow time series.

Computational time step (hours)

Reservoir routing is carried out at shorter time step (say, few hours) to capture the variation in inflows, reservoir storage, and release. Computational time step refers to the length of each time step (in hours) in which reservoir storage and release is to be computed corresponding to known inflow rate. Inflow time series should be available at the selected time step.

Number of data points in E-A-C-RC table

Specify the number of elevations for which corresponding water spread areas, cumulative storage capacity, and release capacity with all gates operational is available. Based on the entered value, the form for entry of E-A-C-RC table will automatically generate the specified number of empty cell rows for input of tabular values.

Gate factor (0 – 1)

As mentioned earlier, gate factor is introduced in the module to specify the variable release capacity from the reservoir. In the E-A-C-RC table, the release capacity from the reservoir at a particular water elevation represents the maximum release capacity with all the gates open (gate factor = 1). However, it is possible to consider different release capacity from the reservoir by varying the gate factor between 0 and 1 and revising the routing analysis. This can help in the analysis of spillway crest and design of spillway gates.

The actual release capacity to be considered for routing analysis is taken as gate factor * maximum spillway release capacity at any elevation. Thus, a gate factor of 0.9 indicates that 90% of maximum spillway release capacity (mentioned in E-A-C-RC table) is to be considered for routing analysis.

Initial reservoir level of routing (m)

Specify the starting reservoir elevation (m) at which the routing analysis begins. Routing analysis is affected by this variable as the reservoir storage and release capacity is affected by the initial reservoir level.

E-A-C-RC table

Clicking on the ***E-A-C-RC Table*** button opens a table for entry of elevation, area, capacity, and release capacity (with all gates open) of the reservoir. The number

of cells depends on the general data specified in the cell corresponding to the number of data points in E-A-C-RC table.

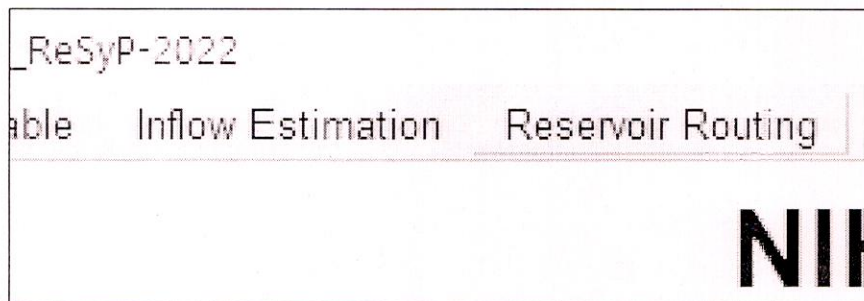
Inflow Time Series

Clicking on the **Inflow Time Series** button opens a table for entry of inflow values at different time steps (hours) of the inflow hydrograph. Number of rows in the table depends on the number of values in inflow series.

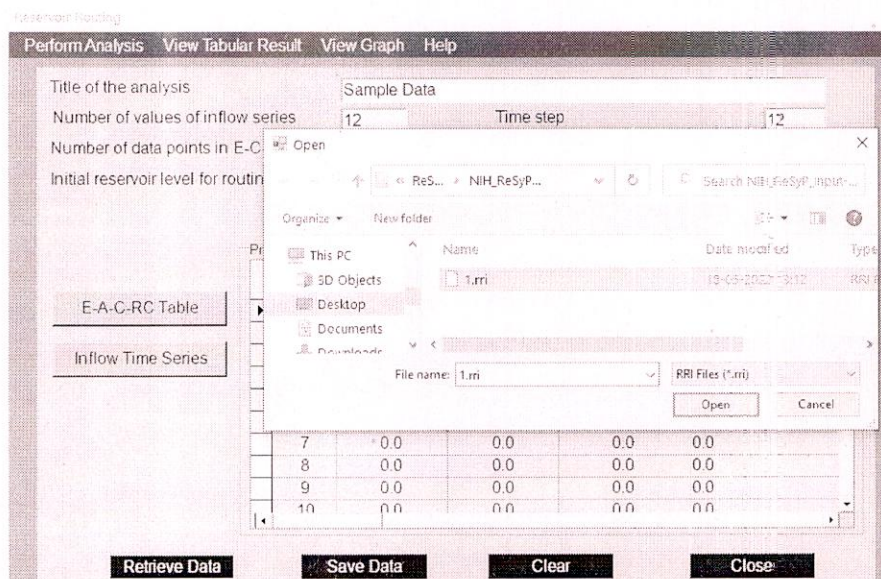
4.3. Steps of Analysis

Following steps are used for Reservoir Routing module:

- Select the **Reservoir Routing** module. The module will open along with the form for entry of general data and tabular data.



- Either retrieve an already existing data file by clicking on the **Retrieve Data** button or generate a new file by clearing the default data (by clicking on the **Clear** button) in the opening data form and fill all the data cells.



- After entry of all data cells in the general data section, click on the **E-A-C-RC Table** button. Depending on the options selected in the general data section, a form with empty cells for input of elevation, area, capacity, and release capacity values will appear. Fill all the values in the table in specified units.

- d) Next, click on the **Inflow Time Series** button. Depending on the options selected in the general data section, a form with empty cells for input of inflow hydrograph values will appear. Fill all the values in the table in specified units.

In all tabular data, it is also possible to **Copy-Paste** the data of all columns from MS-Excel. In that case, copy the data of all columns together from MS-Excel and bring the cursor to the first row in the table and press F1 (function key). Data will get pasted in all columns in the table. Check that data are present in all cells of the table.

- e) After entry of all data cells in the general data section and the tabular data, click on the **Save Data** button. A separate window for saving the data file will appear. First select the desired directory and then specify the desired filename for the data file. The file will be saved as **.rrr** file. There is no need to specify the extension in the filename. It will be automatically attached with the filename.
- f) Click on the **Perform Analysis** button which will open-up a form for the specification of input and output files before the execution of the related program. First click on the **Input File Name** cell and then click on the **Browse** button. This will open a window for selecting the input file. Go to the desired directory and select the requisite data file. Click on the **Open** button to select the file. The file along with the path will appear in the **Input File Name** cell. Next, click on the **Output File Name** cell and repeat above steps. The filename along with the path will appear in the **Output File Name** cell.

AC Table Inflow Estimation Reservoir Routing Reservoir Sedimentation Hydropower Analysis Conservation Operation Flood Operation

Reservoir Routing

Perform Analysis View Tabular Result View Graph Help

Title of the analysis Routing analysis for a dam

Number of values of inflow series 55 Time step 3

Number of data points in E-C-RC table 27 Gate Factor (0 - 1) 1

Initial reservoir level for routing (m) 328

E-A-C-RC Table

Inflow Time Series

Analyze

Input File Name (*.rrr) C:\Users\HP\Desktop\Desktop Browse

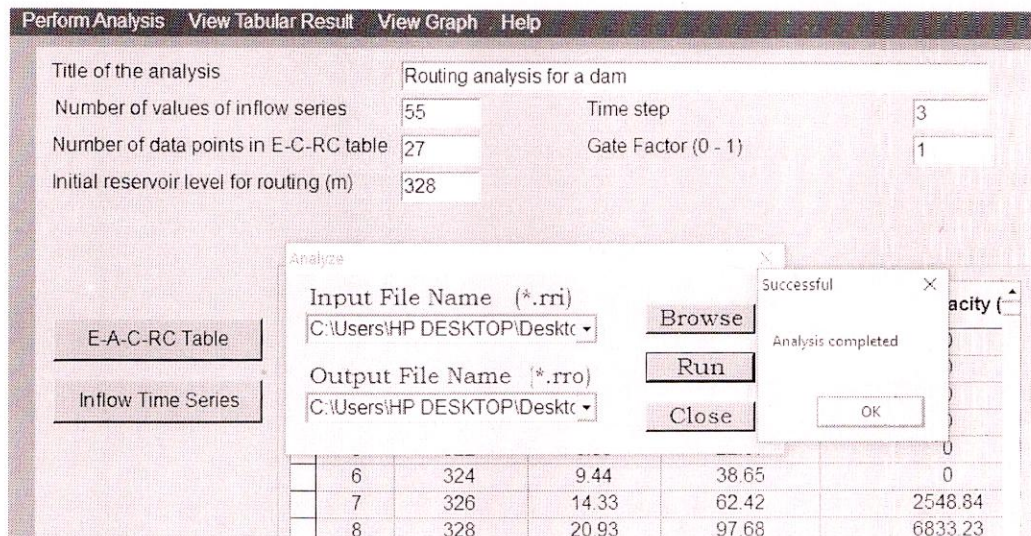
Output File Name (*.rrr) C:\Users\HP\Desktop\Desktop Run Close

	6	7	8	9	10
	324	326	328	330	332
	9.44	14.33	20.93	29.25	38.88
	38.65	62.42	97.68	147.86	215.97
	0	0	0	0	0
	0	2548.84	6833.23	11944.2	17578.75

Release Capacity (M)

Retrieve Data Save Data Clear Close

- g) After specifying the input and output filenames along with their location, the **Run** button gets **activated**. Click on the **Run** button to execute the related program with the specified input and output filenames. The program runs (in a window which closes automatically after the program execution is complete).



- h) Click on the **View Tabular Results** button. To view data/results in tabular form, click on the **Tabular** button which will invoke the **Notepad**. Click on the **File** and then **Open** and a window for file selection will appear. Go to the desired directory and select the requisite Input/Output filenames to see Input/Output files. It needs to be mentioned here that in this window, only files with extension **.rri** or **.rro** will be displayed. Select the desired filename and click on the **Open** button. The file will be displayed in the **Notepad**.

Reservoir Routing

Perform Analysis View Tabular Result View Graph Help

Tabular Data

File	Edit
338.750	102.900
339.000	105.170
339.250	107.440
339.500	109.710
339.750	111.980
340.000	114.250

***** Results *****

Results of Reservoir Routing

Time Hr.	Inflow Cumec	Outflow Cumec	Elevation m	Storage MCM
0	1408.000	1408.000	328.000	97.680
3	1811.000	1811.000	328.000	97.680
6	2214.000	2214.000	328.000	97.680
9	2778.500	2778.500	328.000	97.680
12	3343.000	3343.000	328.000	97.680
15	5360.000	5360.000	328.000	97.680
18	7377.000	7026.182	328.076	99.574
21	9393.000	7990.510	328.453	109.042
24	11409.000	9701.189	329.122	125.838
27	13560.000	11676.450	329.895	145.231
30	15713.000	13538.850	330.566	167.143
33	17214.000	15344.580	331.207	188.978
36	18715.000	16962.160	331.782	208.538
39	20566.500	18416.800	332.279	229.612

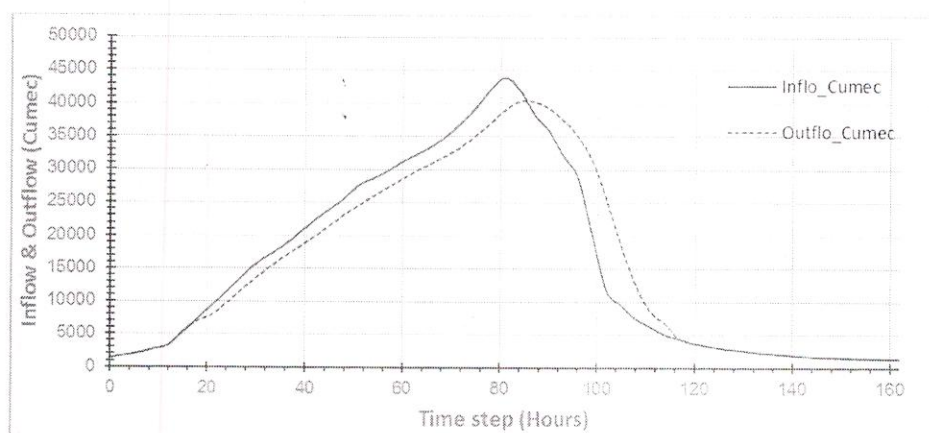
- i) To view the results in graphical form, click on the **View Graphs** button. A window with two graphical options will invoke:
- Inflow and Outflow, and
 - Variation of reservoir elevation.

Select the desired option and then click on the **View** button. The corresponding graph will be displayed which can be copy-pasted in a document.

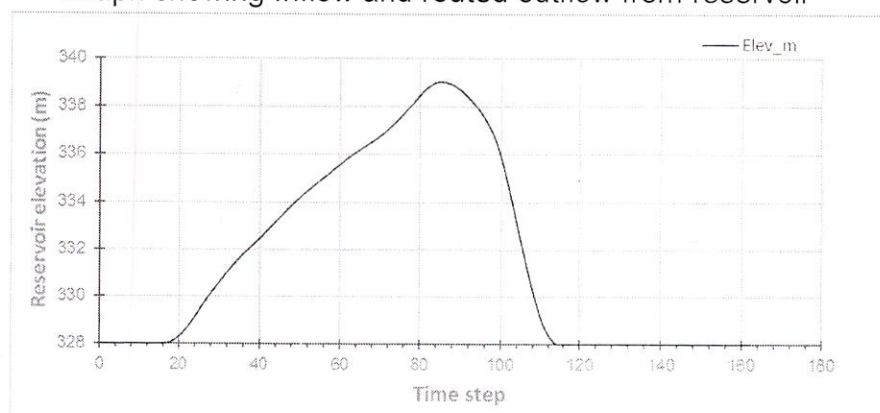
- j) It is also possible to prepare the graphs in MS-Excel with specific requirements. For this purpose, ready-made graphs have been prepared in MS-Excel which can be modified. Open the graphical file (*.rrg) in MS-Excel as **"Delimited"** file with **"Space"** delimiters and with column data format as **"General"**. The file will open in a separate MS-Excel sheet. Select and copy the whole worksheet and paste it in **"Input"** worksheet of **"RR_Graph.xlsx"** file of MS-Excel which is already built in. Two graphs are generated:

- Inflow and Outflow,
- Variation of reservoir elevation, Variation of reservoir storage.

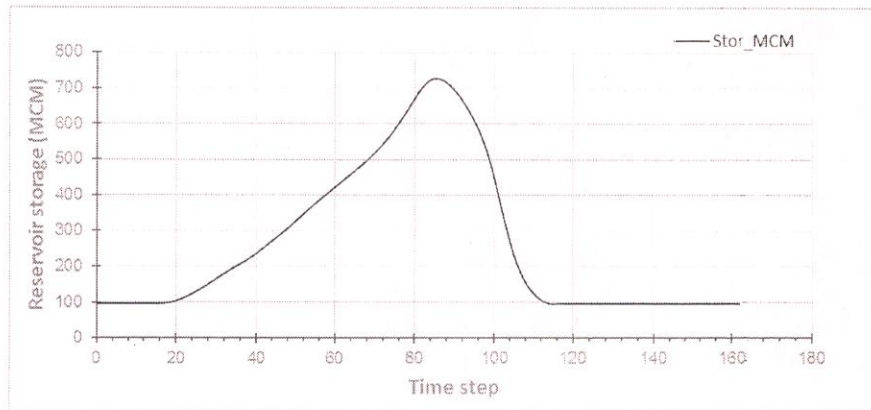
Graphs can be copied and pasted as a picture anywhere in a document. The three graphs for the sample analysis are shown in Figures.



Graph showing Inflow and routed outflow from reservoir



Graph showing variation of reservoir elevation with time



Graph showing variation of reservoir storage with time

- k) Close the **Reservoir Routing** module by clicking on the **Close** button.