ASSOCIATED ATTACHMENTS/ENCLOSURES:

Attachment 02.04.03-8B: SOCH Version 1 SDD, Rev. 0

(12 Pages including Cover Sheet)

L58 090528 003

Tennessee Valley Authority

SOFTWARE DESIGN DOCUMENT

(SDD)

Simulated Open Channel Hydraulics (SOCH)

Version 1.0

	R0	R1	R2	R3
Prepared	Helder de Almeida			
	[signature]			
Reviewed	Angelos Findikakis			
	[signature]			
Approved	K.R. Spates			
	[signature]			
Issue Date	5-28-09			

	REVISION LOG	
Revision Number	**Description of Revision**	**Date Approved**
0	Initial Issue for SOCH Version 1.0.	

TABLE OF CONTENTS

SYMBOLS & ABBREVIATIONS

A	area
B	storage width
cfs	cubic feet per second
ft	feet
ft^2	square feet
$R^{2/3}$	hydraulic radius to the power of two thirds

ACRONYMS

ANSI	American National Standards Institute
SDD	Software Design Description
TVA	Tennessee Valley Authority

1. INTRODUCTION

The computer program Simulated Open Channel Hydraulics (SOCH) is used for flood routing calculations in the Tennessee River basin. In addition to this code, TVA has developed seven auxiliary programs to prepare the required inputs to SOCH. These computer programs are used to meet United States Nuclear Regulatory Commission guidance set forth in Nuclear Regulatory Guide 1.59 (American National Standards Institute [ANSI] ANSI/ANS-2.8-1992) and the requirements of TVA SPP-2.6, Computer Software Control (Reference 1).

This Software Design Description (SDD) document presents a general overview of SOCH and discusses how the SOCH code meets the requirements of Reference 3, SOCH Software Requirements Specification (SRS).

SOCH requires several blocks of input data, which can be prepared using a suite of computer programs. Seven auxiliary codes, UNITGRPH, FLDHYDRO, TRBROUTE, CHANROUT, DBREACH, CONVEY, and WWIDTH, prepare the required input data to SOCH.

Table 1 gives a brief description of the seven codes used together with SOCH. These computer programs are used to meet United States Nuclear Regulatory Commission guidance set forth in Nuclear Regulatory Guide 1.59 (American National Standards Institute [ANSI] ANSI/ANS-2.8-1992) and TVA SPP-2.6, R12, Computer Software Control.

Table 1. Summary of TVA's flood analysis codes

Computer Code	Description
UNITGRPH	Computes unit hydrographs from historical flood data.
FLDHYDRO	Determines inflows from unit hydrographs and rainfall.
TRBROUTE	Routes hydrographs from one point to another using different routing procedures (channel & reservoir).
CHANROUT	Determines channel routing method coefficients.
DBREACH	Determines time of failure of an overtopped earth embankment based on soil type and time and depth of overtopping during a flood.
WWIDTH	Determines equivalent weighted width (B) to account for reservoir volume in SOCH geometry.
CONVEY	Determines cross sectional area (A) and composite conveyance for SOCH geometry.
SOCH	One dimensional unsteady flow model that computes elevation, discharge, and average velocity at selected locations.

Figure 1 illustrates the sequence of use of the codes described in Table 1.

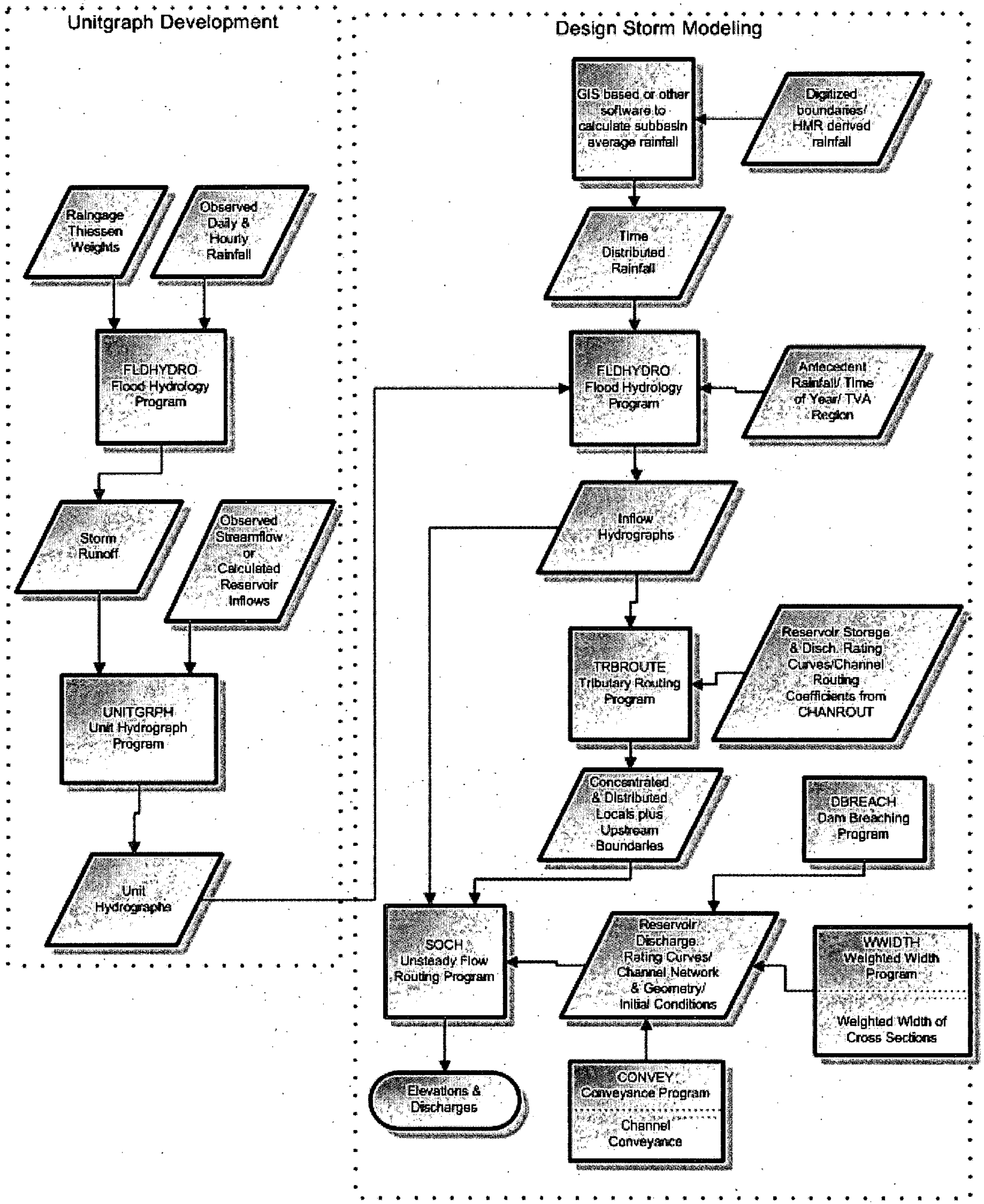

Figure 1. TVA's flood analysis computer codes

2. OVERVIEW OF DESIGN AND THEORETICAL BASIS

SOCH is designed to simulate one-dimensional unsteady flow in open channels. For this purpose, it solves the Saint-Venant equations of continuity and momentum for one-dimensional, unsteady flow in open channels. The independent variables in the equations are the flow depth, h, and the velocity, V. The dependent variables are the distance along the channel, x, and time, t. The flow depth, h, and velocity, V, therefore vary only with the longitudinal (x) direction and time, t.

As a consequence of the one-dimensional flow assumption the following simplifications are introduced:

1. The velocity is uniform across each cross section.
2. The transverse water surface is horizontal at any cross section.
3. The axis of the river is a straight line.

In the development of the mathematical model, the following assumptions are also made:

1. The flow is gradually varied so that the vertical acceleration of the water may be neglected, and therefore the pressure distribution in any cross section is hydrostatic.
2. The bottom slope of the channel is small. This implies that sin $\alpha \sim$ tan α and cos $\alpha \sim 1$, where α is the angle between the channel bottom and the horizontal.
3. The resistance coefficient, as determined for uniform turbulent flow at any given channel cross section, is the same for the given water surface elevation and mean velocity regardless of whether the flow is uniform or non-uniform, steady or unsteady.
4. The mass density, ρ, is a constant, i.e., no density stratification exists.

SOCH solves the St. Venant equations of unsteady flow in open channels, (the continuity equation and the momentum equation), expressed in the following form:

$$\frac{\partial(AV)}{\partial x} + B\frac{\partial h}{\partial t} - q = 0 \qquad \text{Continuity} \qquad (1)$$

$$g\frac{\partial h}{\partial x} + V\frac{\partial V}{\partial x} + \frac{\partial V}{\partial t} + gS_f + V\frac{q}{A} = 0 \qquad \text{Momentum} \qquad (2)$$

where:

A = flow area in ft^2;
V = mean velocity in ft/s;
x = distance in feet;
B = water-surface width in feet;
h = water surface elevation in feet;
t = time in seconds;
q = lateral local inflow per unit distance;
g = the gravitational constant (ft/s^2); and
S_f = the energy gradient given by the Manning's equation (ft/ft):

$$S_f = \frac{n^2 V|V|}{2.21\ R^{4/3}} \tag{3}$$

where:

n = Manning's n; and
R = the hydraulic radius in feet and R = A/P, where A is the flow area in ft^2
P = the wetted perimeter in feet.

Units in this manual are U. S. Standard units (pounds, feet, and seconds). Since SOCH is coded with dimensional constants that are applicable only to U. S. Standard units, correct results are not achieved with SI units.

SOCH implements an explicit finite-difference scheme in the solution of the St. Venant equations using the leap-frog method which employs a staggered time-distance grid and centered differences in space and time to compute the spatial and temporal derivatives in the equations of continuity and momentum. The variables at a spatial position x and for time t +Δt are computed with data at time t and time t-Δt. The staggered grid used in the leap-frog method as programmed in SOCH requires that the number of cross-sections in each channel reach be an odd number. SOCH thus computes water-surface elevations, discharges, and velocities, along the river or reservoir at the specified grid points in space (the cross-sections) at time t +Δt using the known conditions at time t and time t-Δt and the geometric parameters at each cross-section as read in from the SOCH input geometry files.

2.1 Limitations

The use of SOCH is subject to the following limitations.

1. SOCH is restricted to computations in the U. S. Standard system of units. It will not function in the SI system because there are dimensional coefficients hardwired in the code that work only in the U. S. Standard system of units. The dimensions of the input variables as discussed in Section 3 must correspond to those specified in this manual
2. The time step used in SOCH should be selected as close to the limit of numerical stability as practicable in order to obtain an accurate solution. The numerical stability criterion is discussed in Section 2.2.2 of the SOCH User's manual (Reference 2). In setting up SOCH particular attention must be given to the spacing of the cross-sections defining the channel geometry, especially at the location of boundary conditions to assure that inaccuracies are not introduced by the boundary conditions themselves.
3. There must be an odd number of cross-sections in each channel reach used in SOCH.
4. SOCH will not propagate flood waves into channels with initially low flows or low water depths in the channel. This is a limitation of the explicit finite difference scheme used in SOCH. How low a flow or depth can be used depends on the channel or reservoir slope, cross-section geometry, cross-section spacing (Δx), and time step (Δt). A trial and error process may be necessary to establish initial depths and flow that will provide a stable and accurate solution.
5. The initial condition generator for SOCH does not generate a solution to the steady-state condition for a given flow rate, but rather an initial starting condition which eliminates the need for the user to estimate the initial elevation and flow at each

cross section. Therefore, a warm-up period is required to dampen out false transients caused by the initial condition generator and to establish a truly steady-state initial condition for the model. It is noted that TVA practice requires a warm-up period for SOCH regardless of the source of the initial conditions so that this is not a restrictive limitation. The length of this warm-up period can be easily determined by the user by observing the computed profile in the model over the last several time steps of the warm-up period prior to the actual simulation period ensuring that very little or no change is occurring in the computed elevation and flow at each cross section.

6. SOCH prints the name of the geometry input file used in each run rather than printing an "echo check" of the input geometry file. SOCH does not produce an echo check of the channel geometry data. The user must verify that the data in this file have been entered correctly and they conform to the FORTRAN format specification for each piece of data. Since the column positions of each value in the input data files must be correct, the user is responsible for ensuring that problems associated with stability, accuracy and calibration are not due to incorrect input data.

7. Since a direct check of the interpolated sections is not possible because SOCH does not print out the geometric data of the channel sections, the user should exercise caution in the utilization of the SOCH interpolation feature. The most common interpolation approach utilized is the interpolation of a new section between each of the original sections in the reach. For this approach, the SOCH interpolation feature provides an intermediate section consistent with the expected transition section between the two original sections. If alternate methodologies (such as interpolation between separate and distinct sections) are utilized, the user should carefully examine the SOCH results for anomalous conditions. A potential source of an observed anomaly is the number and location of sections interpolated.

8. SOCH does not specifically warn the user for any type of abnormal input.

3. INPUT AND OUTPUT FEATURES

By default, SOCH uses two main user-specified input files for all the required data input, Unit 3 and Unit 5, for geometry parameters and all others, respectively. Optionally, some input data can be specified in separate input files, Unit 1, Unit 8 and Unit 9, for initial conditions, local inflows and upstream boundary inputs, respectively.

By default, a given SOCH simulation produces three output files Unit 4, Unit 6 and the file ".run" with no assigned Unit, for the downstream most node discharge hydrograph, general output, and name and path of all the files used, respectively.

SOCH input and output files are associated with specific Unit numbers in the standard FORTRAN language terminology, except the file with the extension ".run".

3.1 Input Features

To obtain the SOCH solution for a reservoir system, a sequence of SOCH datasets are needed to complete each particular simulation. Typically, each dataset specifies a change in dam operating rules and conditions that can't be accomplished within one dataset for the entire system throughout the entire duration of a given event. The overall sequence of the preparation of the input data to run SOCH is illustrated in Figure 1.

The SOCH code requires the following input files:

- ".sln" – This file (Unit 1) specifies the initial conditions of the system to be modeled. It can contain stages, discharges or both for the downstream most node or every node in the system. (optional separate file)
- ".geo" – SOCH input channel geometry parameters are read from files with this extension (Unit 3). The geometry is tabulated by Area, $R^{2/3}$ and Storage Width as a function of the elevation.
- ".dat" – SOCH input data are read from files with this extension (Unit 5). The overall input data required, except for the channel geometry, are included in the ".dat" file. There are options that allow a separation of the data in the ".dat" file throughout other independent input units.
- ".loc" – This file (Unit 8) specifies the local point source or distributed local inflows to be included in a given simulation. The requirement to specify local inflows in this input file is that a constant time interval must be used. (optional separate file)
- ".bnd" – This file (Unit 9) specifies the upstream boundaries to be included in a given simulation. The hydrographs can be specified in the same way as in Unit 5 and the time interval can be constant or variable. (optional separate file)

The data needed to run SOCH, their format and the structure of the input files are described in detail in Section 3 of the SOCH User's manual (Reference 2).

3.2 Output Features

The output produced by the SOCH model at every node is specified at selected time intervals. Output from SOCH is saved in files with the following extensions:

- "**.out**" - SOCH output listing is written to files with this extension, which includes the resulting flows, average velocities, and water surface elevations. This file contains all the "echoed" input except the geometry parameters from the ".geo" file. Similarly, it does not contain the geometry parameters for interpolated cross sections, in case cross section interpolation is used.
- "**.sto**" - The discharge hydrograph at the downstream most node is saved in a separate file with this extension and in the end of the ".out" file. There is no option to eliminate the redundancy.
- ".sav" - Ending lines are saved to files with this extension (optional separate file)
- "**.run**" - Name and path to all the input/output files used in a given run.
- ".prt" - Stage and flow hydrographs at specific locations at the specified output print interval (optional separate file)

The results at the nodes are grouped by channels (in proper sequence) and show: River Mile (mi), stage (ft) , discharge (cfs) , velocity (ft/s) , flow area (ft^2) , storage width (ft), R $^{2/3}$, Manning's n assigned to this node, local inflow (cfs), depth (ft), and Froude number (non-dimensional). Example output files are presented in Reference 2.

A tabulation of maximum elevation, discharge, and velocity at all nodes, with the exact time and day of occurrence follows the computation. It can be used to plot envelope maximum profiles of these three variables along the extension of the channels/reservoirs.

4. REFERENCES

1. TVA: SPP-2.6, Computer Software Control.
2. TVA, 2009: SOCH User's Manual (EDMS No. L58090528002)
3. TVA, 2009: SOCH Software Requirements Specification (SRS) (EDMS No.L58090528001)