OPEN CHANNEL OVERFLOW DIVERSION STRUCTURES WITH SIDE WEIRS

By

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ABSTRACT

Combined sewer systems are designed to bypass excess flows directly to the receiving water during rainstorm events. This is commonly achieved by means of diversion structures incorporating side spillways, oblique weirs or orifices.

The simulation of diversion devices by the EXTRAN Block of the Stormwater Management Model is examined. Results for the weir algorithm were not satisfactory. Therefore, a new procedure is written to compute the overflow and the water surface profile along the side weir. The hydraulics of flow over side weirs is reviewed in detail. The momentum approach is used in computing the water surface profile. The coefficient of discharge is estimated from a newly proposed relationship. A method for predicting the formation of a hydraulic jump along the weir section is derived from the momentum balance between the upstream and downstream side of the jump.

A computer program called OVRFLO3 is developed to compute the overflow and the water surface profile. Validation tests show good agreement with observations.

Finally, OVRFLO3 is adjusted to fit the SWMM package. The new Block is called SIDWEIR.

ACKNOWLEDGEMENTS

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NOTATION

A = cross sectional area of flow (m^2 or ft^2)

A_o = cross sectional area of orifice (m^2 or ft^2)

a = weir exponent; 3/2 for transverse weirs and 5/3 for side weirs

ALPHA = velocity distribution correction factor

B = width of channel (m or ft)

B_w = width of channel at weir crest level (m or ft)

BETA = momentum distribution correction factor

C = discharge coefficient of side weir by Ackers

C_o = discharge coefficient of orifice

C_M = DeMarchi discharge coefficient of side weir

C_w = discharge coefficient of side or transverse weirs

c = height of weir crest above channel bed (m or ft)

D = pipe or sewer diameter (m or ft)

d = depth of flow in main channel (m or ft)

d_c = critical depth of flow (m or ft)

d_{c1} = critical depth of flow at the upstream end of side weir (m or ft)

d_h = hydraulic depth of flow (m or ft)

d_n = normal depth of flow (m or ft)

d_{n1} = normal depth of flow at the upstream end of side weir (m or ft)

d_{n4} = normal depth of flow at the downstream end of side weir (m or ft)

d_1 = depth of flow at upstream end of side weir (m or ft)

d_{1c} = initial value of critical depth (m or ft)

d_{1n} = initial value of normal depth (m or ft)

d_4 = depth of flow at downstream end of side weir (m or ft)

d_5 = depth of flow at upstream end of hydraulic jump (m or ft)

d_6 = depth of flow at downstream end of hydraulic jump (m or ft)

$\bar{d}_5$ = vertical distance from water surface to centroid of section 5 (m or ft)

$\bar{d}_6$ = vertical distance from water surface to centroid of section 6

d_o = pipe or sewer diameter in Chow's Tables (m or ft)

dB/dx = rate of change of channel width along side weir

dQ/dx = rate of change of main channel flow along side weir (m^2/sec or ft^2/sec)

E_s = specific energy of flow (m or ft)

E_w = total energy of flow referred to weir crest (m or ft)

EPSI = pressure distribution correction factor

F = Froude Number

F_f = friction force in a short length of channel (Kg or lb)

F_1 = Froude Number at upstream end of side weir

G_1 = dimensionless term in Eq.(4.1)

g = gravitational acceleration (9.81 m/sec^2 or 32.2 ft/sec^2)

H = total energy of flow (m or ft)

h_1 = depth of flow over side weir at upstream end (m or ft)

h_2 = depth of flow over side weir at downstream end (m or ft)

h_L = head loss in sewer or channel (m or ft)

L = length of side weir (m or ft)

L_f = length of free surface flow in pipe (m or ft)

L_j = length of hydraulic jump (m or ft)

L_{max} = maximum length of side weir (m or ft)

N = parameter; 1.0 for metric units and 1.486 for english units

n = Manning's roughness coefficient

P_a = hydrostatic pressure force acting on section a(Kg or lb)

P_b = hydrostatic pressure force acting on section b(Kg or lb)

PHI = dimensionless function in depth of flow along side weir

Q = discharge in main channel (m^3/sec or ft^3/sec)

Q_o = discharge in main channel upstream of side weir (m^3/sec or ft^3/sec)

Q_r = discharge in main channel downstream of side weir (m^3/sec or ft^3/sec)

Q_s = discharge over side weir (m^3/sec or ft^3/sec)

Q_{sj} = discharge over side weir from hydraulic jump (m^3/sec or ft^3/sec)

Q_5 = discharge at section 5 (m^3/sec or ft^3/sec)

Q_6 = discharge at section 6 (m^3/sec or ft^3/sec)

q = discharge per unit length of weir (m^2/sec or ft^2/sec)

R = hydraulic radius (m or ft)

S_d = bed slope of downstream channel

S_f = slope of friction line (m/m or ft/ft)

S_o = bed slope of main channel

T = water surface width (m or ft)

THETA = angle between channel bed and horizontal

U = longitudinal component of velocity of spill flow (m/sec or ft/sec)

V = mean velocity in main channel (m/sec or ft/sec)

V_1 = mean velocity at upstream end of side weir (m/sec or ft/sec)

V_2 = mean velocity at downstream end of side weir (m/sec or ft/sec)

V_5 = mean velocity at section 5 (m/sec or ft/sec)

V_6 = mean velocity at section 6 (m/sec or ft/sec)

W = parameter; 1 for one side weir and 2 for two side weirs

x = distance measured along side weir (m or ft)

y_c = critical depth of flow in Chow's Tables (m or ft)

Z = height of channel bed above datum (m or ft)

Z_c = critical section factor ($m^{2.5}$ or $ft^{2.5}$)

Z_f = section factor ($m^{2.5}$ or $ft^{2.5}$)

Z_s = square of section factor (m^5 or ft^5)

z = side slope of trapezoidal section (1 vertical to z horizontal)

CHAPTER I

INTRODUCTION

1.1 Appurtenances of a Sewer System

1.1.1 Introduction

Sewer Systems are essential to public health and welfare in all areas of concentrated population and development. Every community produces wastewater and is subject to stormwater runoff. Separate sanitary sewers are provided primarily to carry wastewater to a point of treatment, or sometimes to an outfall in a receiving water. Stormwater sewers conduct runoff to the nearest outfall, all in sufficient time to avoid damage and inconvenience. The combined sewer is a conduit that receives both wastewater and stormwater, at least under conditions of high runoff. Certain appurtenances are essential to the proper functioning of every system of storm or combined sewers. These include manholes, terminal cleanouts, service connections, inverted siphons, inlets, catch basins, junction chambers, outfalls tide gates, overflow and diversion structures.

1.1.2 Definition of Terms

The following terms referred to in this dissertation are important.

Sewer	A pipe or conduit that carries wastewater.
Wastewater	The spent water of a community, including domestic, industrial, commercial and human wastewater.

Sanitary sewer : A sewer that carries liquid and water carried wastes from residences, commercial buildings, and industrial plants together with minor quantities of storm, surface and infiltrated groundwater.

Storm sewer : A sewer that carries storm runoff and surfacewater but excludes domestic wastewater.

Combined sewer : A sewer receiving both wastewater and stormwater.

Relief sewer : A sewer built to carry away flows in excess of the capacity of an existing sewer.

Outfall sewer : A sewer that receives wastewater from a treatment plant (or collecting system) and carries it to a point of final discharge.

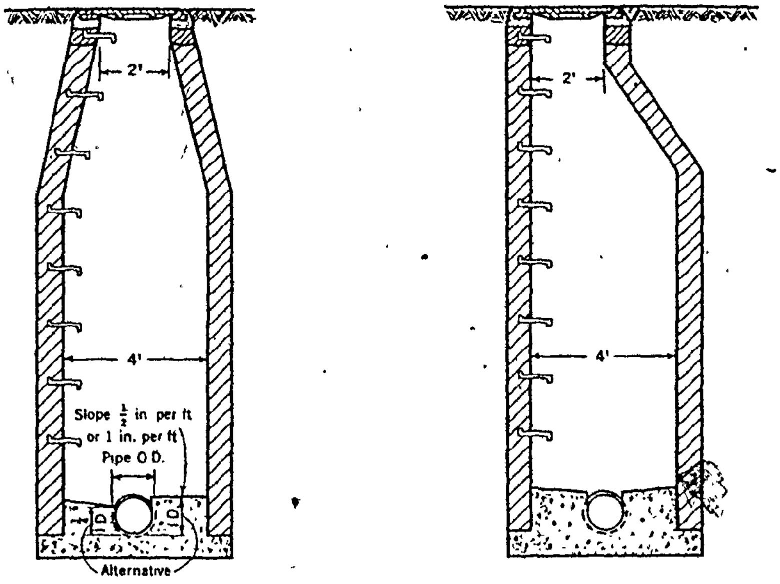
CBD : Central Business District
CCB : Chedoke Creek Basin
CSO : Combined Sewer Outfall
DS : Diversion Structure
RCB : Redhill Creek Basin
STP : Sewage Treatment Plant

1.1.3 Elements of a Sewer System

For completeness, various elements of a sewer system are described here. Not all of these structures need to be explicity modelled in a computer program to simulate an urban diversion system.

a- Manholes

A manhole is a structure which provides convenient access to the sewer for observation and maintenance operations. Most manholes are circular with a minimum inside diameter of 4 ft, being maintained up to a conical section a short distance below the top as shown in Fig. (1.1a) and Fig. (1.1b).



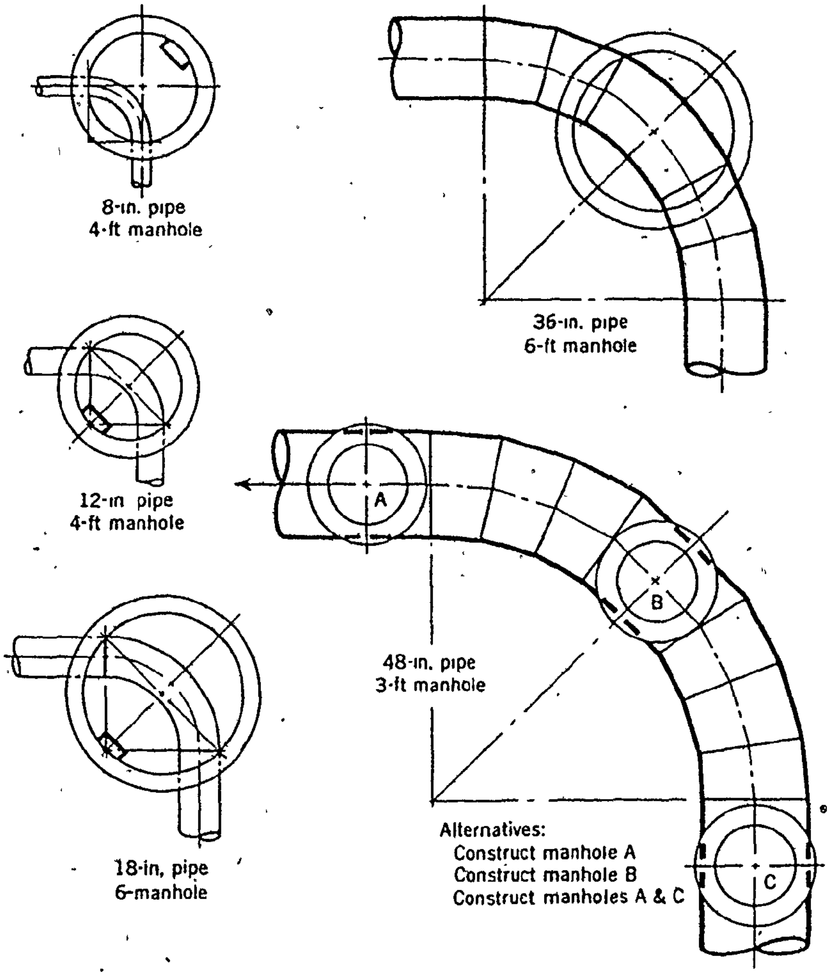
(a) (b)

(Source : Design and Construction of Sanitary and Storm Sewers, ASCE and WPCF, 1969)

Fig. (1.1)-Manholes

b- Bends

Particular care must be taken in construction of curved channels to accomodate bends. Some authorities recommend that the radius of the centre-line be three times the pipe diameter. Fig. (1.2) shows some of the possible designs for manholes on bends although it is not essential that each bend be completed within a manhole.



(Source : Design and Construction of Sanitary and Storm Sewers, ASCE and WPCF, 1969)

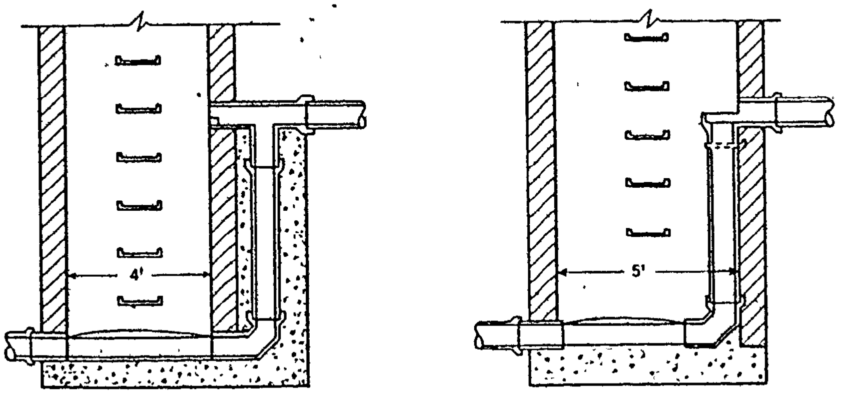
Fig. (1.2)-Manhole Placement for Various Types of Bends

c- Junctions

On small sewers junctions are made in ordinary manholes, the branch line being curved into the main channel. Excessive widening of the main channel at the branch line should be avoided. The invert of the branch line should be higher than the invert of the main channel where the two join.

d- Drop Manholes

If an incoming sewer is considerably higher than the outgoing sewer, a drop manhole should be constructed. Fig. (1.3a) shows a common but unsafe type. If the drop pipe blocks, flow spills out from the end of the pipe making the manhole dangerous for workmen. Fig. (1.3b) shows a better design where any stoppage in the drop pipe can be removed easily from the surface.



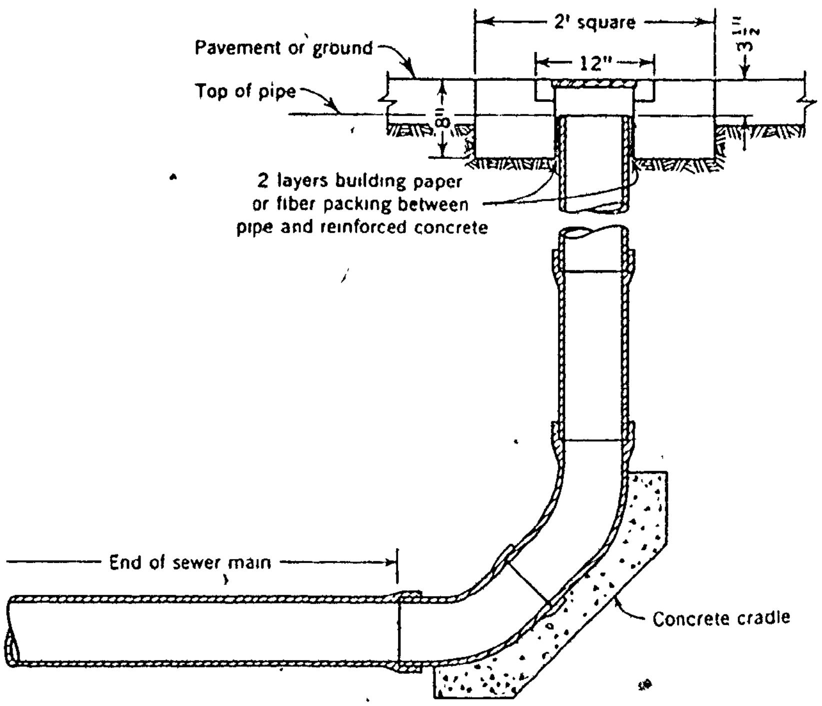
(a) (b)

(Source: Design and Construction of Sanitary and Storm Sewers, ASCE and WPCF, 1969)

Fig. (1.3)-Drop Manholes

e- Terminal Cleanout Structures

These are used at the ends of sewers. Their purpose is to provide a means for inserting cleaning tools, or an inspection light into the sewer as shown in Fig. (1.4).



Note:
Cleanout line to be of the same diameter and material as sewer main

(Source: Design and Construction of Sanitary and Storm Sewers, ASCE and WPCF, 1969)

Fig. (1.4)-Terminal Cleanout Structures

f- Check Valves and Relief Overflows

Where the floor of a building is at an elevation lower than the top of the next upstream manhole on the sewer system, a stoppage in the main sewer can cause sewage to backflow into the building. This is a common problem with basements in Ontario. Double check valves may be specified for such cases although they frequently do not remain effective over a long period of time. Where overflow must occur from a manhole in the street at a designated point, a relief device may be installed that encases a ball resting on a seat to close the end of a vertical riser but constructed so that the ball will rise and allow backflowing sewage to escape.

g- Stormwater Inlets

(1) Curb inlets have a vertical opening in the curb piece through which the gutter flow passes. They are called deflectors when equipped with diagonal notches cast into the gutter. The cross slope of the inlet is 1 in/ft to a distance of 3 ft from the curb line.

(2) A gutter inlet is a horizontal opening in the gutter covered by one or more grates through which the gutter flow passes.

(3) A curb and a gutter inlet acting as a unit is known as a combination inlet. A multiple inlet is made up of two closely spaced inlets acting as a unit. Fig. (1.5) shows different types of inlets.

h- Catch Basins

A catch basin is a form of grit chamber intended to retain the heavy debris which otherwise would be carried on into the sewer. It is usually cleaned at various intervals between storms.

i- Side-Overflow Weirs

Side overflow weirs are among the devices used for regulation of flow on combined sewers. There are several primary objectives which should be considered in the design of overflow structures. These include:

(1) The weir should not operate until a certain dilution is reached, preferably at least six times dry-weather flow.

(2) The weir should be of sufficient capacity to avoid creating any obstruction to the free flow of stormwater through the incoming sewers.

(3) During storm times the flow continuning on to the STP should not exceed the downstream sewer capacity, e.g., not greater than the minimum dilution above.

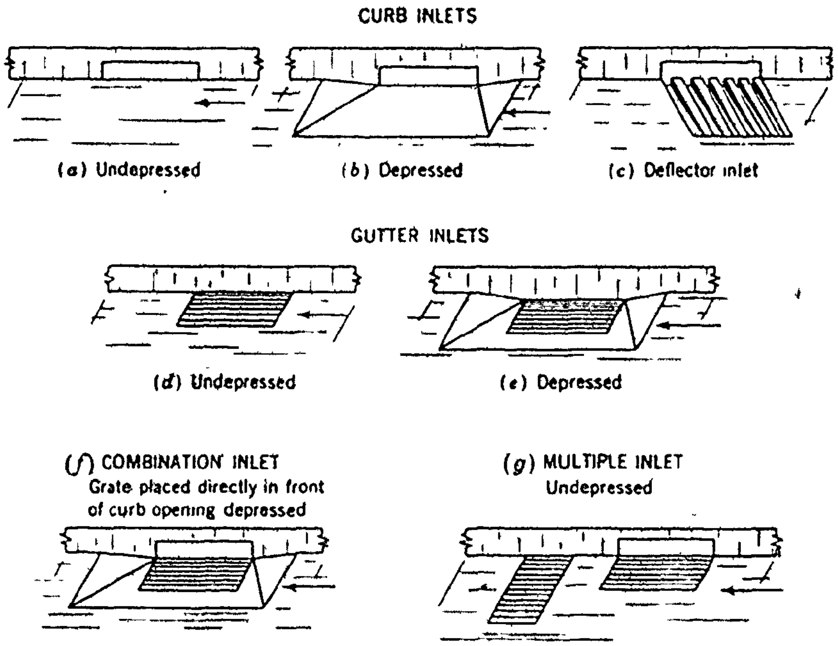
(4) The overflow device should achieve some measure of control, the worse pollutant load proceeding for treatment and the least objectionable being by-passed.

(5) The manhole and adjacent sewers must be entirely self-cleansing under all conditions.

Side weirs are constructed along one or both sides of the combined sewer. They divert excess flows during storm periods to the receiving waters or natural drainage courses. The crest of the weir is set at an elevation corresponding to the desired flow in the sewer. Fig.(1.6) illustrates the operation of a diversion (overflow) structure.

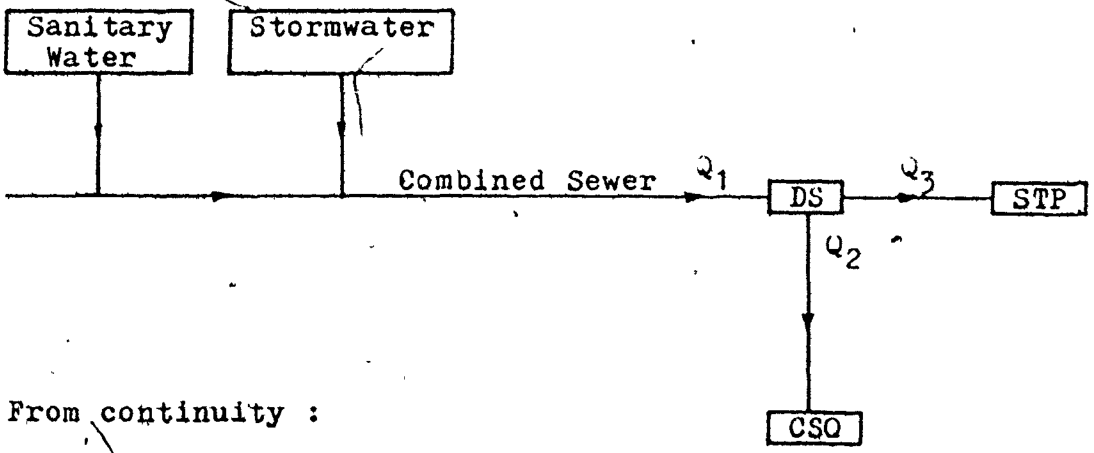
j- <u>Others</u>

Some other appurtenances and special structures used in a sanitary or stormwater system include house connections, siphons, overflow devices other than side weirs, backwater gates and outfalls.



(Source : Design and Construction of Sanitary and Storm ,Sewers, ASCE and WPCF, 1969)

Fig.(1.5)- Stormwater Inlets



From continuity :

$Q_1=Q_2+Q_3$

(a) Dry Weather Flow Condition : $Q_2 = 0$, $Q_3 = Q_1$
(b) High Flow Condition : $Q_2 > 0$, (often $Q_3=0$, $Q_2=Q_1$)

Fig.(1.6)- Definition Sketch of the Study Problem

1.2 Study Problem

Clearly, the removal of excess water from the sewer network is important, and a widely used method is by means of side weirs. When the water level rises above the weir crest, flow is diverted from the channel. The side weir should be arranged such that dry weather flow proceeds to the STP, and in times of heavy rainfall most of the incoming flow passes over the weir to the CSO as shown on Fig. (1.6). The dangers of errors in the design of a side weir are obvious. In the case of open channels, overtopping will cause flooding and may, by scour, damage the channel. In sewers where side weirs are used to a great extent, surcharging of the downstream section can, and often does, occur, and the pressures so developed may cause damage to the sewer itself. A complete analytical solution of the equations governing the flow in side weir channels for an arbitrary DS geometry is not possible and, until quite recently, methods were based on empirical design data derived from experiments conducted over a limited range of the many variables involved.

However, relatively simple step computation procedures permit solutions for many shapes of cross section and for a wide range of variables. This does not imply that the underlying hydrodynamic equations of the problem have been rigorously solved. It is of great importance to explain flow behaviour in the region of the side weir and calculate diverted flow for the different possible flow states upstream and downstream. A suitable computer program that can handle the problem properly is vital to any drainage model. It is also of great importance to study computer models that are currently widely used and see how well they handle this problem. One such model is the Stormwater Management Model (SWMM) developed in 1971 and gradually improved by several programming groups in the United States with some contributions from Canada. Computer results should of course be compared with observed data and other previous work in order to determine the reliability of the new technique.

1.3 Scope of the Problem

Diversion structures are widely used in Hamilton, where an efficiently operating sewer system has been considered essential. The city is subject to short duration high intensity thunderstorms in summer time, long duration low intensity storms in fall, infrequent hurricanes and snow in winter. Hamilton consists of three major drainage sectors namely the CCB, the CBD and the RCB as shown in Fig. (1.7). The CCB drains into Cootes Paradise, whereas the RCB drains into Windermere Basin. The CBD, which includes the older part of the city, drains directly into Hamilton Harbour. There are about 30 large overflow chambers in the Chedoke, whereas in the CBD there almost 75 large chambers. Figs. (1.8) to (1.10) show some typical overflow chambers in Hamilton.

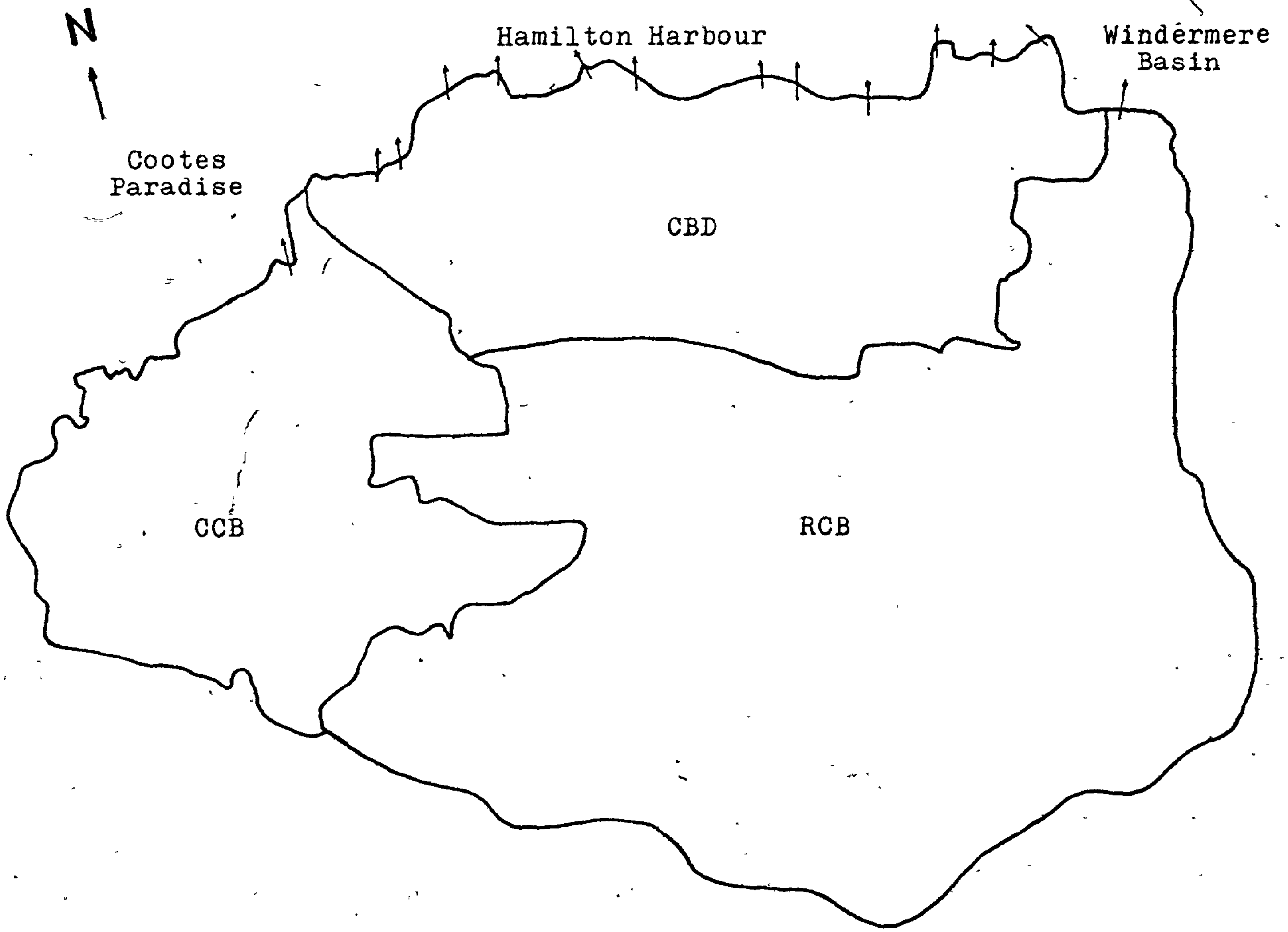
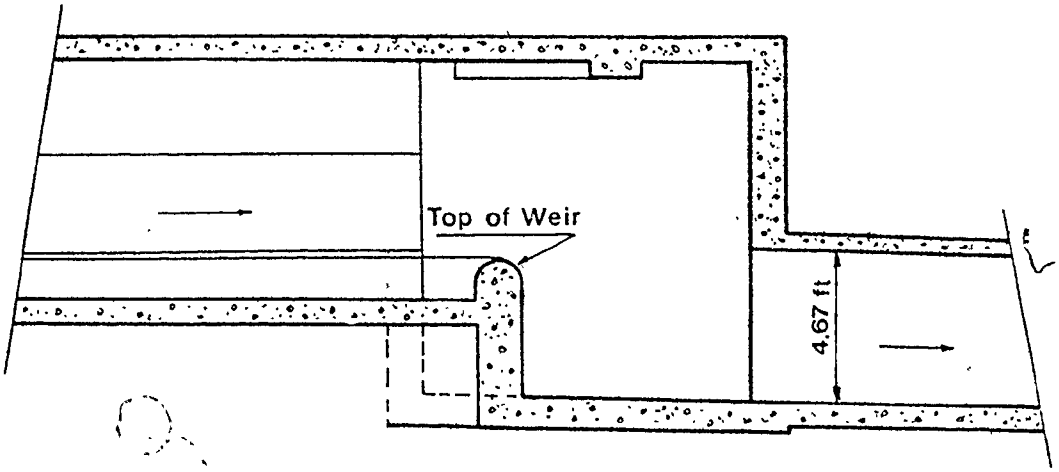
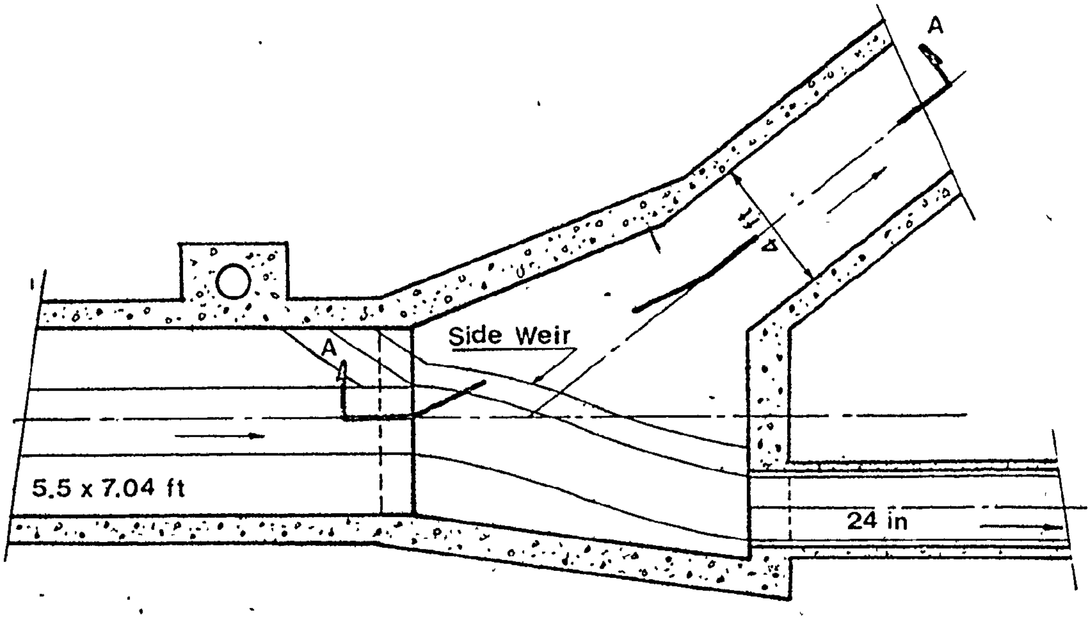


Fig.(1.7)- Major Drainage Sectors in the City of Hamilton



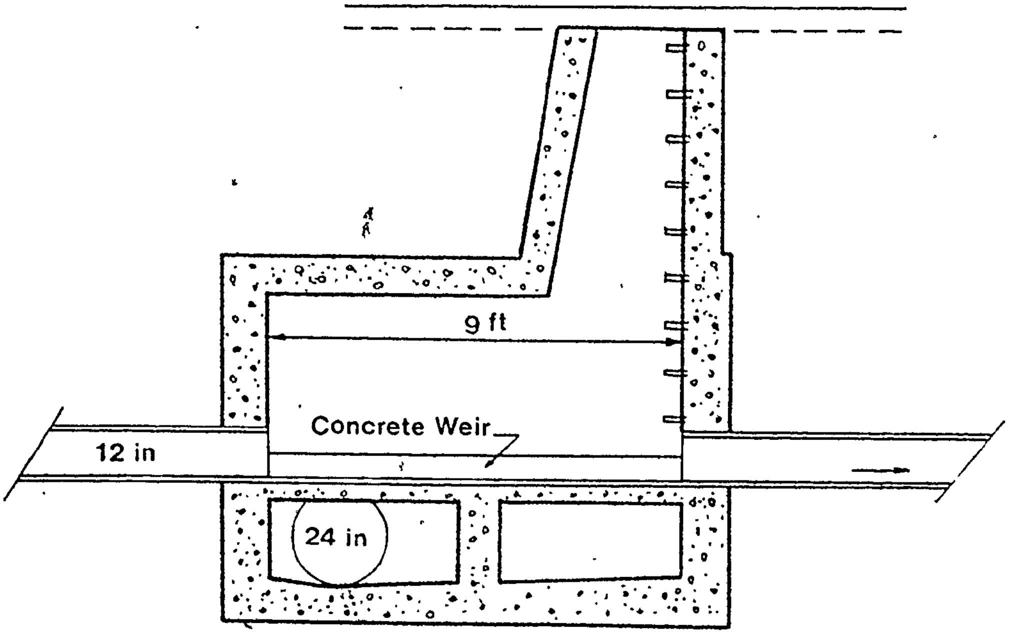
SEC. A_A



PLAN

(Source: Hamilton-Wentworth Regional Engineering Department)

Fig.(8.1) Details of Overflow Chamber on Sterling St. at STA 0+00



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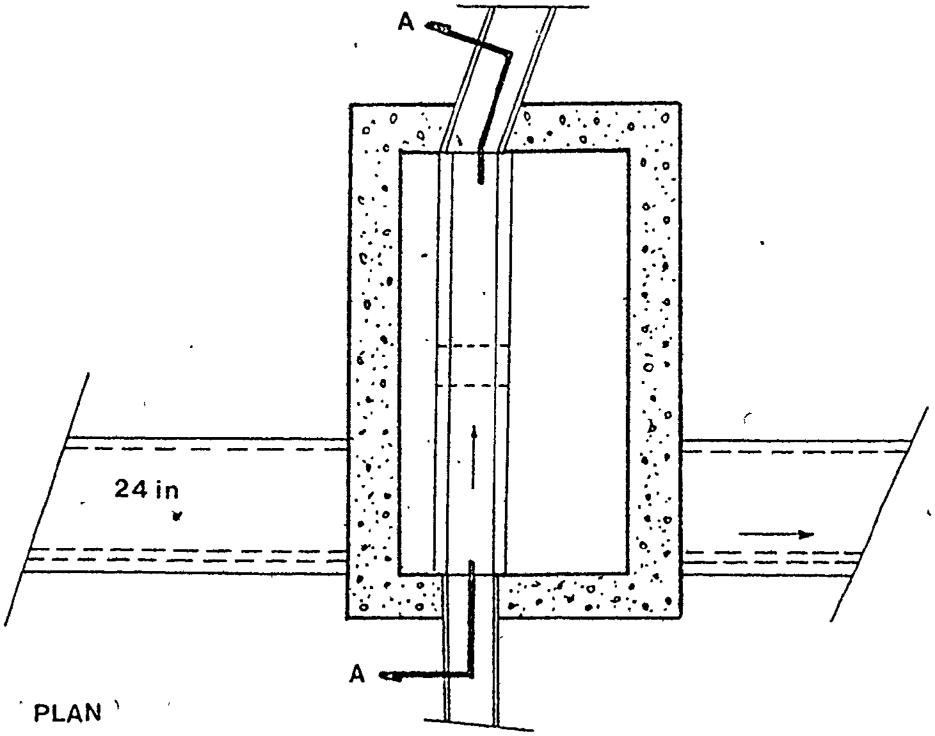
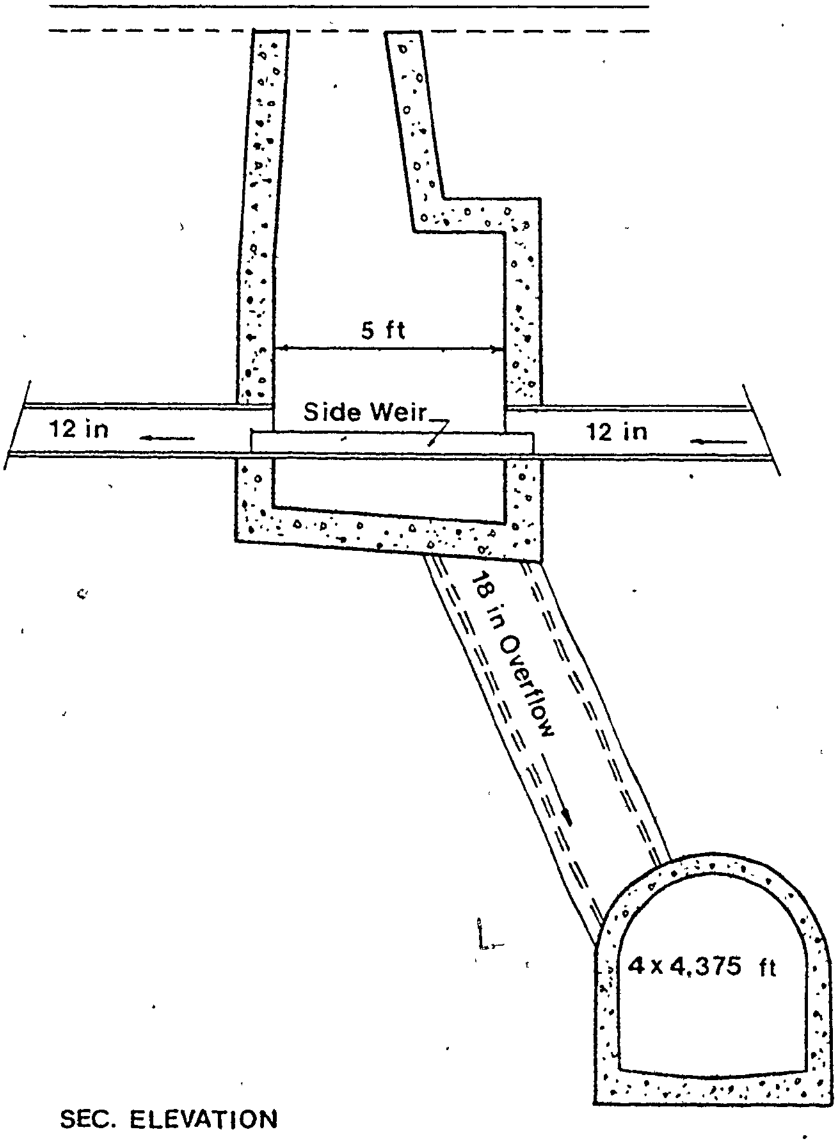


PLAN

(Source: Hamilton-Wentworth Regional Engineering Department)

Fig.(1.9) Details of Overflow Chamber on the Corner of Dunsmere Rd. and St. Clair Ave.



(Source: Hamilton-Wentworth Regional Engineering Department)

Fig.(1.10) Details of Overflow Chambers on Dunsmere Rd. from Connaught Ave. to Spadina Ave.

1.4 Purpose of the Study

This study is a part of a joint study implemented on the urban drainage system in the city of Hamilton by McMaster University, the Hamilton-Wentworth Regional Engineering Department and the Ontario Ministry of the Environment. The purpose of the present study is to formulate a model of the Hamilton urban drainage system in order to estimate annual loadings to the harbour receiving water of the different pollutants including suspended solids, BOD_5, Nitrogen, Phosphate and Coliforms.

The McMaster University group, headed by Dr. Wm. James, has covered several aspects of the problem. James and Robinson (1980) have recently examined the interactive design using microprocessors communicating with large scale batch-oriented packages at remote mainframes. James, Drake and Shtifter (1980) developed a kinematic storm model called THOR to produce rainfall hyetographs. El-Zawahry (1980) wrote an algorithm for sediment deposition and resuspension, and applied to the Chedoke Creek. Meanwhile, Shivalangaiah (1981) is using SWMM-STORAGE/TREATMENT Block to evaluate pollutional loads from stormwater and Henry (1981) is studying the feasible alternative solutions to the problem. Further publications on the project are also available (James, 20,21,22,23).

CHAPTER II

SIMULATION OF FLOW DIVERSIONS BY THE EXTRAN BLOCK (SWMM)

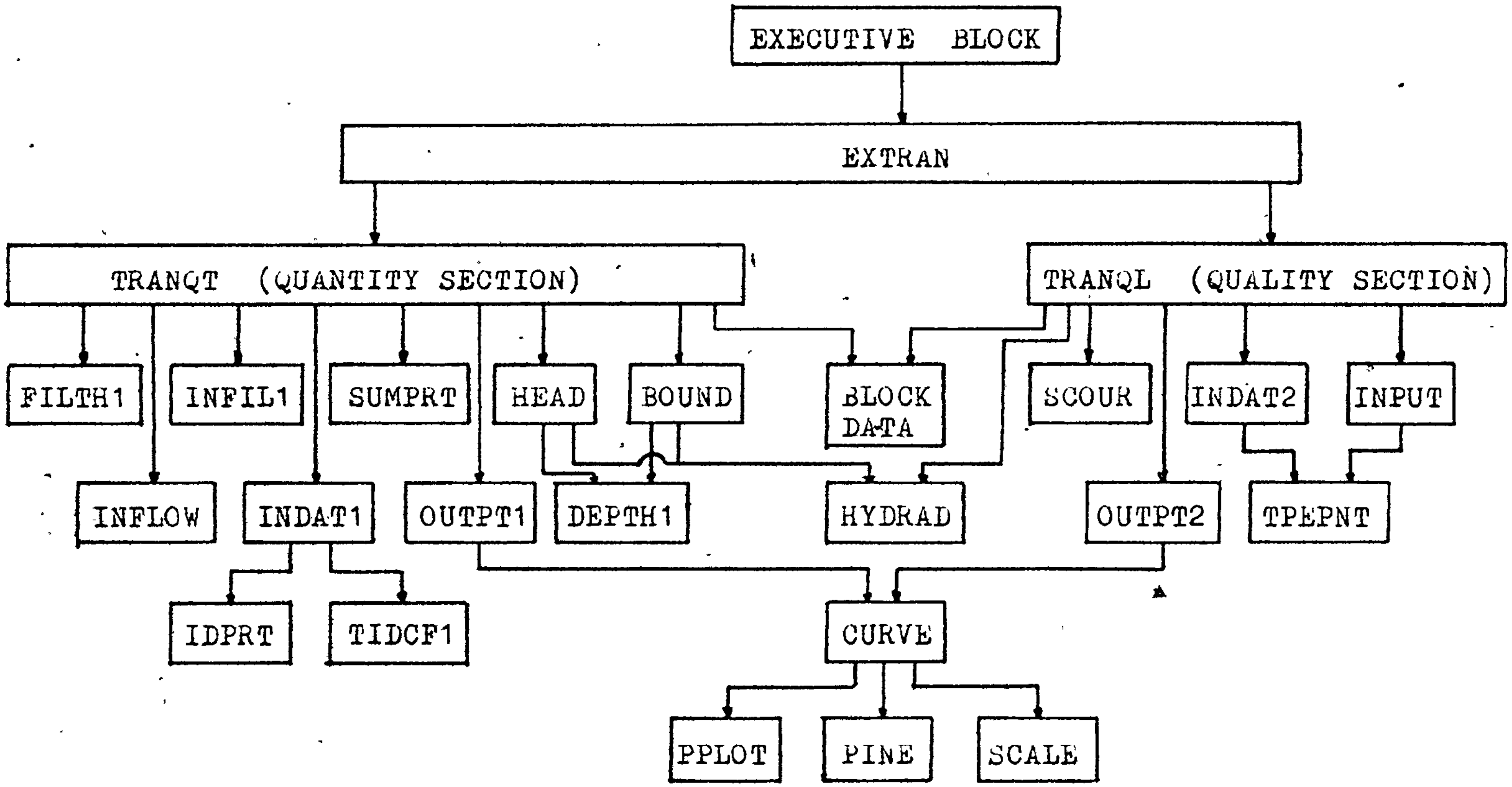
2.1 Introduction

SWMM is the joint effort of several programming groups in U.S.A. with some contributions from Canada, see (17,18). The basic structure of SWMM consists of several main models blocks including. RUNOFF, TRANSPORT, EXTENDED TRANSPORT, STORAGE/TREATMENT and RECEIVE. The RUNOFF Block produces hydrographs and pollutographs at inlet manholes resulting from a rainfall hyetograph distributed evenly over a subcatchment area. The TRANSPORT and/or EXTRAN Block is used to represent the physical works that convey the surface runoff hydrographs and pollutographs, which form the input to this block, from the inlet manholes to the point of discharge. This point may be a storage treatment facility or a receiving water. The inlet flows are modified by combination with flows from other drainage areas and by any dry weather flow in the system. The flows are attenuated during their passage through the pipe network to an extent depending on the capacity of the system and the function of in-system storage. The output from the TRANSPORT and/or EXTRAN Block may be routed to the storage units. These units are specified by simple regular geometries with various alternative inlet and outlet controls. It is recommended that the EXTRAN Block be used when surcharging effects are important. The resulting hydrographs and pollutographs can form the input to the RECEIVE Block.

The structure of the EXTRAN Block is presented in Fig.(2.1). Each box in the figure represents a subroutine of the block. Boxes from which arrows are drawn represent the calling routines. As noted in Fig.(2.1) the EXTRAN Block consists of two sections, the quantity section and the quality section, which may be simulated together or separately. In the quantity section the time history of conduit flows and velocities and junction depths are generated to describe the sewer system flow regime in response to a storm event. In the quality section the time history of the pollutant concentrations (mg/l) and mass emission rates in (lb/sec) at each node are generated from the hydraulic solution provided by the quantity simulation. It is understood that the quality section code is unreliable at this time (1981). A discussion of the modeling approach employed in the water quantity section is presented first, followed by a set of verification tests on some of the flow regulation devices such as outfalls, orifices and weirs.

2.2 Modeling Approach of the Quantity Section of EXTRAN

The quantity section uses a link-node description of the sewer system which facilitates discretization of the drainage system. Links transmit flow from node to node. Properties associated with the links are roughness, length, cross-sectional area, hydraulic radius and surface width,



(Source: Stormwater Flow Routing TRANS and EXTRAN Blocks of SWMM, McMaster Univ., Feb./March, 1979)

Fig.(2.1)- Structure of the EXTRAN Block (SWMM)

The last three properties are generally functions of the instantaneous depth of flow. Length may also be a function of flow (adverse flow). The primary dependent variable in the links is the discharge, Q, which is time dependent. In a given time interval, it is assumed that Q is constant in the link, while velocity and the cross-sectional area of flow, or depth, are variable in the link. Thus the flow condition in the link is both non-uniform and unsteady. Infiltration is not added along the pipe and so flow is not spatially varied in the link. Nodes are the storage elements of the system and correspond to manholes or pipe junctions in the physical system. The variables associated with a node are volume, head and surface area. The primary dependent variable is the head, H, which is assumed to be changing in time but constant throughout any one time increment. Inflow, such as inlet hydrographs, and outflow, such as weir diversion, take place at the nodes of this conceptual sewer system. The volume of the node at any time is the water volume in the manhole plus the volume in the several half-pipe lengths connected to any one node. The change in nodal volume during a given time step, Δt, forms the basis of head and discharge calculations.

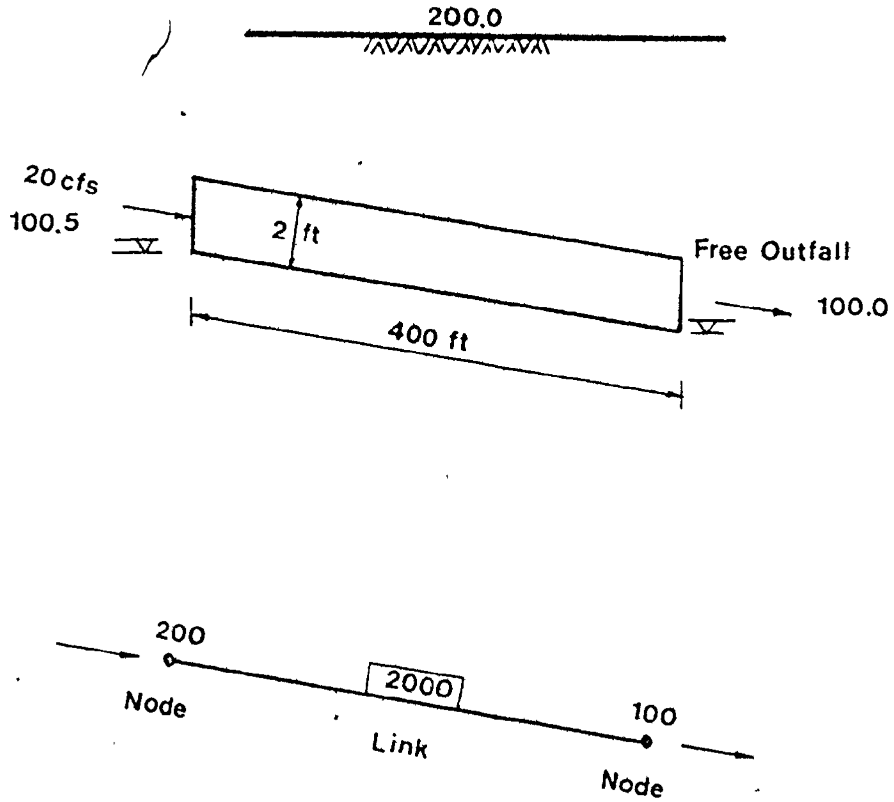
2.3 Verification Tests

In model verification, it is imperative to use specific conditions for which the model response could be exactly predicted if the model is structured as intended. Verification tests are not conducted by comparisons of model responses with those of the actual modeled system; rather comparisons between model responses and theoretically anticipated results are made in as many cases as possible for which this is known, see (16,23).

In this chapter, verification tests are classified into 3 groups. Each group concerns a certain control device and includes several tests on that device. Those groups are:

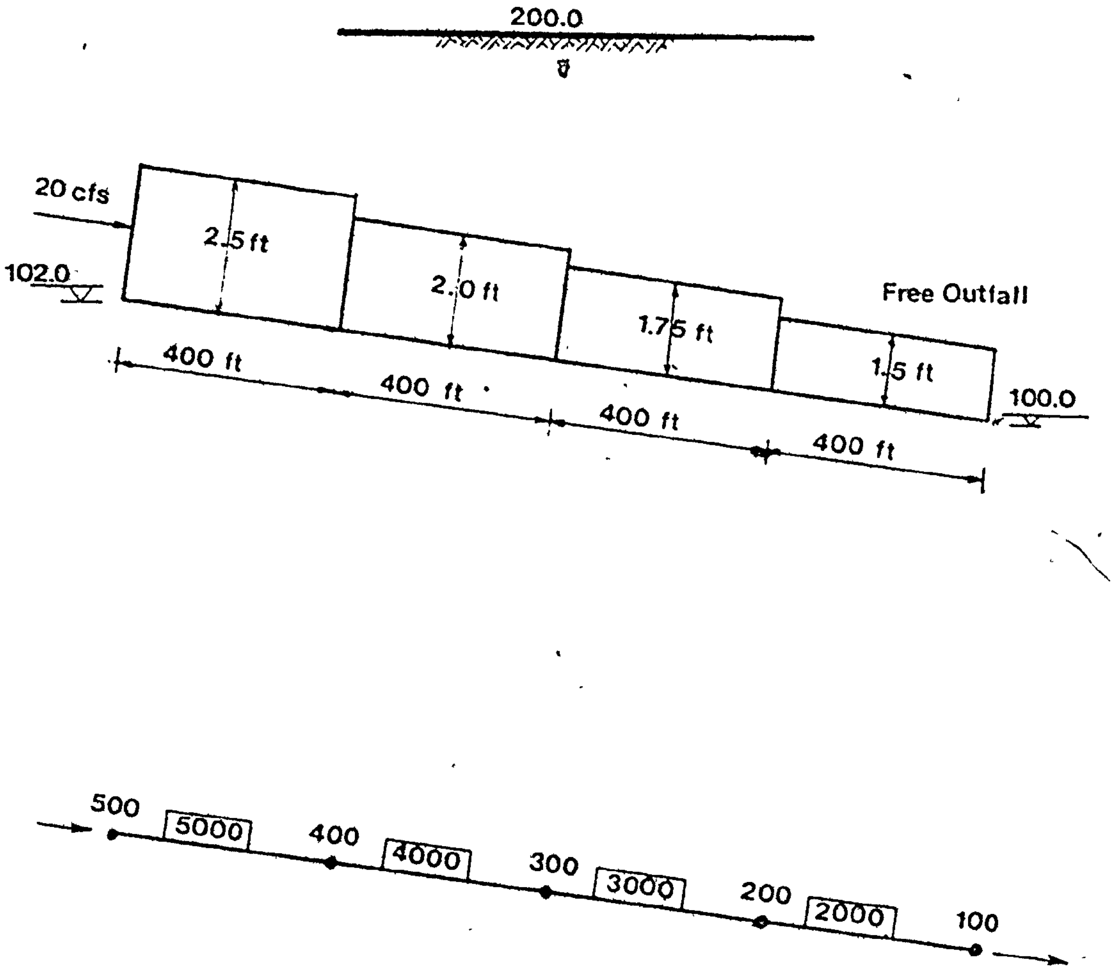
Group A - Outfalls
Group B - Orifices
Group C - weirs

Figs.(2.2) to (2.9) illustrate all the cases tested. Each figure contains a schematic of the physical case and its conceptual representation in EXTRAN. Table (2.1) presents a list of the tests and the purpose of each.



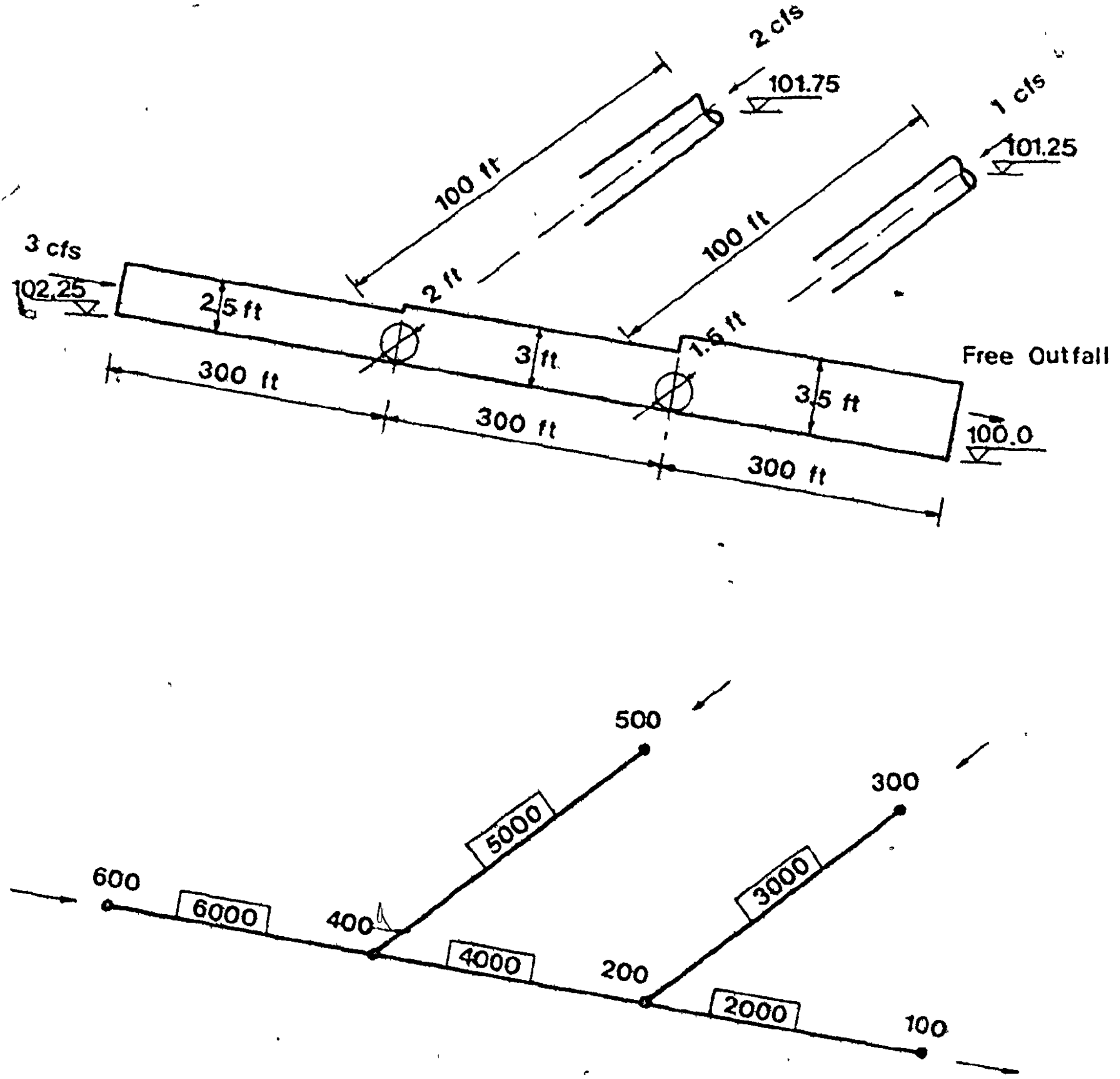
SINGLE PIPE

Fig.(2.2) Representation of Test No. 1A



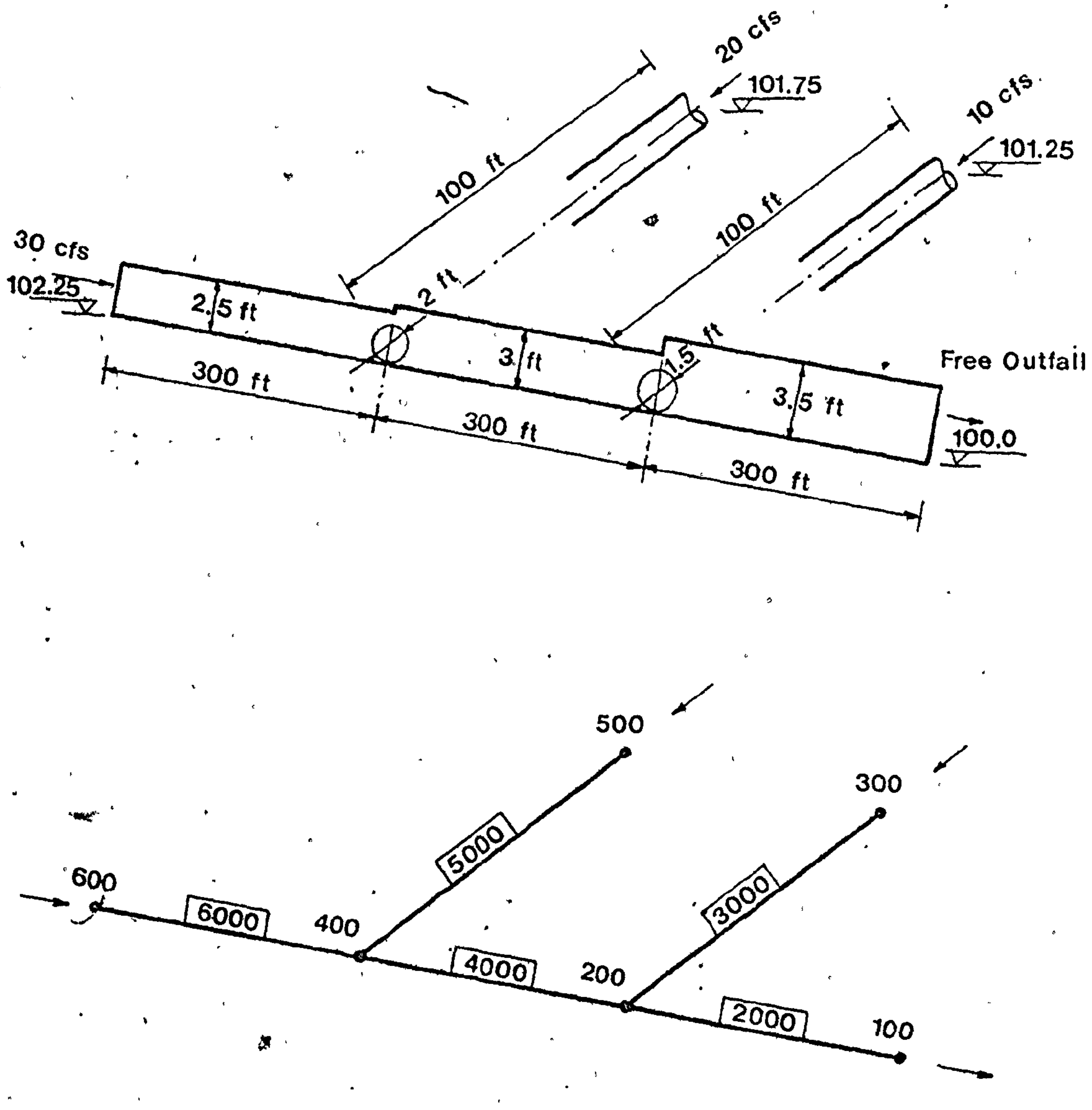
CONTINUOUS PIPES

Fig.(2.3) Representation of Test No. 2A



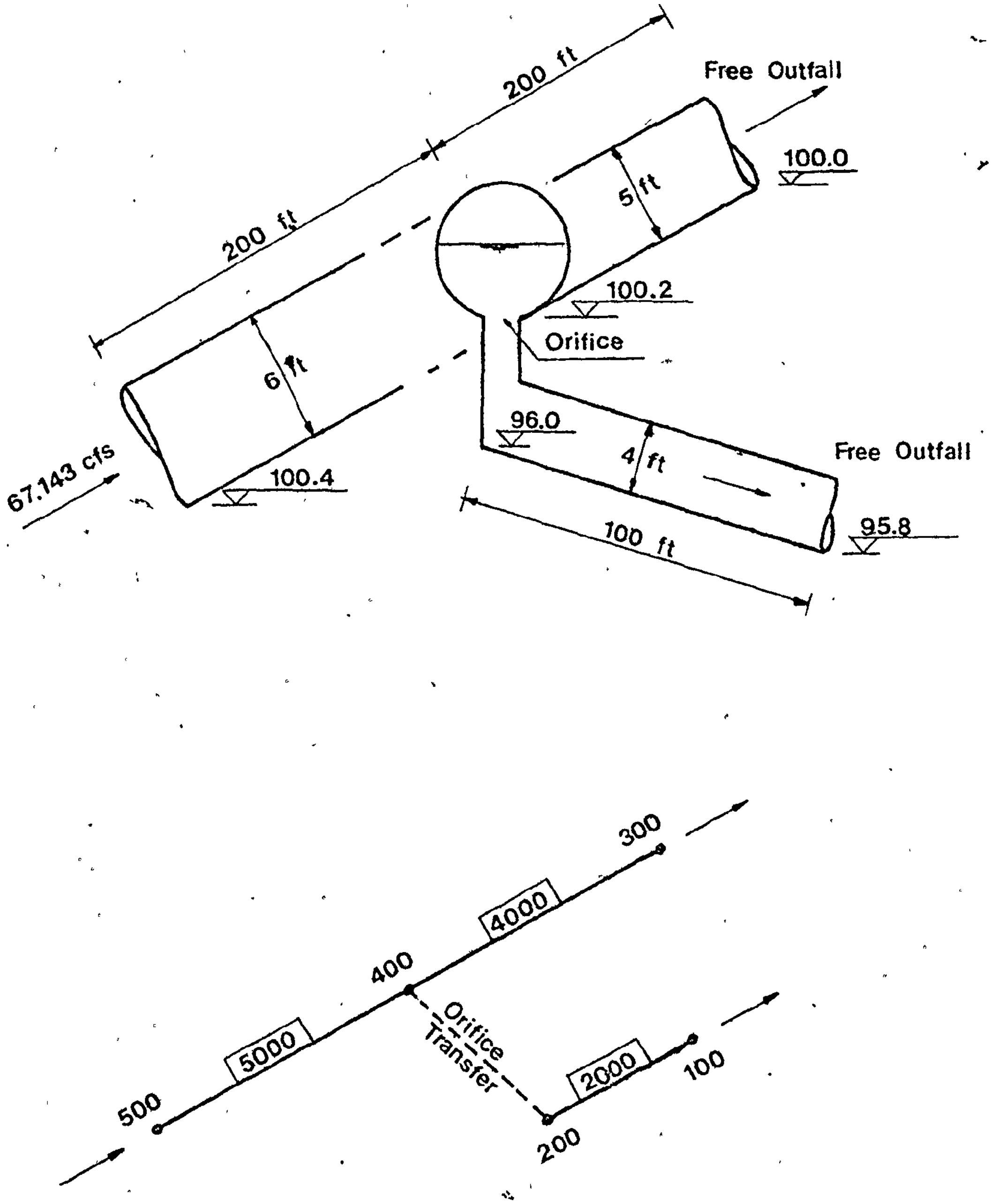
SIMPLE NETWORK

Fig.(2.4) Representation of Test No. 3A



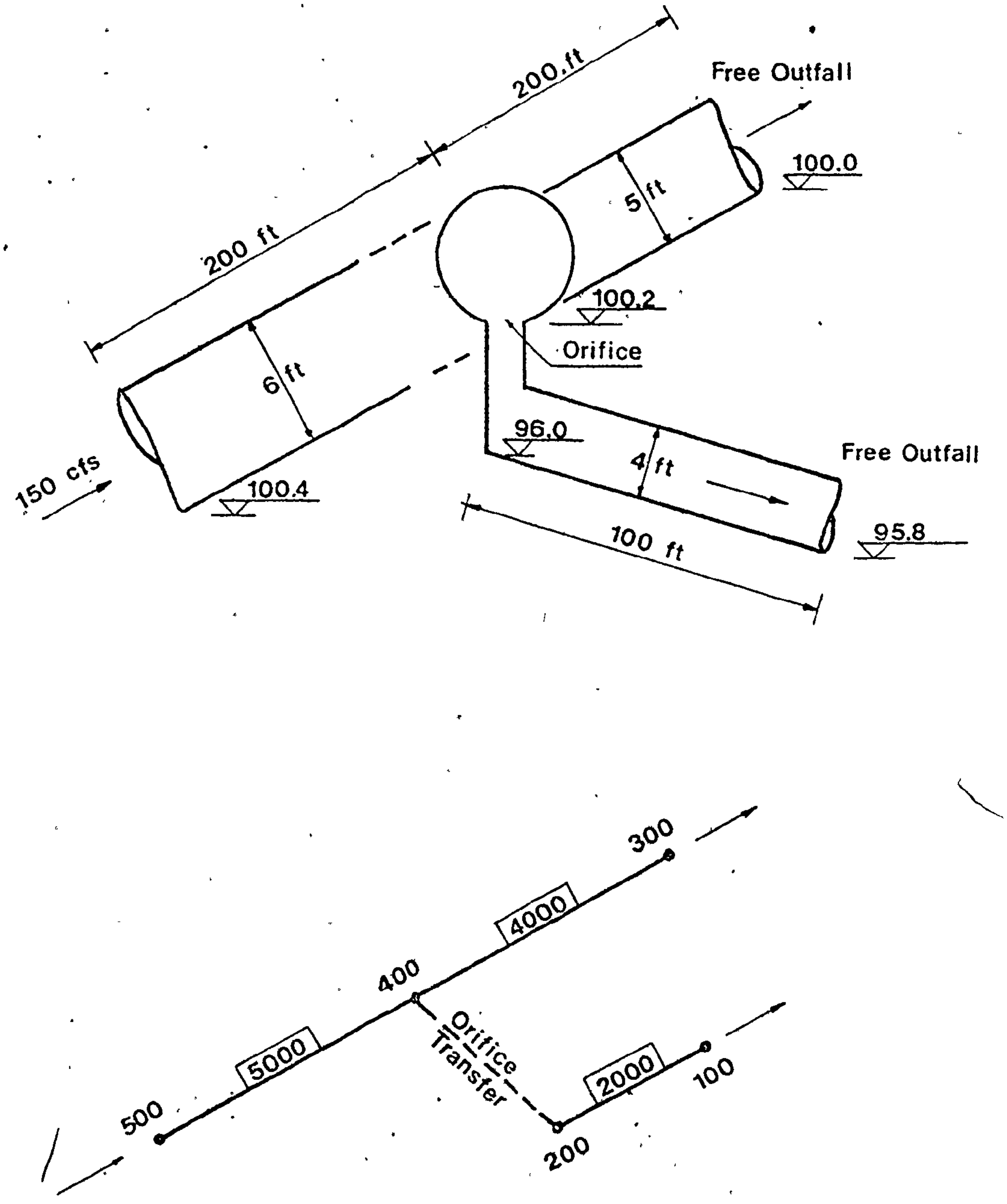
SIMPLE NETWORK

Fig.(2.5) Representation of Test No. 4A



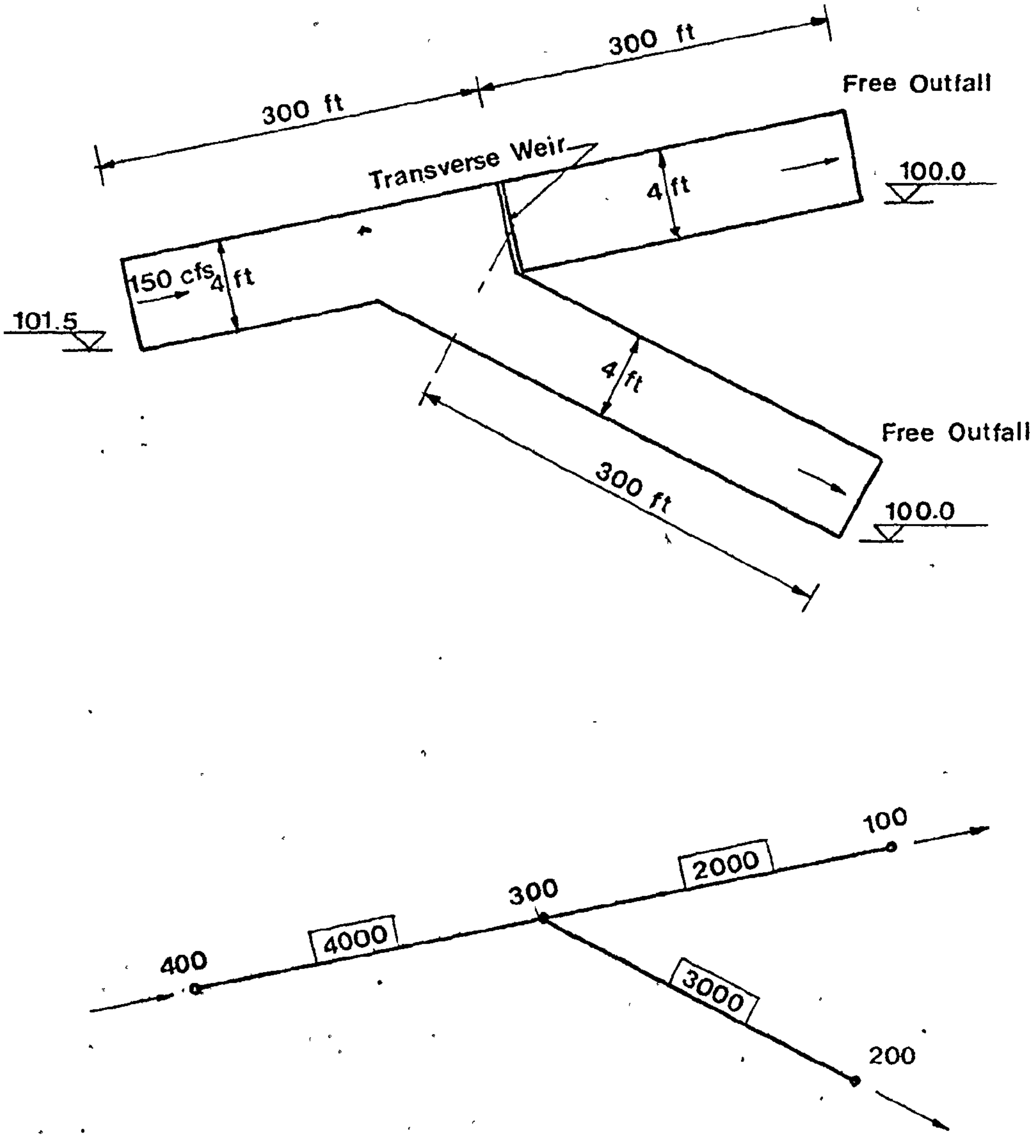
ORIFICE DIVERSION

Fig.(2.6) Representation of Test No. 1B



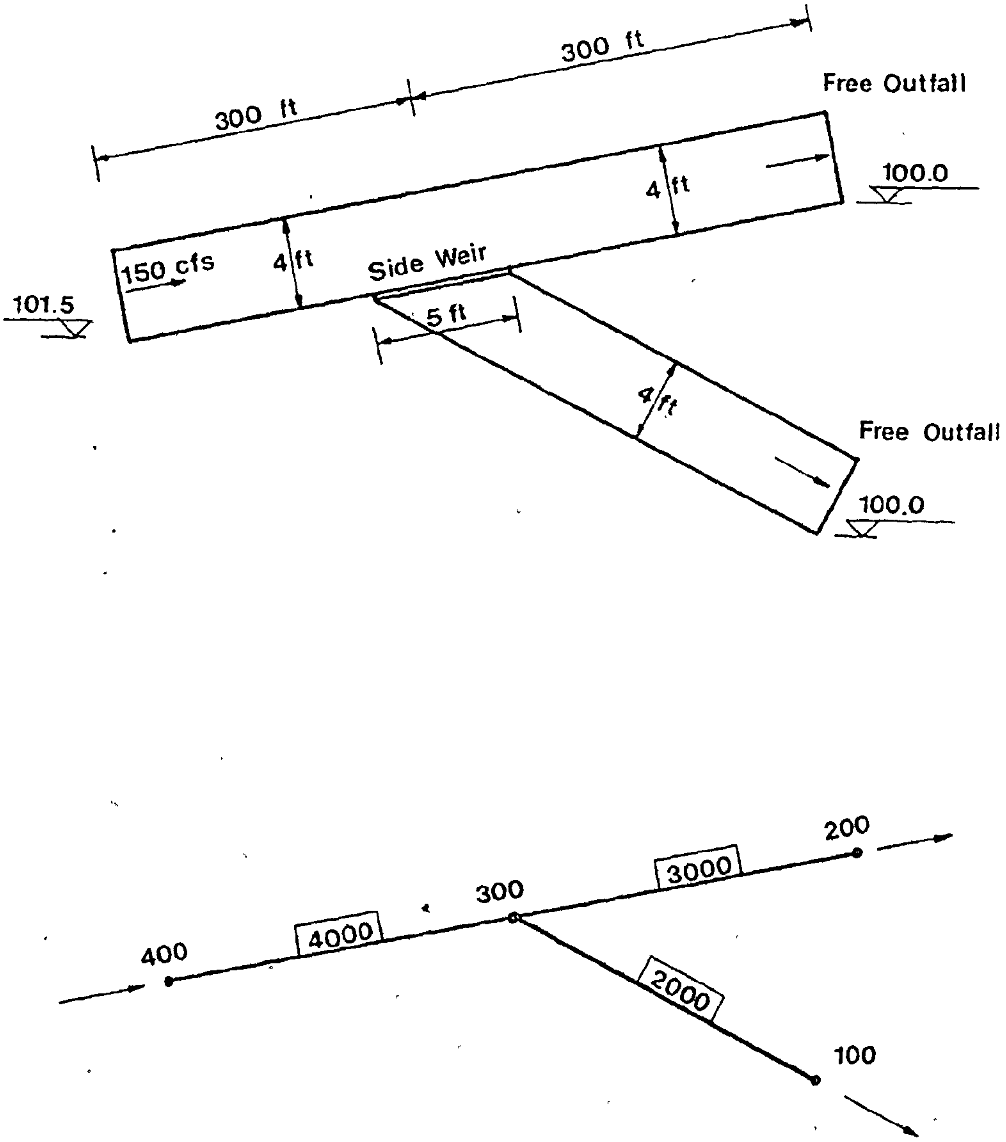
ORIFICE DIVERSION

Fig.(2.7) Representation of Test No. 2B



TRANSVERSE WEIR DIVERSION

Fig.(2.8) Representation of Test No. 1C



SIDE WEIR DIVERSION

Fig.(2.9) Representation of Test No. 2C

Test No.	Condition	Data File
1A	Free Outfall Single Pipe Flowing Under Pressure	HS1EXDA
2A	Free Outfall Continuous Pipes Flowing Under Pressure	HS2EXDA
3A	Free Outfall Simple Network - Free Water Surface	HS3EXDA
4A	Free Outfall Simple Network - Pressure Flow	HS4EXDA
1B	Orifice Diversion Structure Free Water Surface in Pipe	HS1EXDB
2B	Orifice Diversion Structure Pressure Flow in Pipe	HS2EXDB
1C	Weir Diversion Structure Transverse Weir	HS1EXDC
2C	Weir Diversion Structure Side Weir	HS2EXDC

Table(2.1) List of Verification Tests on the EXTRAN Block

2.3.1 Group A - Outfalls

The EXTRAN Block simulates both weir outfalls and free outfalls. Either type may be protected by a tide gate. A weir outfall is a weir which discharges directly to a pipe ending in a free outfall (Section 2.3.3). The free outfall is simply an outfall without a weir which discharges to a receiving water body under given backwater conditions. The free outfall may be truly free if the elevation of the receiving water is low enough or it may consist of a backwater condition. In the former case, used in the next four tests, the water depth at the free outfall is taken as critical or normal, whichever is less. If a backwater exists, the receiving water elevation is taken as the water surface elevation at the free outfall.

Figs.(2.10) and (2.11) show the hydraulic and energy grade lines (HGL and EGL) as calculated by hand and computed by EXTRAN for tests No.1A and 2A respectively. All the hand calculations of test group A are attached in Appendix (A.1).

2.3.2 Group B-Orifice Diversions

The orifice is completely characterized by its full cross-sectional area, A_o, and by a discharge coefficient, C_o. The value of the discharge coefficient depends upon the type of opening and the length of the orifice tube. It is prespecified as input data along with the cross-sectional area of the orifice. The discharge through the orifice is then computed with the standard orifice equation:

$$Q_o = C_o \cdot A_o \sqrt{2gh} \qquad \ldots(2.1)$$

where g is the gravitational constant and h is the head of the orifice.

All the hand calculations of test group B are attached in Appendix (A.2).

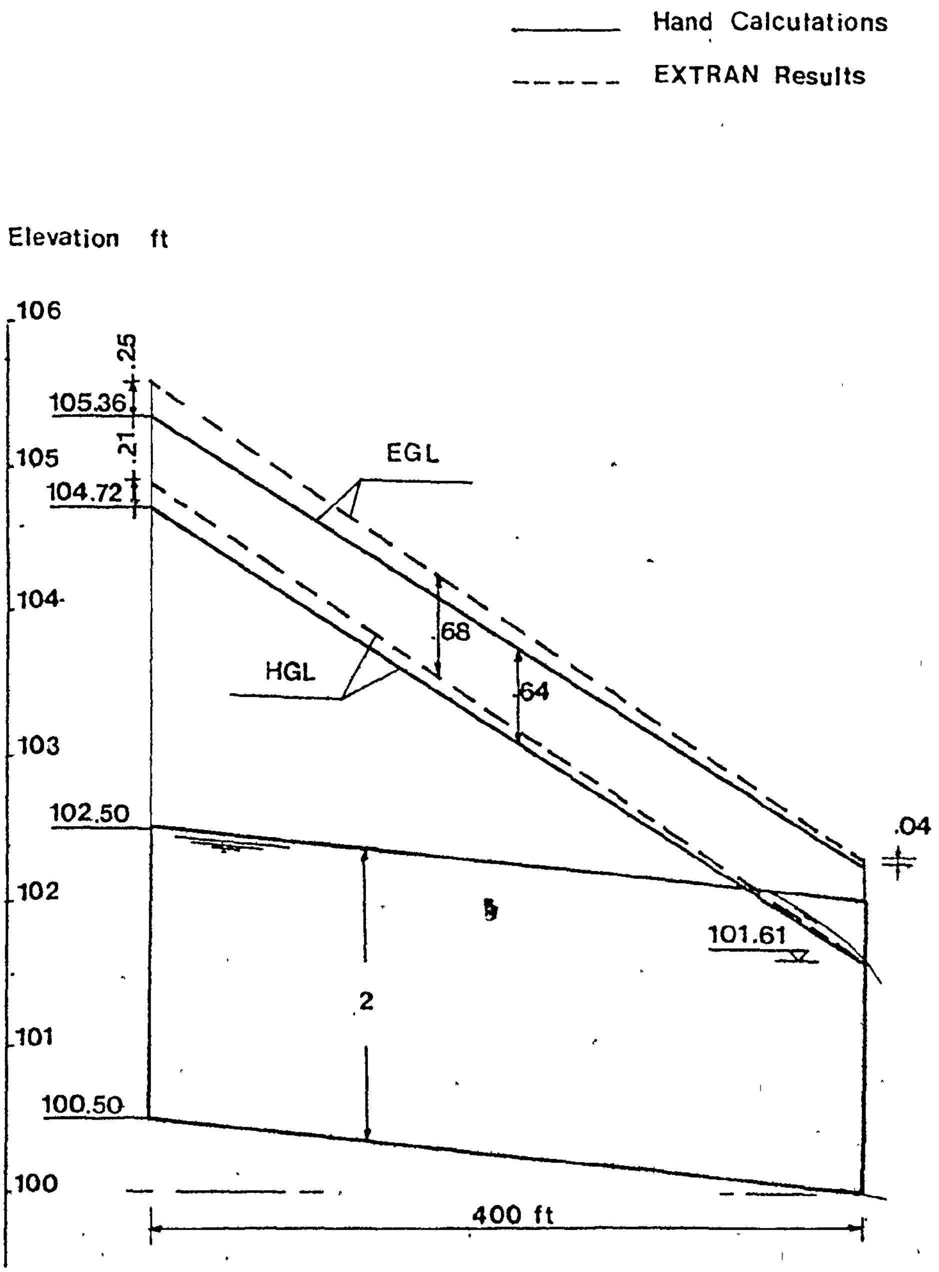


Fig.(2.10) Results of Test No. 1A

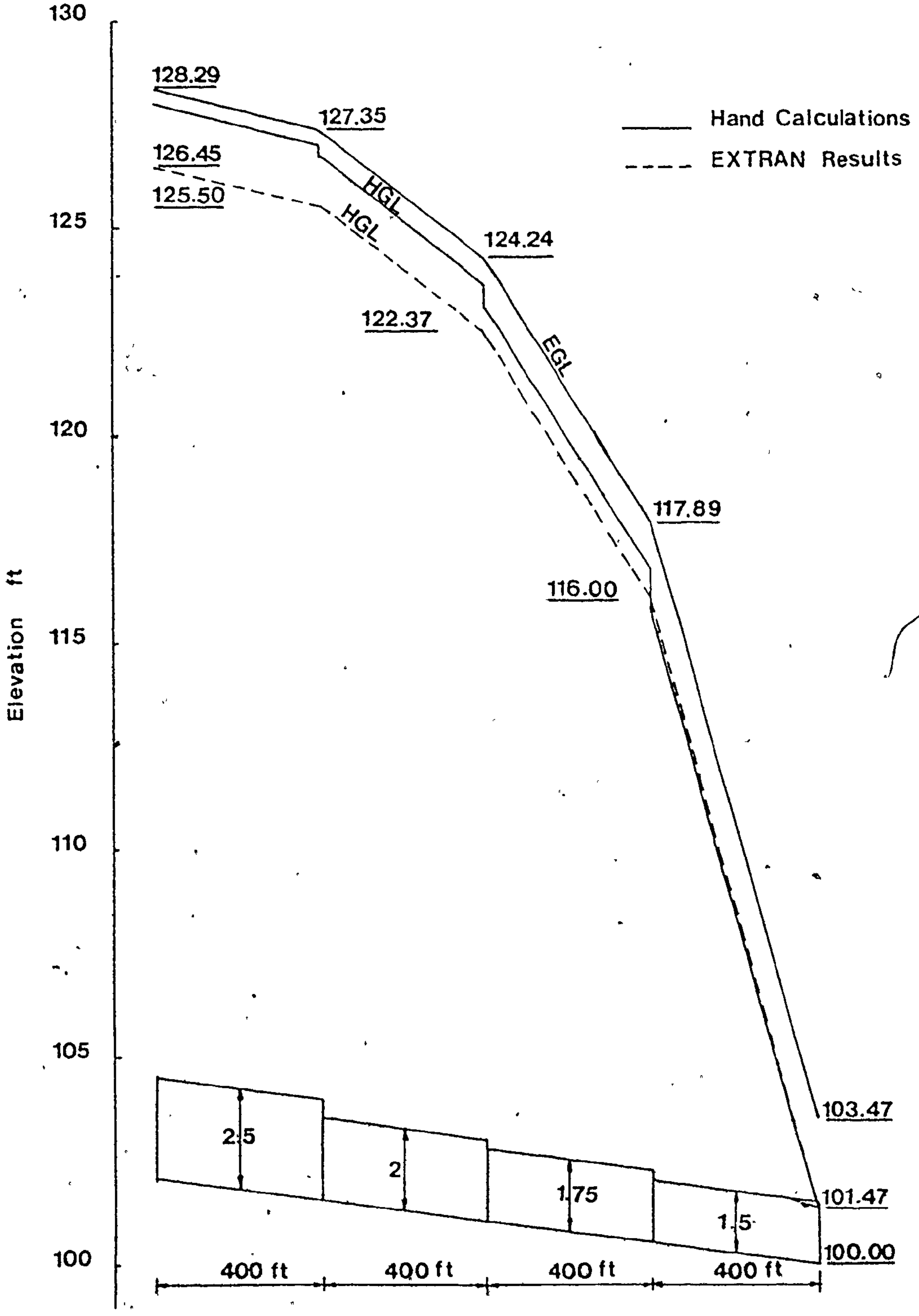


Fig.(2.11) Results of Test No. 2A

2.3.3 Group C - Weir Diversion Structures

Weir diversions provide relief to the combined sewer system during periods of storm runoff. Flow over a weir is computed by the equation:

$$Q_s = C_w L((h + \frac{v^2}{2g})^a - (\frac{v^2}{2g})^a) \quad \ldots(2.2)$$

where C_w = discharge coefficient

L = weir length

h = driving head on the weir

v = approach velocity

a = weir exponent; 3/2 for transverse weirs and 5/3 for side weirs

The magnitude of flow over the transverse weir is checked in Test No.1C whereas that over the side weir is checked in Test No.2C.

All the hand calculations of test group C are attached in Appendix (A.3).

2.4 Results and Discussion

Tables (2.2) and (2.3) summarise these results. The following observations can be made.

(i) EXTRAN keeps the system balanced in terms of equating the sum of inflows to the sum of outflows, until the system is under pressure when the numerical scheme tends to become unstable.

(ii) The error in computing velocities in conduits with very low flows may reach 51%.

(iii) The error in the free flow orifice discharge is only 5.20%. It could not be evaluated for pressure flow.

(iv) The expression used for describing the flow over weirs, Eq.(2.2) does not seem to be applied correctly by the program. Calculated errors of 46% were obtained.

From the above observations, one may conclude that simulation of weir diversions in SWMM-EXTRAN does not appear to be sufficiently accurate and the program could benefit from a new procedure for side weirs.

Test No.	% error in computing		
	Continuity	Depth at node 100	Velocity in conduit 2000
1A	0.0	-0.25	-3.125
2A	0.0	-2.25	0.16
3A	0.0	0.68	-1.69
4A	Unbalanced System		

Table (2.2) Summary of Results of Test Group A.

Test No.	% error in computing		
	Continuity	Flow through orifice	Flow over weir
1B	0.02	5.20	——
1C	0.0	——	42.43
2C	0.0	——	46.40

Table (2.3) Summary of Results of Test Groups B and C.

CHAPTER III

THEORETICAL BACKGROUND

3.1 Type and State of Flow

The flow of water in a conduit may be either open channel flow or pipe flow. Open channel flow must have a free surface whereas pipe flow has none, since the water must fill the whole conduit. The flow in a closed conduit is not necessarily pipe flow. It must be classified as open channel flow if it has a free surface. The storm sewer, or the combined sewer, which is a closed conduit, is generally designed for open channel flow because the flow in the sewer is expected to maintain a free surface most of the time.

Flow in an open channel incorporating a side weir is described as spatially varied or discontinuous flow. It is also steady and nonuniform. Steady flow means that the depth and velocity of flow do not change or can be assumed constant during the time interval under consideration at a certain position. Nonuniform flow means that velocity and depth change with respect to position. Spatially varied flow means that the discharge is nonuniform along the channel, i.e. discharge decreases along the side weir. Varied flow may be further classified as either rapidly or gradually varied. Flow is rapidly varied if the depth changes abruptly over a comparatively short distance, otherwise, it is gradually varied.

The behaviour of flow in a side weir open channel is governed basically by the effects of gravity and viscosity relative to the inertial forces. It is also affected by the surface tension.

The effect of gravity upon the state of flow is represented by a ratio of inertial forces to gravity forces. This ratio is given by the Froude Number:

$$F = \frac{V}{\sqrt{gd_h}} \qquad \ldots(3.1)$$

where the hydraulic depth d_h is defined as the cross sectional area of the water normal to the direction of flow in the channel divided by the width of the free surface. When F is equal to unity or $V = \sqrt{gd_h}$, the flow is said to be critical. If F is less than unity, or $V < \sqrt{gd_h}$ the flow is subcritical and often described as tranquil. If F is greater than unity, the flow is supercritical and usually described as rapid.

3.1 Literature Review - Side Weirs

The hydraulic behaviour of side-weirs has received considerable interest since the beginning of the century. However, a large number of the studies were empirical in nature. In 1905, Parmley derived the relation:

$$L = \frac{Bw.V}{1.67} \left(\sqrt{\frac{1}{h_2}} - \sqrt{\frac{1}{h_1}} \right) \qquad \ldots(3.2)$$

where L = Length of weir

B_w = Width of stream at weir crest level

V = Mean velocity of flow in channel

h_1 and h_2 are the depths of flow over the weir at the upstream and downstream ends respectively.

Eq.(3.2) has the disadvantage that the length L tends to infinity as the downstream head h_2 decreases. It is generally accepted that for h_2 = 1/16 ft, the relation becomes:

$$L = \frac{Bw.V}{1.67} \left(4 - \sqrt{\frac{1}{h_1}}\right) \qquad \ldots(3.3)$$

In 1917, *Engels* published the results of extensive tests he had carried out on a large-scale model. Using rectangular channels, he conducted tests with the following limits:

Channel width	:	0.67 to 6.56 ft
Length of crest	:	1.64 to 32.8 ft
Main channel velocity	:	1.75 to 1.90 ft/sec

Engels observed that the depth of water was drawn down from its normal value some distance upstream of the weir to a minimum value at the upper end of the weir, and steadily increased along the weir to a maximum at the lower end of the weir (profile A, Fig.(3.1)). From his experiments Engels derived the formula:

$$Q_s = 3.32\ L^{0.83} (d_2 - c)^{1.67} \qquad \ldots(3.4)$$

where Q_s is the discharge over the weir; c is the height of the weir crest and d_2 is the downstream depth of water; both dimensions measured from the channel bottom. Engels also carried out some work on the discharge over side weirs when the channel width is gradually reduced along the length of the weir. From these tests he obtained the formula:

$$Q_s = 3.32\ L^{0.9}\ (d_2 - c)^{1.60} \qquad \ldots(3.5)$$

Coleman and Smith (1923) produced three formulae, the first two being applicable especially to the model on which they carried out their experiments and the third one is generally known as the Coleman and Smith formula and is applicable to normal-size sewers. These formulae are:

$$L = 29.06\ B^{1.4}\ h_1^{0.513} \qquad \ldots(3.6)$$

$$Q_s = 1.67\ B\ L^{0.72}\ h_1^{1.645} \qquad \ldots(3.7)$$

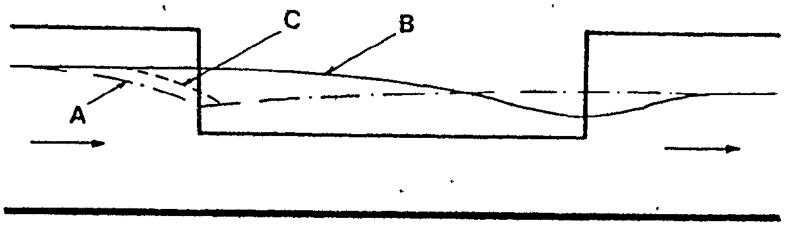
$$L = 0.548\ B\ V\ h_1^{0.13}\ \left(\sqrt{\frac{1}{h_2}} - \sqrt{\frac{1}{h_1}}\right) \qquad \ldots(3.8)$$

In all cases they observed a falling profile along the length of the weir, with an increase in depth beyond the end of the weir (profile B, Fig. (3.1)).

Babbit carried out a series of tests on two circular pipes with diameters of 18 and 24 in using weir lengths from 16 to 42 in. He observed that the profile along the weir was, for all tests, falling as shown by profile B, Fig. (3.1) i.e. the same as that observed by Coleman and Smith. The formula that Babbit evolved was for the length of weir crest necessary to reduce the depth from d_1 to d_2. The formula is:

$$L = 2.30\ V_1\ D\ \log_{10}\left(\frac{d_1 - c}{d_2 - c}\right) \qquad \ldots(3.9)$$

where V_1 is the velocity of flow at the upstream end of weir and D is the pipe diameter.



A : Engels
B : Coleman and Smith
C : Tyler, Carollo and Steyskal

Fig.(3.1)- Water Surface Profiles

<u>Nimmo</u> (1928) presented a paper in which he developed a theoretical approach to the problem. He considered the general case of a sloping channel, with the width and the slope of the sides varying from section to section. Taking two sections across the channel a distance dx apart; the change in momentum over length dx minus the momentum lost in the overflowing water must equal the sum of external forces. From this, he obtained an equation for the slope of the water surface $\frac{dd}{dx}$. Taking the simplified case of a rectangular channel of constant width, this reduced to:

$$\frac{dd}{dx} = \frac{S_o - S_f - \frac{Q}{gA^2}\frac{dQ}{dx}}{1 - Q^2T/(gA^3)} \qquad \ldots(3.10)$$

where S_o = Slope of channel bed

S_f = Slope of friction line

$\frac{dQ}{dx}$ = Rate of change of flow in main channel

T = Water surface width

Nimmo applied his theory to a practical case and, despite a curved inlet, high velocities, and standing waves upstream of the weir, he obtained a computed discharge of 370 cfs against a measured value of 360 cfs.

Tyler, Carollo, and Steyskal (1929) discussed in some detail the results of previous workers, and carried out further tests on side weirs with and without baffles. They found that a profile was obtained similar to that obtained by Engels, but with the point of minimum depth a little way along the weir (profile C, Fig. (3.1)).

DeMarchi (1934) published a theory developed from the assumption of constant total energy along the weir. He made the following assumptions:

(i) Conditions of steady flow exist.

(ii) The weir is situated in an infinitely long channel of uniform cross section.

(iii) The weir crest is parallel to the channel bed.

(iv) At certain distance upstream and downstream of the weir, flow in the channel is uniform.

(v) The discharge over any given length of the weir can be calculated from the normal weir formula namely:

$$\frac{dQ}{dx} = -\frac{2}{3} C_M \sqrt{2g}\, (d-c)^{1.50} \qquad \ldots(3.11)$$

in which C_M is the DeMarchi discharge coefficient.

(vi) The total-energy line remains parallel to the bed of the channel. This means that the theory is confined to short weirs, or to those where the depth of water in the channel does not change appreciably.

DeMarchi showed that 3 possible profiles existed:

(i) If the channel bed slopes steeply, producing uniform supercritical flow upstream of the weir, the resultant profile is as shown in Fig. (3.2a). The weir has no effect in the upstream direction because the flow is supercritical. Along the length of the weir there is a gradual reduction in depth as explained previously, and beyond the weir the depth increases as the flow is retarded, tending asymptotically to the normal depth.

(ii) For channel of low slope giving uniform subcritical flow some distance upstream of the weir, the effect of the weir is felt in the upstream direction only, see Fig. (3.2b). Downstream of section 3-3 the depth will be the normal depth corresponding to the flow Q_r remaining in the channel. Along the length of the weir there will be a gradual increase in depth (since the flow is subcritical), and upstream of 1-1 the depth will tend asymptotically to the normal depth for the initial flow Q_o.

(iii) If the weir crest is below the critical depth corresponding to the initial flow Q_o and the weir is long, then the reduction in depth at sections progressively farther upstream of section 3-3 will lead to a depth less than the critical depth. This will cause the flow to become supercritical, and thus lead to the profile shown in Fig.(3.2c). Finally, DeMarchi derived the following equations:

$$L = \frac{B}{C_M}\left(PHI\left(\frac{d_2}{E_s}\right) - PHI\left(\frac{d_1}{E_s}\right)\right) \qquad \ldots(3.12)$$

$$Q_r = Bd_2\ (2g(E_s - d_2))^{0.50} \qquad \ldots(3.13)$$

where $PHI(d/E_s)$ is a depth function and E_s is the total energy referred to channel bed, or specific energy.

Fig.(3.3) shows the curves that DeMarchi developed and used in solution. Knowing c/E_s and d/E_s , one can obtain $PHI(d/E_s)$. If the discharge and type of flow (and thus d/E_s) are known at one end of the weir, then Eq.(3.12) can be used to find d/E_s at the other end. This in turn will give flow at the end of the weir Q_r, using Eq.(3.13).

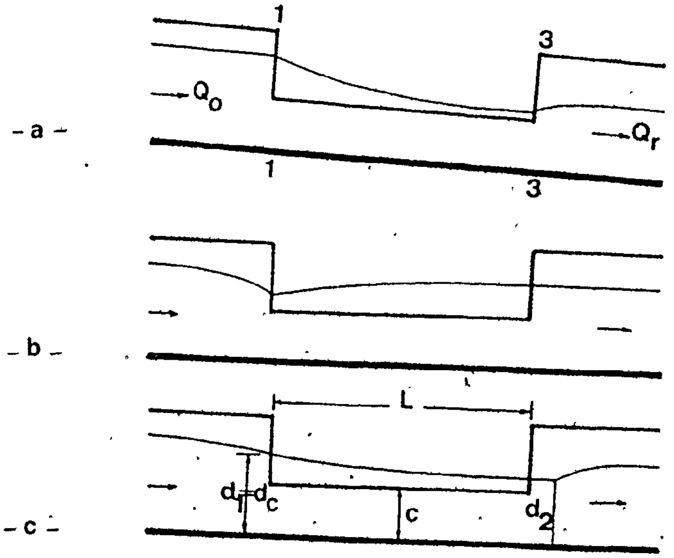


Fig.(3.2)- Water Surface Profiles by DeMarchi

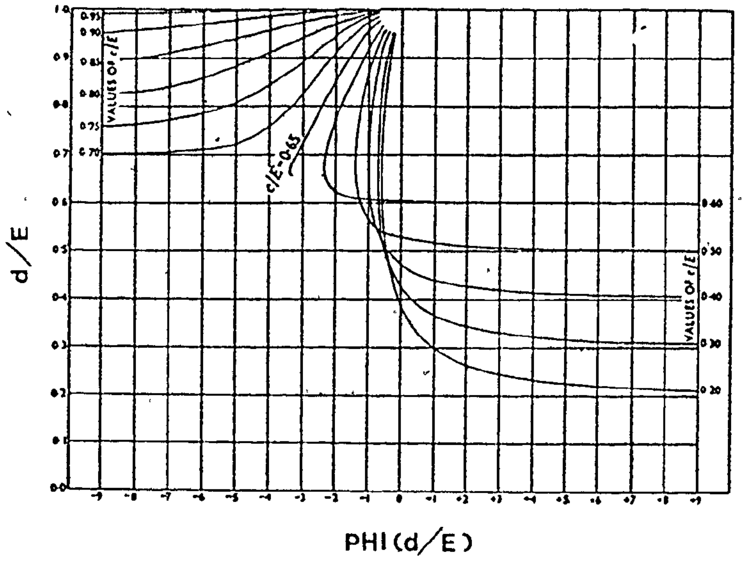


Fig. (3.3)-Curves Developed by DeMarchi

Gentilini (1938) carried out a series of experiments designed to follow up the work of DeMarchi. He obtained quantitative confirmation of the theory for tranquil flow, with marked difference between theory and practice for shooting flow.

A symposium of four papers on Side Weirs was reported in 1957. These Papers were presented by Ackers, Allen, Collinge and Frazer. Ackers revealed the disadvantages of Coleman and Smith's Theory. They were as follows:

(1) The velocity is assumed constant although it varies along the side weir.

(2) The velocity is not readily determined.

(3) The Theory applies only to rectangular channels with

constant width.

Ackers developed "The Profile Method" to calculate the water surface profile along the side weir in rectangular channels in case of falling profile only assuming constant energy, along the side weir. The general equation for the water surface profile was

$$Ch^{3/2} = \frac{-dB}{dx}(h + c)V + B\left((h + c)\frac{g}{V} \cdot \frac{EPSI}{ALPHA} - V\right)\frac{dh}{dx} \quad ..(3.14)$$

where:

C = Discharge coefficient of weir = 3.33

ALPHA = Velocity distribution coefficient = 1.40

EPSI = Pressure distribution coefficient = 0.80

Substituting for C, ALPHA and EPSI, he obtained the design empirical formula:

$$L = 2.03\ B\ (5.28 - 2.63\ c/E_w) \quad ..(3.15)$$

where $E_w = \frac{V^2}{2g} + EPSI.h$

= total energy referred to weir crest; see Fig.(3.4)

this gives $5.40 < L < 9.6$ ft

and $0.20 < c/E_w < 1.0$

Allen conducted a series of experiments on side weir of lengths 9.25, 12, 15 and 18 inches in steel pipe 7 feet in length overall and 6 inch internal diameter. He confirmed that the average velocity increases along the side weir because of the drawdown effect caused by the weir. He also correlated the experimental results with a simple theory and reached a formula for the maximum weir length,

L_{max}:

$$L_{max} = C_w . D \qquad ...(3.16)$$

where $C_w = (1/C)^{3/2}$

$$= (3.33\ D/B_w)^{3/2} \qquad ...(3.17)$$

where B_w is the breadth of water at the weir crest level and D is the pipe diameter.

Collinge carried out his experiments with four principal aims in view. These were:

(i) Determination of water surface profiles.

(ii) Examination of the application of the DeMarchi Theory.

(iii) Studying the effects of velocity of flow in the main channel on the weir coefficients.

(iv) Determination of the movement of the bed load.

Some of his results were:

(i) There is agreement with the profile observed by DeMarchi (Fig.(3.2b))until the Froude Number at the upstream end of the weir F_1 is 0.98.

(ii) Over a wide range of flow much of bed load in the channel is carried over to an area near the upstream edge of the weir, and, under suitable conditions, it can be carried over the weir.

Frazer determined five cases for the flow along a side weir in a prismatic channel, see Fig.(3.5). These are:

Case (1) : Critical condition at the entrance with super-critical flow in the weir section, falling profile along

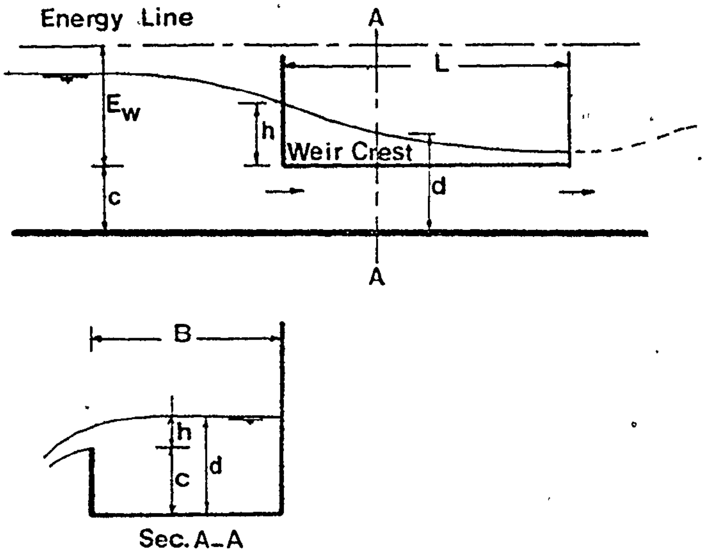


Fig.(3.4) Theoretical Water Profile by Ackers

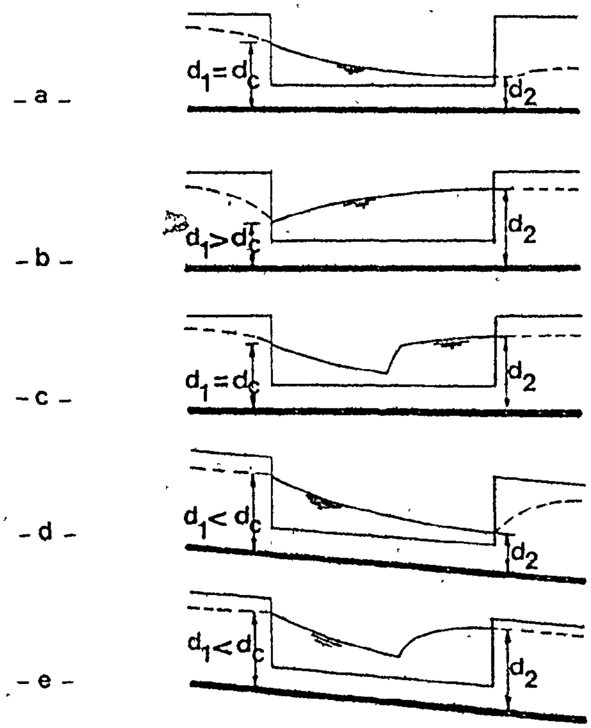


Fig.(3.5) Water Surface Profiles by Frazer the weir as shown in Fig.(3.5a).

Case (2) : Depth of flow greater than critical at the entrance with subcritical flow in the weir section, rising profile along the weir, as shown in Fig.(3.5b).

Case (3) : Case (1) flow at the beginning of the weir section followed by a hydraulic jump, and case (2) after the jump with less specific energy, as shown in Fig.(3.5c).

Case (4) : Depth of flow less than critical at the entrance with supercritical flow in the weir section, falling profile along the weir, as shown in Fig.(3.5d).

Case (5) : Case (4) flow at the beginning of the weir section followed by a hydraulic jump, and case (2) after the jump with less specific energy, as shown in Fig.(3.5e).

Frazer's experimental investigations were focused on the first three cases only, with an attempt to derive a pair of correlations for each case, one being quantity and depth of flow and the other quantity and length of weir. It is noteworthy that Frazer attempted to analyse the third case, hydraulic jump in the weir section, which is the most difficult case from both experimental and analytical point of view.

Some of his notes on this case were:

(i) As with a hydraulic jump in a normal open channel, two types of jump were noted, the undular jump and the surface roller type.

(ii) The presence of a jump in the weir section has no effect on the flow before the jump.

(iii) The position of the jump is conditioned by the downstream channel characteristics.

In 1973 Smith developed a computer program to calculate the flow over the side weir by means of iterative procedures. The differental equation of the water surface profile is based on the assumption of constant energy along the side weir less the frictional losses. From this assumption, Smith derived the differential equation of the water surface profile:

$$\frac{dd}{dx} = \frac{S_o - S_f - \text{ALPHA}\,\frac{Q}{gA^2}\,\frac{dQ}{dx}}{1 - \text{ALPHA}.Q^2T/(gA^3)} \qquad \ldots(3.18)$$

which is similar to Nimmo's equation, Eq.(3.10), when ALPHA equals one.

It was believed that the assumption of a constant energy line (excluding the effects of friction) was generally valid until 1976 when El-Khashab found a considerable difference between the total energy line (less estimated friction) and the observed total energy line based on adding ALPHA $\frac{V^2}{2g}$ to the mean water surface elevation, see Fig.(3.6). This difference is due to the fact that at any section along the side weir, the longitudinal component of velocity of the spill flow, U, is greater than the mean velocity, V, in the side weir channel. The new approach adopted by El-Khashab, which is based on the momentum equation, is discussed in Section (3.3).

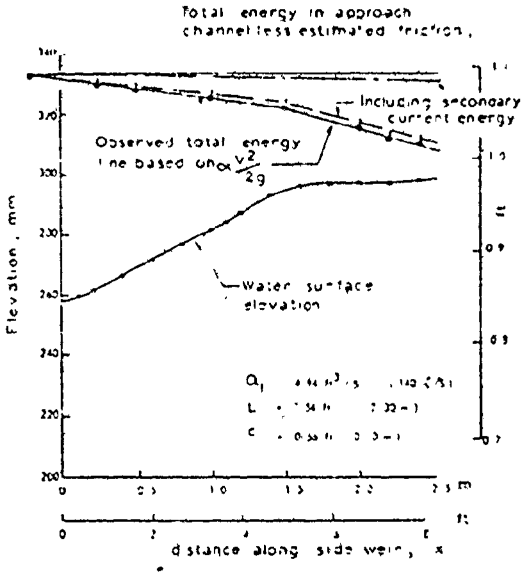


Fig.(3.6)- Energy Variation Along Side Weir

3.3 Differential Equation of Water Surface Profile

Considering two sections Δx apart as in Fig.(3.7) with discharges Q and (Q+ ΔQ) respectively at sections a and b, the momentum equation parallel to the channel invert can be written:

Rate of change of momentum - Momentum loss due to discharge over the side weir

= Sum of external forces

i.e.

$$\text{BETA.RHO.}(Q+\Delta Q)(V+\Delta V) - \text{BETA.RHO.}QV - \text{RHO}\frac{dQ}{dx}\Delta x\ U$$

$$= P_a - P_b + w\sin(\text{THETA}) - F_f \quad \ldots(3.19)$$

where P_a and P_b are the hydrostatic pressure forces acting on the cross sectional areas of a and b. For small Δx, $P_a - P_b = -$ RHO.gAΔd; where RHO is the density, Δd is the difference in depth of flow between the two sections and A is the average cross sectional area between a and b. The weight of water in length Δx is w = RHO.gAΔx. THETA is the angle that the invert makes with the horizontal and S_o is the invert slope = sin(THETA), i.e., w sin(THETA) = RHO.gA $S_o\Delta x$. BETA is the momentum coefficient due to nonuniform velocity distribution; F_f is the friction force in the length Δx = RHO.gA$S_f\Delta x$; where S_f is the slope of energy line.

Subsituting for $P_a - P_b$, w sin(THETA) and F_f and dividing by RHO.gA, Eq.(3.19) may be written as:

$$\frac{\text{BETA}}{gA}(Q\Delta V + \Delta QV + \Delta Q\Delta V) - \frac{dQ}{dx}\frac{U\Delta x}{gA}$$

$$= -\Delta d + S_o.\Delta x - S_f.\Delta x \qquad \ldots(3.20)$$

The term $\Delta Q\Delta V$ can be neglected in Eq.(3.20). Dividing by Δx and letting $\Delta x \to 0$

$$\frac{dd}{dx} + \text{BETA}\,\frac{V}{g}\frac{dV}{dx} = S_o - S_f - \frac{V}{gA}\frac{dQ}{dx}\,\text{BETA} + \frac{U}{gA}\frac{dQ}{dx} \qquad \ldots(3.21)$$

$$\text{but } \frac{dQ}{dx} = \frac{d(AV)}{dx} = V\frac{dA}{dx} + A\frac{dV}{dx}$$

$$\text{thus } \frac{dV}{dx} = \frac{1}{A}\left(\frac{dQ}{dx} - V\frac{dA}{dx}\right)$$

Subsituting for $\frac{dV}{dx}$ in Eq.(3.21) gives:

$$\frac{dd}{dx} + \text{BETA}\,\frac{V}{gA}\frac{dQ}{dx} - \text{BETA}\,\frac{Q^2}{gA^3}\frac{dA}{dx} = S_o - S_f - \text{BETA}\,\frac{V}{gA}\frac{dQ}{dx} + \frac{U}{gA}\frac{dQ}{dx}$$

Collecting terms,

$$\frac{dd}{dx} = S_o - S_f - \frac{1}{gA}\,(2.\mathrm{BETA}.V - U)\,\frac{dQ}{dx} + \mathrm{BETA}\,\frac{Q^2}{gA^3}\,\frac{dA}{dx} \quad ..(3.22)$$

which is the general differential equation for the water surface profile along the side weir location in the main channel. Depending upon the value of $\frac{dA}{dx}$, the final expression for $\frac{dd}{dx}$ can be derived for either prismatic or tapering channels.

3.3.1 Tapering channels

In this case, the main channel breadth decreases uniformly along the side weir and the cross sectional area, A, becomes a function of both the geometry of the section and its location along the side weir.

From Fig.(3.7), the area of a rectangular or trapezoidal section is given by:

$$A = (B + zd)d - \frac{1}{2}\,z(d - c)^2$$

where the side slope z is zero in case of rectangularity.

Differentiate w.r.t. B,

$$\frac{\partial A}{\partial B} = d$$

Differentiate w.r.t. d,

$$\frac{\partial A}{\partial d} = B + 2zd - z(d - c)$$

$$= T$$

Since $A = f(B,d)$

then $\frac{dA}{dx} = \frac{\partial A}{\partial B}\,\frac{dB}{dx} + \frac{\partial A}{\partial d}\,\frac{dd}{dx}$

$$= d\,\frac{dB}{dx} + T\,\frac{dd}{dx}$$

Substituting for $\frac{dA}{dx}$ in Eq.(3.22),

$$\frac{dd}{dx} = \frac{S_o - S_f - \frac{1}{gA}\,(2.BETA.V-U)\,\frac{dQ}{dx} + BETA\,\frac{V^2 d}{gA}\,\frac{dB}{dx}}{1 - BETA.Q^2T/(gA^3)} \qquad ..(3.23)$$

The expression for the area of flow in a pipe with free surface is:

$$A = \frac{D^2}{4}\cos^{-1}\frac{D-2d}{D} + \frac{1}{2}\,(2d-D)(Dd-d^2)^{1/2}$$

where D is the pipe diameter. Differentiate w.r.t. D,

$$\frac{\partial A}{\partial D} = \frac{D^2}{4}\,(-1)\left(1-\left(\frac{D-2d}{D}\right)^2\right)^{-1/2}\left(\frac{2d}{D^2}\right) + \frac{2D}{4}\cos^{-1}\frac{D-2d}{D} +$$

$$\frac{1}{2}\,(2d-D)\left(\frac{d}{2}\right)(Dd-d^2)^{-1/2} + \frac{1}{2}\,(-1)(Dd-d^2)^{1/2}$$

Collecting terms,

$$\frac{\partial A}{\partial D} = \frac{D}{2}\cos^{-1}\frac{D-2d}{D} - (Dd-d^2)^{1/2}$$

$$= \frac{D}{2}\cos^{-1}\frac{D-2d}{D} - \frac{T}{2} \qquad ..(3.24)$$

Differentiate w.r.t. d,

$$\frac{\partial A}{\partial d} = \frac{D^2}{4}\,(-1)\left(1-\left(\frac{D-2d}{D}\right)^2\right)^{-1/2}\left(\frac{-2}{D}\right) + \frac{1}{4}\,(2d-D)(D-2d)(Dd-d^2)^{1/2}$$

$$+ \frac{1}{2}\,(2)(Dd-d^2)^{1/2}$$

Collecting terms,

$$\frac{\partial A}{\partial d} = 2(Dd-d^2)^{1/2}$$

$$= T$$

Since $A = f(D,d)$

$$\text{then } \frac{dA}{dx} = \frac{\partial A}{\partial D}\frac{dD}{dx} + \frac{\partial A}{\partial d}\frac{dd}{dx}$$

$$= \frac{\partial A}{\partial D}\frac{dD}{dx} + T\frac{dd}{dx}$$

Subsituting for $\frac{dA}{dx}$ in Eq.(3.22),

$$\frac{dd}{dx} = \frac{S_o - S_f - \frac{1}{gA}(2.BETA.V - U)\frac{dQ}{dx} + BETA\frac{V^2}{gA}\frac{\partial A}{\partial D}\frac{dD}{dx}}{1 - BETA.Q^2T/(gA^3)} \quad (3.25)$$

where $\frac{\partial A}{\partial D}$ is given by Eq.(3.24) and $\frac{dD}{dx}$ is the rate of change of diameter along the side weir.

3.3.2 Prismatic Channels

In this case the channel breadth is constant, that is, $\frac{dB}{dx} = 0$ (Eq.(3.23)) and $\frac{dD}{dx} = 0$ (Eq.(3.25)). Both equations will reduce to:

$$\frac{dd}{dx} = \frac{S_o - S_f - \frac{1}{gA}(2.BETA.V - U)\frac{dQ}{dx}}{1 - BETA.Q^2T/(gA^3)} \quad ...(3.26)$$

which is applicable to any prismatic triangular, rectangular, trapezoidal or circular channel.

3.4 DeMarchi Discharge Coefficient C_M

The coefficient of discharge is important in estimating the overflow. Yet no relationships to evaluate the discharge coefficient for a given flow condition are available.

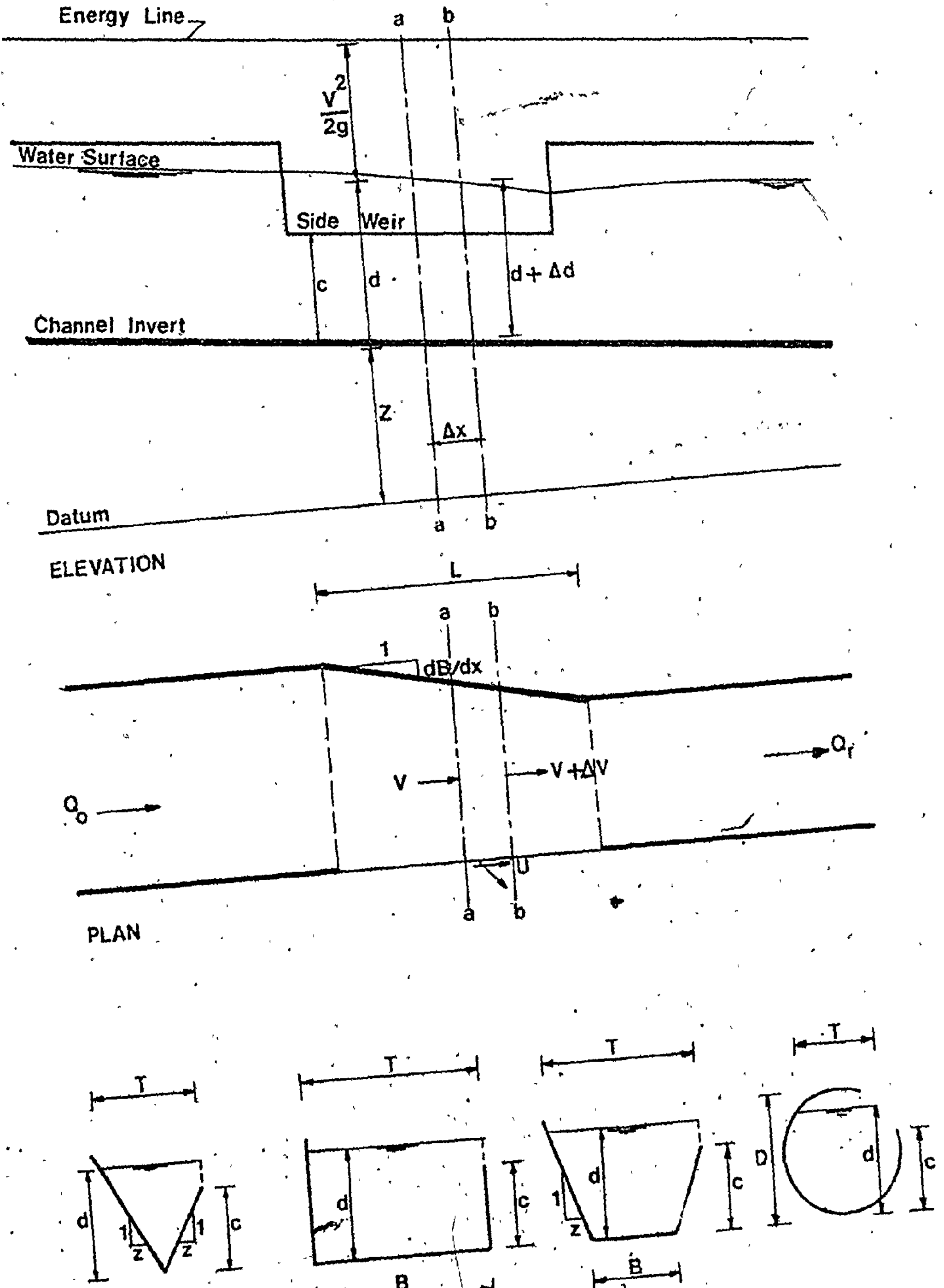


Fig.(3.7) Definition Sketch of a Channel with Side Weir

3.4.1 Historical Review

Collinge (1957) related C_M to the Froude Number F_1 at the upstream end of the side weir and recommended an average value for C_M of 0.616 for F_1 less than 0.95 and greater than 1.15. Frazer (1957) conducted a large number of experiments and finally proposed values of C_M ranging from 0.424 to 0.647 for subcritical flow in the main channel and from 0.806 to 0.555 for supercritical flow. In 1972, Subramanya and Awasthy gave special emphasis to defining the variation of the DeMarchi coefficient C_M for a rectangular, prismatic, horizontal, frictionless channel. The formula for the discharge over the side weir unit length is given by Eq.(3.11). A total of 200 experiments conducted on two horizontal channels resulted in the following conclusions.

(i) The variation of the DeMarchi coefficient C_M with the FroudeNumber F_1 at the upstream end of the side weir, for subcritical flow is given by the equation:

$$C_M = 0.611\ (1 - (\frac{3F_1^2}{F_1^2+2}))^{1/2} \qquad \ldots(3.27)$$

(ii) For supercritical flow and $F_1 > 2$, the variation is:

$$C_M = 0.36 - 0.08\ F_1 \qquad \ldots(3.28)$$

Fig.(3.8) shows such variations.

3.4.2 Proposed Relationships

Before stating these relationships, which are based on Subramanya's experimental work, it is important to mention the following points:

(i) If F_1 takes any value between 1.0 and 2.0 the Subramanya relations do not apply.

(ii) If F_1 takes values between 0.6 and 1.0, the Subramanya C_M will range between 0.45 and 0.0, values that seem to be impractial.

(iii) Between $F_1 = 0.6$ and 1.0 the Subramanya relations are not supported by any experimental points.

(iv) C_M should increase as F_1 decreases from 1.6 to 1.0.

Therefore, it was seen convenient to suggest four expressions to complete the range of F_1 as shown in Fig. (3.9). These expressions are:

$$C_M = 0.611 \left(1 - \left(\frac{3F_1^2}{F_1^2+2}\right)\right)^{1/2} \qquad F_1 < 0.60 \qquad ..(3.29)$$

$$C_M = 0.45 - 0.06\ (F_1 - 0.6) \qquad 0.60 \leq F_1 < 1.0 \qquad ..(3.30)$$

$$C_M = 0.950\ \left(2 - \left(\frac{3F_1^2}{F_1^2+2}\right)\right)^{1/2} \qquad 1.0 \leq F_1 < 1.8 \qquad ..(3.31)$$

$$C_M = 0.362 - 0.018\ (F_1 - 1.8) \qquad F_1 \geq 1.8 \qquad ..(3.32)$$

3.5 Relationships for the Forward Velocity Component U of the Spill Flow

All the terms of Eq.(3.26) can be evaluated by means of a computer program except for the forward component of flow velocity going over the side weir U along the channel direction. In order to develop the program, a relation is required between the velocity U and some other hydraulic parameters which can be measured or calculated directly.

Before considering the relations derived by El-Khashab, the following important points should be mentioned.

(i) The ratio of the discharge spilling over the weir Q_s to the discharge upstream of the weir Q_1 is an important factor governing the flow along the weir and affects the ratio and relations between the other hydraulic parameters; e.g. the flow along the weir for $Q_s/Q_1 = 0.25$ is different in behaviour when $Q_s/Q_1 = 0.75$.

(ii) From the flow patterns of the velocity vector V and the forward velocity component along the weir U, it is obvious that for Q_s/Q_1 greater than 0.5, the variation of the velocity U along the weir crest is a function of the velocity at the upstream end of the weir, V_1. Fig.(3.10b) presents the relation between the ratios $(d-c)/(d_1-c)$ and V_1/U.

(iii) The velocity U decreases along the side weir in the downstream direction. Also, proceeding downstream along the weir, the spill flow decreases.

(iv) For subcritical flow when the ratio of Q_s/Q_1 is less than 0.5; due to the large amount of water flowing in the main channel, it was found that the velocity U at any section along the weir depends to a large extent on the mean velocity at that section, V. The velocity U decreases along the weir crest in the downstream direction in a similar way to the reduction in the mean velocity V. Fig.(3.10a) presents the relation between the ratios d/c and U/V.

(v) For supercritical flow, from the flow patterns along the weir length, it is apparent that U is a function of the mean velocity at any section along the weir, V. The increase of the velocity U compared with the velocity V is nearly constant along the weir length, and this increase depends on the condition of the control section at the upstream end of the weir. It was found that it could be related to F_1, the Froude Number at the upstream end of the weir. See Fig.(3.11).

Table (3.1) presents a summary of the relationships that El-Khashab derived by means of curve fitting to the data points shown in Figs.(3.10) and (3.11).

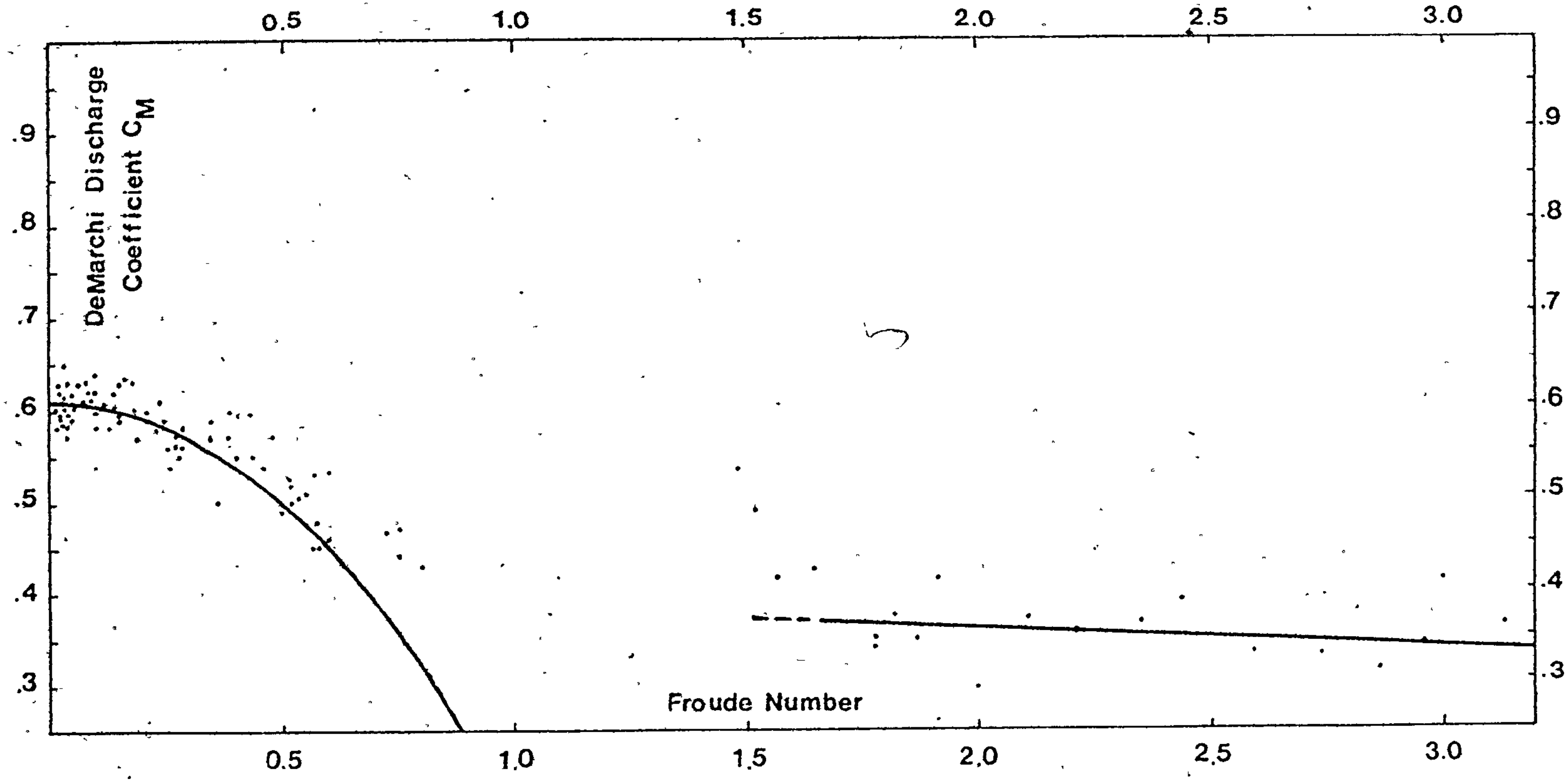


Fig.(3.8) Variation of DeMarchi Discharge Coefficient C_M with the Froude Number

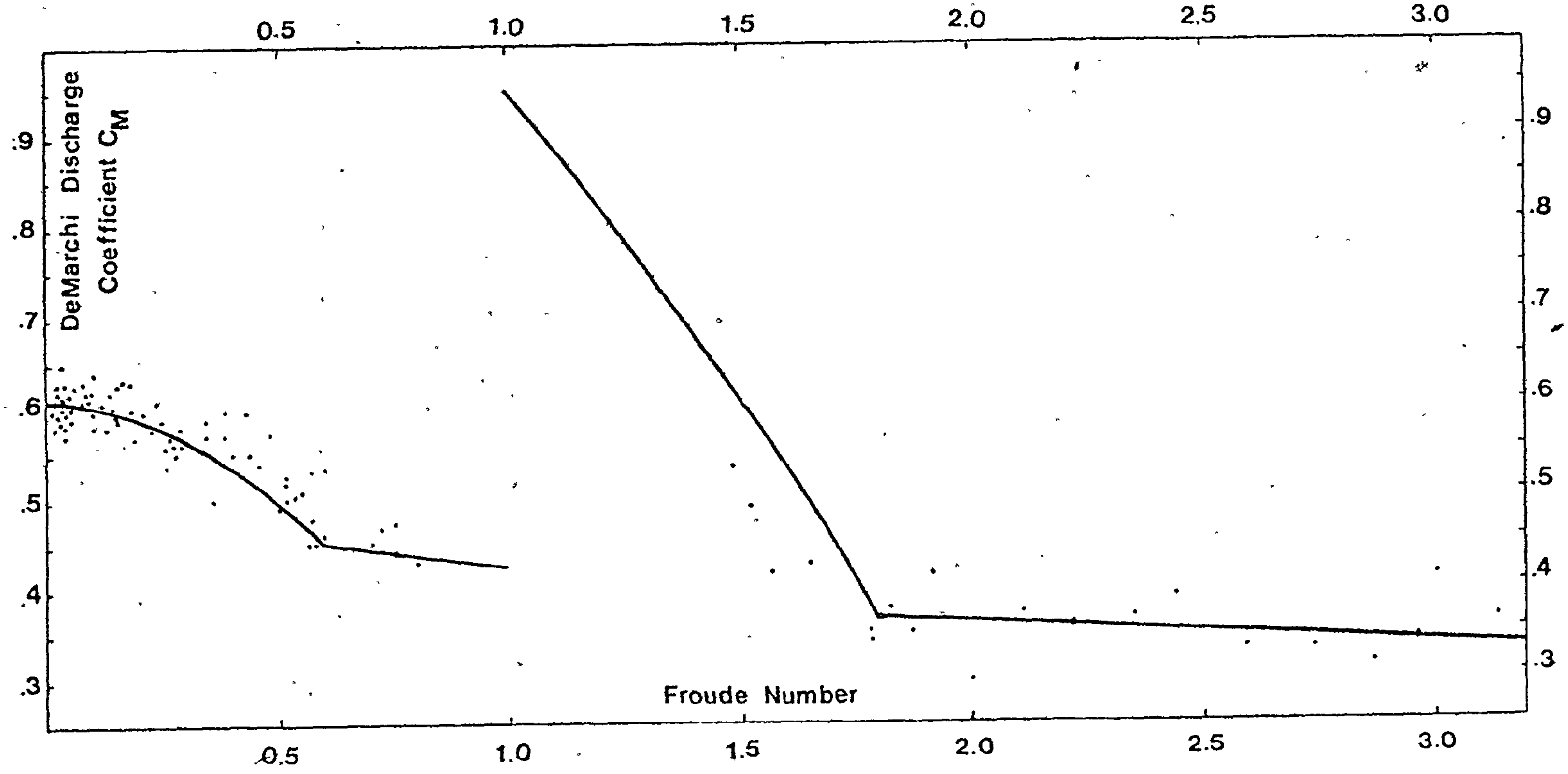


Fig.(3.9) Proposed Relationships for DeMarchi Discharge Coefficient C_M

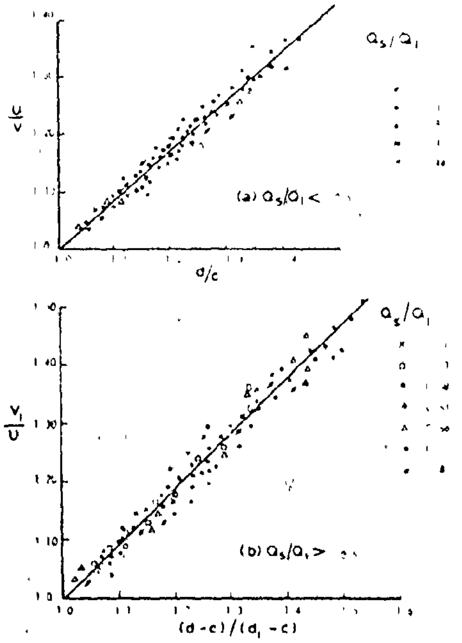


Fig.(3.10) Relationships for Spill Flow Forward Velocity - Subcritical Flows

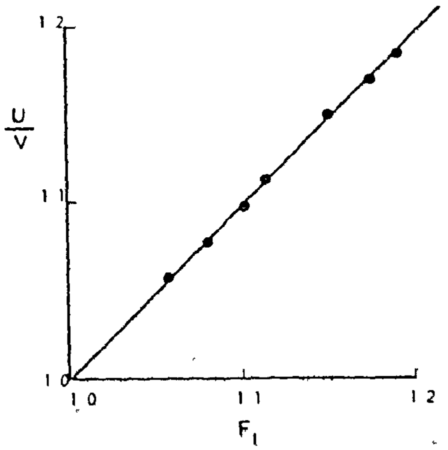


Fig.(3.11) Relationships for Spill Flow Forward Velocity - Supercritical Flows

Approach Channel	Along Side Weir	Q_s/Q_1	Relationship
Subcritical	Subcritical	less than 0.50	$U = 0.91 \frac{d}{c} V$
Subcritical	Subcritical	more than 0.50	$U = 1.08 \frac{d_1 - c}{d - c} V_1$
Subcritical	Supercritical	—	$U = F_1 . V$
Supercritical	Supercritical	—	$U = V$

Table(3.1) Relationships for Spill Flow Forward Velocity Component

3.6 Hydraulic Jump

It is important to know where a hydraulic jump will form. If the jump forms in the downstream channel, there will be no effect on the computation methods presented in earlier sections. If the jump forms along the side weir, the actual overflow will be greater than the computed one. Therefore, the formation of hydraulic jump must be predicted in order to decide whether or not the computed overflow is correct. The method of prediction developed in this study is based on these assumptions:

1- The necessary condition for a hydraulic jump to form is that the flow should be supercritical upstream of the jump and subcritical downstream of it.

2- The sufficient condition for the formation of jump is that the backwater curve AB should cross the curve of depths CD conjugate to profile EF as shown in Fig.(3.12). The point of intersection G is the upstream end of the jump.

3- The length of the jump, L_j, is six times its height, i.e.

$$L_j = 6\ (d_6 - d_5) \qquad \ldots(3.33)$$

where d_5 and d_6 are the depths of water at the upstream and downstream ends of the jump respectively.

4- The water surface profile along the hydraulic jump is a straight line (HI in Fig.(3.12)). The slope of this line is 1/6.

3.6.1 General Momentum Equation

Considering two sections, (5-5) and (6-6), at the

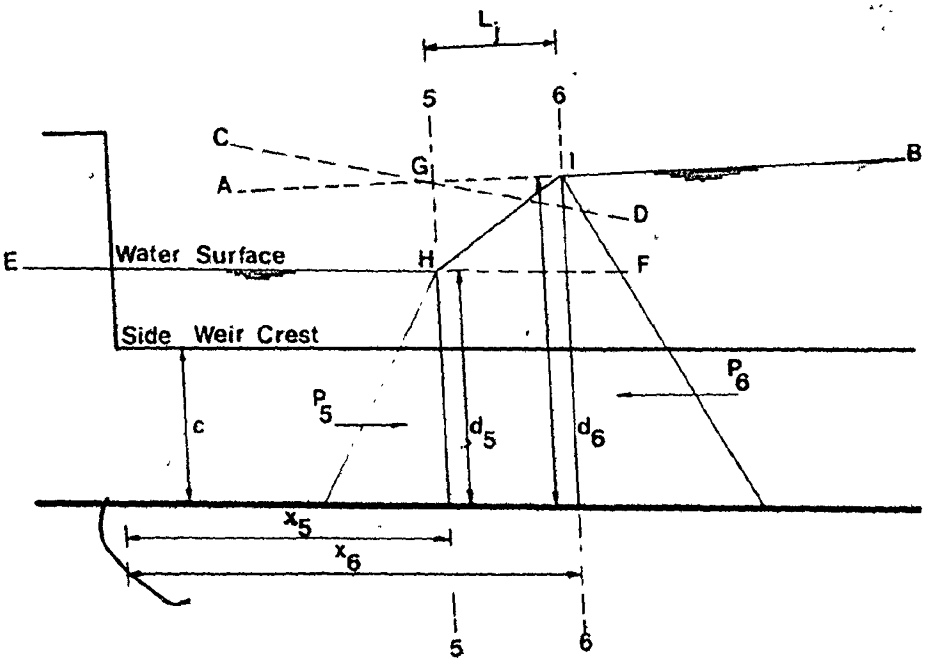


Fig.(3.12) Hydraulic Jump in a Channel with Side Weir

upstream and downstream end of the hydraulic jump with discharges Q_5 and Q_6 respectively, the momentum equation parallel to the channel invert can be written:

Rate of change of momentum - Momentum loss due to discharge over the side weir = Sum of external forces

i.e.

$$\mathrm{BETA.RHO.}Q_6V_6 - \mathrm{BETA.RHO.}Q_5V_5 - \mathrm{RHO.}Q_{sj}\ U$$
$$= P_5 - P_6 + w \sin(\mathrm{THETA}) - F_f \qquad \ldots(3.34)$$

where P_5 and P_6 are the hydrostatic pressure forces acting on the cross sectional areas of 5-5 and 6-6,

$$P_5 = RHO.g.A_5\ \overline{d}_5 \qquad \ldots(3.35)$$

where $\overline{d}_5$ is the vertical distance from the water surface to the centroid of section (5-5).

Similarly,

$$P_6 = RHO.g.A_6\ \overline{d}_6 \qquad \ldots(3.36)$$

From the continuity equation,

$$Q_6 = Q_5 + Q_{sj}$$

Subsituting for P_5, P_6 and Q_6 in Eq.(3.34), neglecting the terms w sin (THETA) and F_f, assuming BETA = 1.0 and dividing through by RHO, Eq.(3.34) becomes:

$$Q_5V_5 + gA_5\ \overline{d}_5 = Q_5V_6 + (V_6 \geq U)Q_{sj} + gA_6\ \overline{d}_6 \quad \ldots(3.37)$$

which is the general momentum equation for a hydraulic jump forming along a side weir in a channel of any shape. The velocities V_5 and V_6 may be replaced by Q_5/A_5 and Q_6/A_6 respectively. The spill flow froward velocity component, U, is obtained from Table (3.1). All that is now required is to derive an expression for Q_{sj}, the total overflow along the jump, in order to solve Eq.(3.37) and obtain the conjugate depth d_6.

3.6.2 Overflow Along the Hydraulic Jump

Referring to Eq.(3.11), the overflow per unit length is given by:

$$\frac{dQ}{dx} = \frac{-2}{3} C_M \sqrt{2g} \; (d-c)^{1.5}$$

From Fig.(3.12),

$$\frac{d-d_5}{x-x_5} = \text{slope of the line HI}$$

$$= \frac{1}{6}$$

$$d-d_5 = \frac{1}{6} (x-x_5)$$

$$\text{Thus } \frac{dQ}{dx} = \frac{-2}{3} C_M \sqrt{2g} \; \left(\frac{1}{6} (x-x_5) + d_5-c\right)^{1.5}$$

The total overflow Q_{sj} between sections (5-5) and (6-6) becomes:

$$Q_{sj} = \int_{x_5}^{x_6} \left(\frac{dQ}{dx}\right) dx$$

$$= \int_{x_5}^{x_6} \frac{-2}{3} C_M \sqrt{2g} \; \left(\frac{1}{6} (x-x_5) + d_5-c\right)^{1.5} dx$$

$$= \frac{-2}{3} C_M \sqrt{2g} \; \frac{6}{2.5} \left(\left(\frac{1}{6} (x_6 - x_5) + d_5 - c\right)^{2.5} - (d_5-c)^{2.5}\right)$$

But $x_6 - x_5 = L_j$

$$= 6 \; (d_6 - d_5)$$

Substituting for x_6-x_5,

$$Q_{sj} = \frac{-2}{3} C_M \sqrt{2g} \; \frac{6}{2.5} \left((d_6-c)^{2.5} - (d_5-c)^{2.5}\right)$$

$$= - 2.2627 \; C_M \sqrt{g} \left((d_6-c)^{2.5} - (d_5-c)^{2.5}\right) \qquad \ldots(3.38)$$

CHAPTER IV

COMPUTER PROGRAM OVRFLO3

4.1 Introduction

The computer program developed in this study is based on a program first developed in 1973 by K.V.H. Smith (OVRFLO1) and based on the assumption that the total energy in a side weir channel remains constant, apart from friction losses. In 1976, the program was modified by El-Khashab (OVRFLO2) when he discovered that at any section along the side weir, the longitudinal component of velocity of the spill flow is greater than the mean velocity in the side weir channel as previously shown in Section (3.5). The difference between these velocities was taken into account in the new program, called OVRFLO3. Given the geometry of the main channel and side weir, the water surface profile along the side weir and the spill flow Q_s can be computed for each incident flow Q_o in the upstream channel. Table (4.1) shows the main modifications introduced in the newly developed program.

In this Chapter, a complete description of the control logic and the subroutines is presented, followed by a set of verification tests. Six subroutines are called by the control logic, namely DCRIT, DNORM, WSP, ENDCONT, DCONJ and COEFF.

	OVRFLO1	OVRFLO2	OVRFLO3
Approach for Water Surface Computation	Constant energy less friction	Momentum balance	Momentum balance
Main Channel Section	Rectangular Trapezoidal	Rectangular Trapezoidal	Rectangular Trapezoidal Triangular
Channel Bed Along Side Weir	Prismatic Tapering	Prismatic	Prismatic Tapering
Coefficient of Discharge	Assumed	Assumed	Computed

Table (4.1) Comparison Between the Programs

4.2 Modes of Flow and Control Points

The classification of flow types can be seen in broad terms from the general equation for the water surface profile. Referring to Eq.(3.26) which is valid for prismatic channels (i.e. dB/dx = 0),

$$\frac{dd}{dx} = \frac{S_o - S_f - (2.BETA.V - U)\frac{1}{gA}\frac{dQ}{dx}}{1 - BETA.Q^2T/(gA^3)} = \frac{G_1}{G_2} \qquad \ldots(4.1)$$

In normal cases the invert and friction slope terms are much smaller than the term in dQ/dx and for a general appreciation of the flow situation they may be neglected.

Considering first a channel in which the width remains constant and assuming BETA = 1 in the following discussion, the numerator G_1 in Eq.(4.1) is positive. Therefore, dd/dx will be positive if:

$1 - Q^2T/(gA^3) > 0$

$1 - F^2 > 0$

i.e. $F < 1$

where F is the Froude Number. Hence there will be a rising profile along the weir if the flow is subcritical. Similarly, dd/dx will be negative (a falling profile along the weir) if the flow is supercritical.

There are six possible flow profiles to consider, as shown in Fig.(4.1).

4.2.1 Case (1): Subcritical Profile Throughout

If the main channel bed slope is mild and the side weir height is greater than the critical depth for the flow at the upstream end of the side weir, then it is impossible for the flow to draw down to critical depth. Flow will be subcritical throughout with a rising profile along the weir, Fig.(4.1a).

4.2.2 Case (2): Subcritical/Supercritical Profile

If the side weir height is less than the critical depth, the flow will draw down to the critical depth a short distance upstream of the weir approximately L/10, Fig.(4.1b). The water depth at the upstream end of the weir will be less than critical depth. The ratio d_1/d_c at upstream end is found to range experimentally from 0.90 to 0.97. An average value of 0.93 is used here. The condition necessary for critical flow is $F = 1$. Accordingly,

$$1 - Q^2T/(gA^3) = 0 \qquad \ldots(4.2)$$

At a critical depth control point, by Eq.(4.2), the denominator G_2 in Eq.(4.1) is zero. Such a point therefore represents a singularity in that both G_1 and G_2 must be simultaneously zero if the water surface slope is to remain finite. In the approach channel just before the side weir, the numerator of the slope term is:

$$G_o = S_o - S_f \qquad \ldots(4.3)$$

since other terms in numerator of Eq.(4.1) are equal to zero. Just downstream of the start of the side weir, the numerator of the slope term is:

$$G_1 = S_o - S_f - (2V - U)\,\frac{1}{gA}\,\frac{dQ}{dx} \qquad \ldots(4.4)$$

If for the given discharge in the approach channel, the critical depth d_c is found, Eq.(4.2) is automatically satisfied. For the depth d_c, G_o and G_1 may be evaluated. On a mild slope, G_o will be negative. Therefore, if G_1 is positive a control will exist at the upstream end of the side weir because the numerator G_1 of Eq.(4.1) passes through zero at this point.

However, if G_1 is negative, the flow on the weir should remain subcritical.

4.2.3 Case (3): Subcritical/Supercritical Profile and Hydraulic Jump

The conditions of this case are similar to those of case (2) except that the hydraulic jump forms along the side weir, see Fig.(4.1c). The formation of hydraulic jump is predicted by comparing the normal depth at the downstream end, d_{n4}, to the maximum conjugate depth obtained along the side weir, d_{6max}. If d_{6max} is greater than d_{n4}, then a hydraulic jump will form along the weir and its upstream end is defined by the point where the backwater curve from the downstream channel crosses the curve of depths conjugate to the supercritical profile as previously explained in Section (3.6).

4.2.4 Case (4): Supercritical Profile Throughout

In this case, the flow in the approach channel is supercritical and it will draw down as a supercritical flow along the weir (falling profile), starting from the normal depth of flow in the approach channel. In the downstream channel, the profile will rise to normal depth as shown in Fig.(4.1d).

4.2.5 Case (5): Supercritical Profile and Hydraulic Jump

This is similar to case (4) conditions with mild bed slope in the downstream channel. The normal depth d_{n4} and the conjugate depth d_6 at the downstream end are compared. If $d_{n4} > d_6$, then a hydraulic jump will form along the weir and the flow will be subcritical after the jump, see

Fig.(4.1e).

4.2.6 Case (6): Supercritical Profile and Hydraulic Jump in Downstream Channel

In this case, the normal depth d_{n4} is less than the depth d_6 conjugate to the supercritical profile at the downstream end. Therefore, the flow will be supercritical along the weir and the hydraulic jump will form in the downstream channel as shown in Fig.(4.1f).

In all cases it is desirable to compare the normal depth of flow d_{n1} at the upstream end of the weir with the height c of the weir. If d_{n1} is less than c, the computation can be terminated. In addition, the condition of flow in the channel downstream of the weir needs to be considered. For a subcritical profile, case (1), the depth of flow at the downstream end of the side weir depends on the type of control which is incorcporated in tne downstream channel. The assumption by many investigators that this is determined by "normal" depth of the downstream flow is not necessarily correct.

4.3 Control Logic for Modes of Flow

The control logic is shown in the flow diagram in Fig.(4.2), arranged so as to investigate a number of cases in sequence. After the usual preliminaries of reading in data etc., appropriate subroutines calculate the critical and normal depths of flow in the approach channel. If the normal depth of flow is not substantially greater than the height of the weir ($d_n > 1.1c$ is used here), a statement is printed to this effect. Otherwise, the program is directed to modes (C), (B) or (A) as shown in Fig.(4.2). Additionally, for mode (B) a check is made to see whether Q_1 is positive and if this is not so the calculation is redirected to a subcritical profile. In cases (B) and (C) all that is now required is a routine calculation of a supercritical water profile followed by a calculation of the normal and conjugate depths of flow in the downstream channel. The procedure adopted for a subcritical profile, mode (A), is that a value for d_4 is assumed, Q_4 calculated from the characteristics of the downstream channel and then a backwater curve is computed to position 1. Q_1 is then compared with the actual flow in the approach channel Q_o and the procedure is repeated using different values of d_4 until Q_1 and Q_o agree sufficiently accurately.

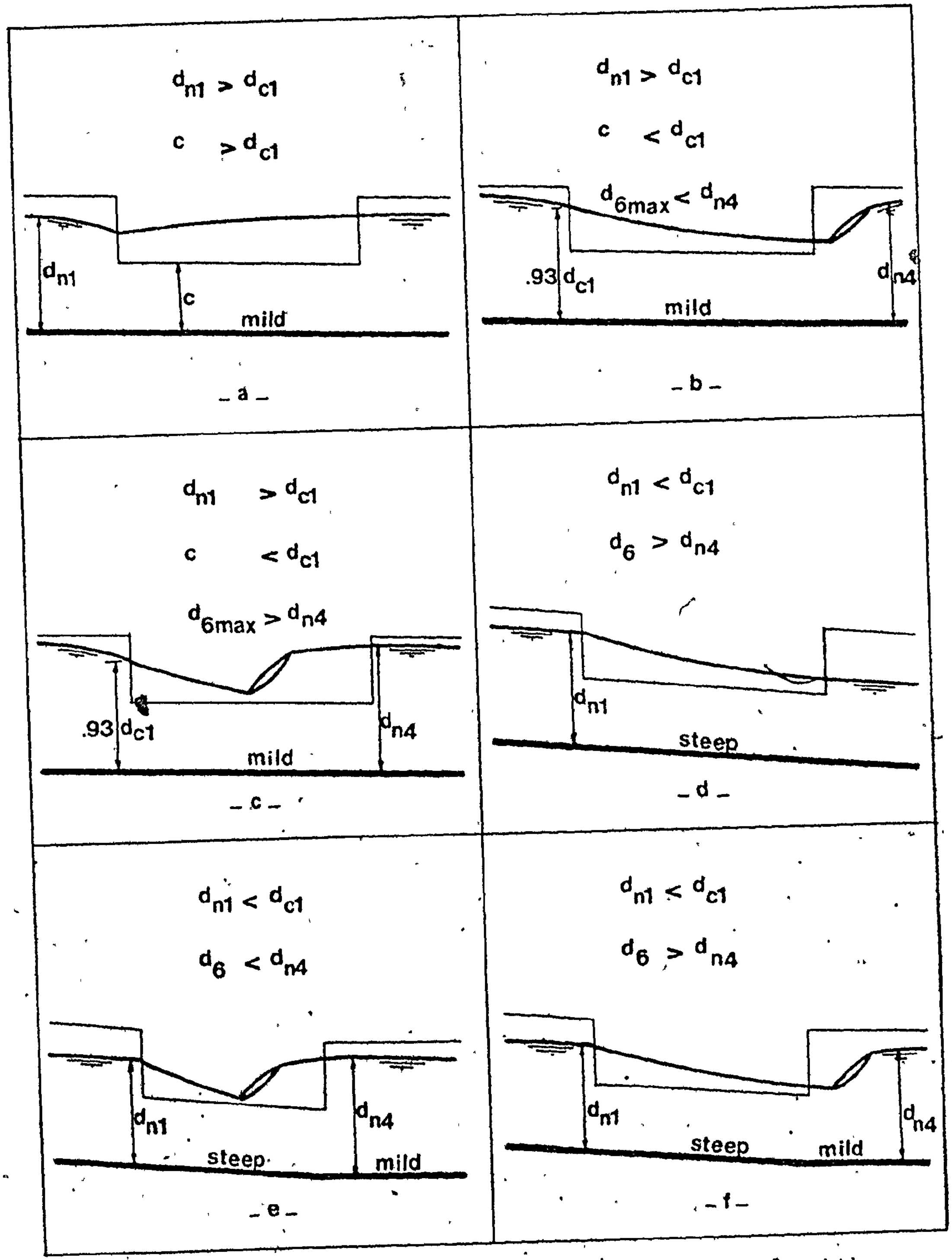
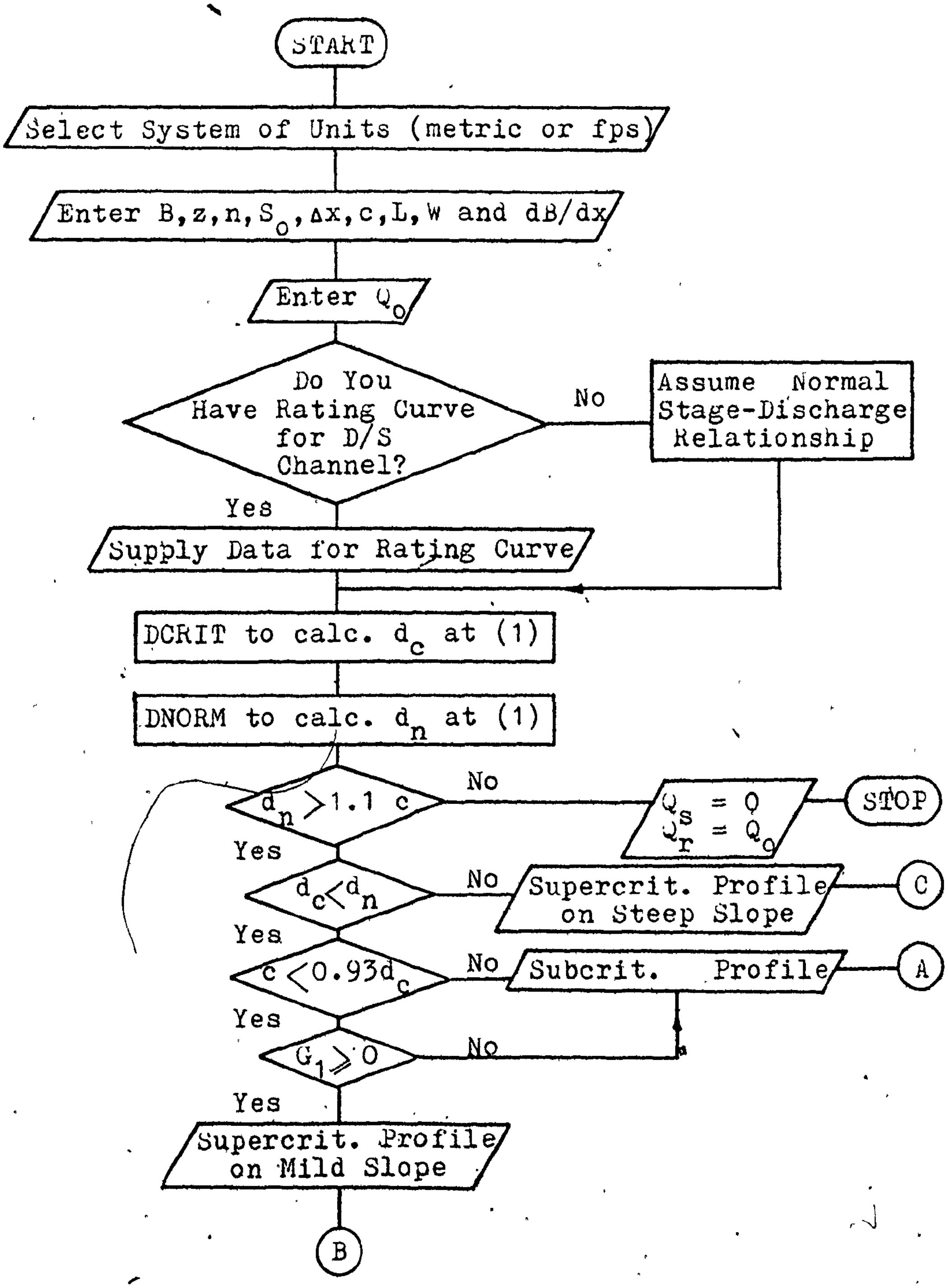
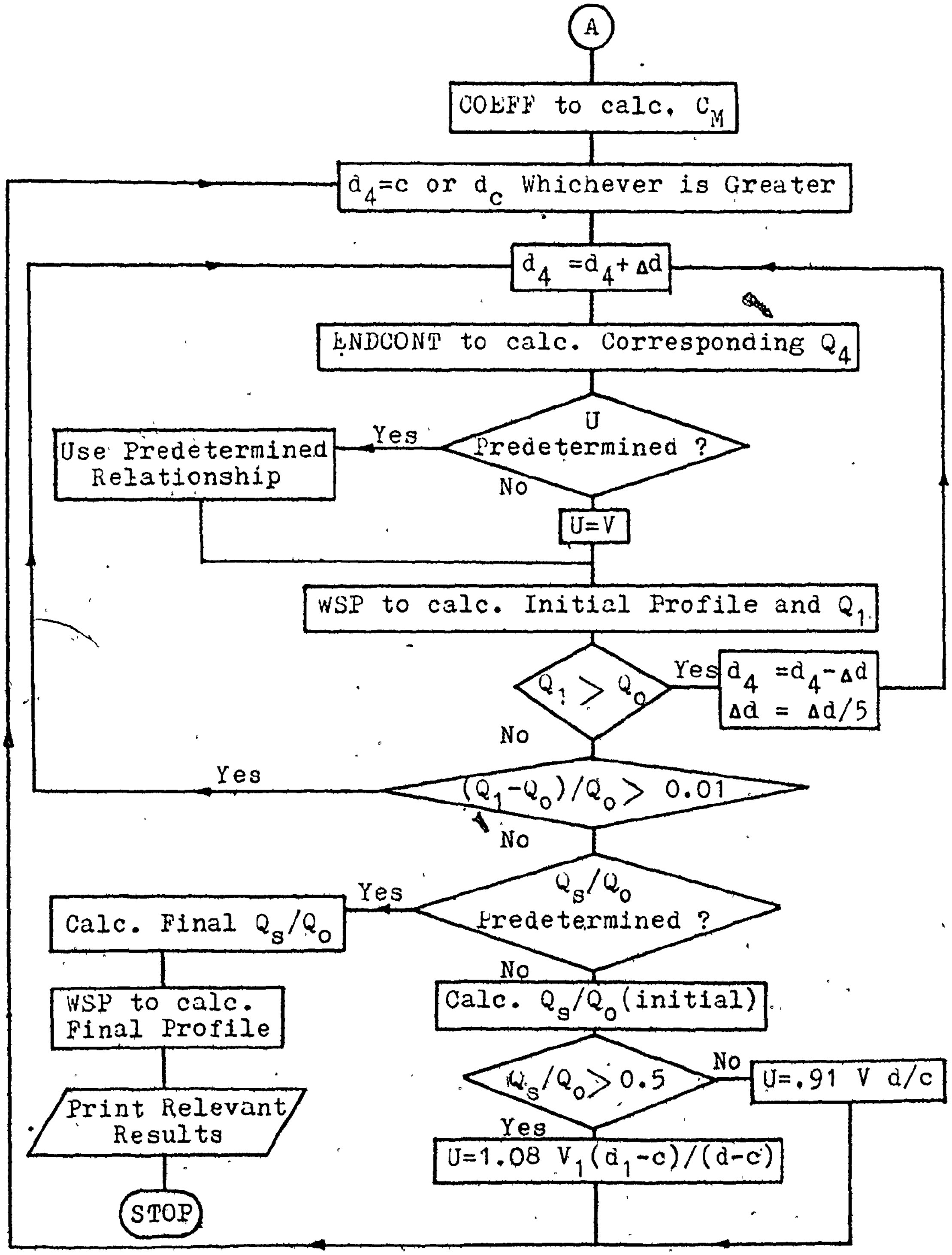
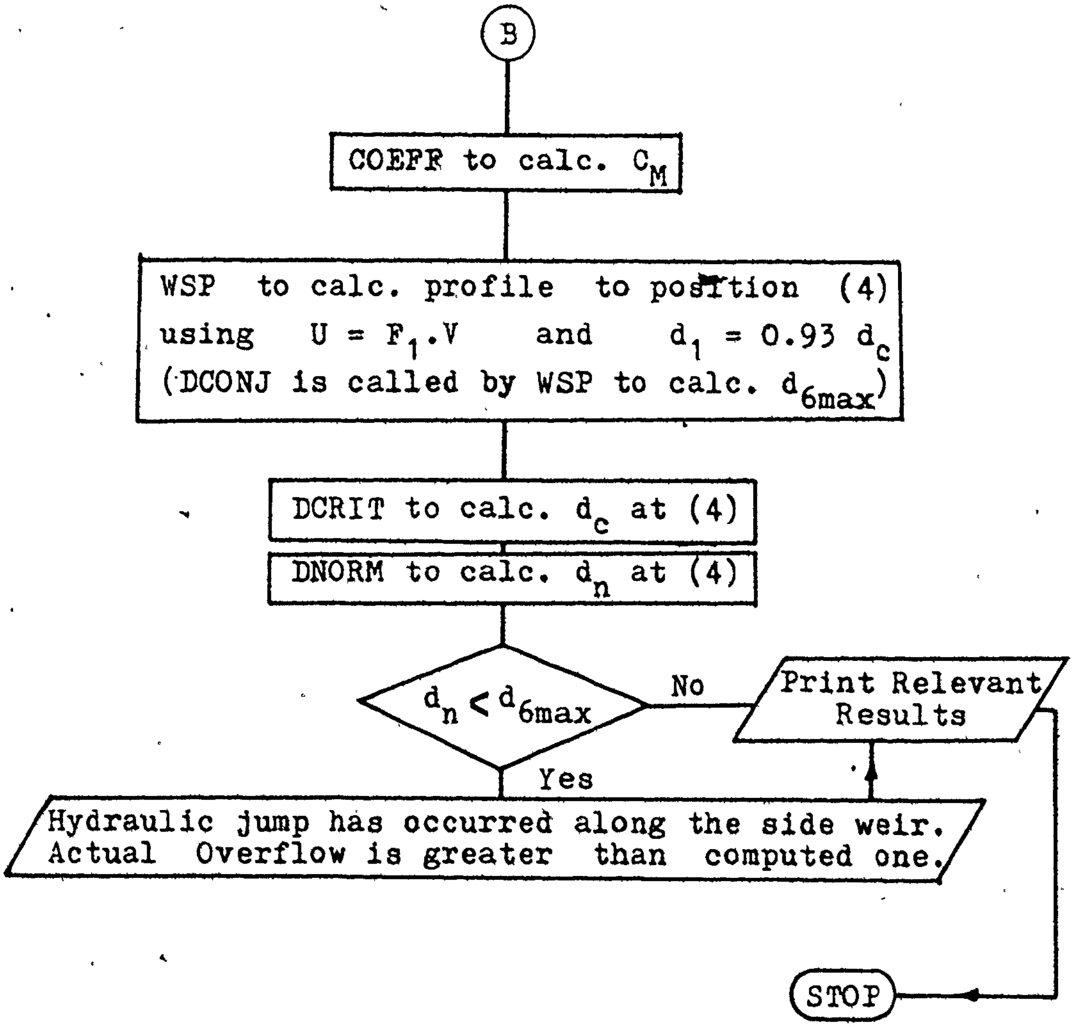


Fig.(4.1) Various Flow Profiles in a Channel with Side Weir


START
Select System of Units (metric or fps)
Enter B, z, n, S₀, Δx, c, L, W and dB/dx
Enter Q₀
Do You Have Rating Curve for D/S Channel?
No
Assume Normal Stage-Discharge Relationship
Yes
Supply Data for Rating Curve
DCRIT to calc. d_c at (1)
DNORM to calc. d_n at (1)
d_n > 1.1 c
No
Q_s = 0
Q_r = Q₀
STOP
Yes
d_c < d_n
No
Supercrit. Profile on Steep Slope
C
Yes
c < 0.93d_c
No
Subcrit. Profile
A
Yes
G₁ ≥ 0
No
Yes
Supercrit. Profile on Mild Slope
B


A
COEFF to calc. C_M
d_4=c or d_c Whichever is Greater
$d_4 = d_4 + \Delta d$
ENDCONT to calc. Corresponding Q_4
U Predetermined ?
Yes
Use Predetermined Relationship
No
U=V
WSP to calc. Initial Profile and Q_1
$Q_1 > Q_o$
Yes
$d_4 = d_4 - \Delta d$
$\Delta d = \Delta d/5$
No
$(Q_1-Q_o)/Q_o > 0.01$
Yes
No
Q_s/Q_o Predetermined ?
Yes
Calc. Final Q_s/Q_o
No
Calc. Q_s/Q_o(initial)
WSP to calc. Final Profile
$Q_s/Q_o > 0.5$
No
U=.91 V d/c
Yes
$U=1.08\ V_1(d_1-c)/(d-c)$
Print Relevant Results
STOP


B
COEFF to calc. C_M
WSP to calc. profile to position (4) using $U = F_1 . V$ and $d_1 = 0.93\ d_c$ (DCONJ is called by WSP to calc. d_{6max})
DCRIT to calc. d_c at (4)
DNORM to calc. d_n at (4)
$d_n < d_{6max}$
No
Yes
Print Relevant Results
Hydraulic jump has occurred along the side weir. Actual Overflow is greater than computed one.
STOP

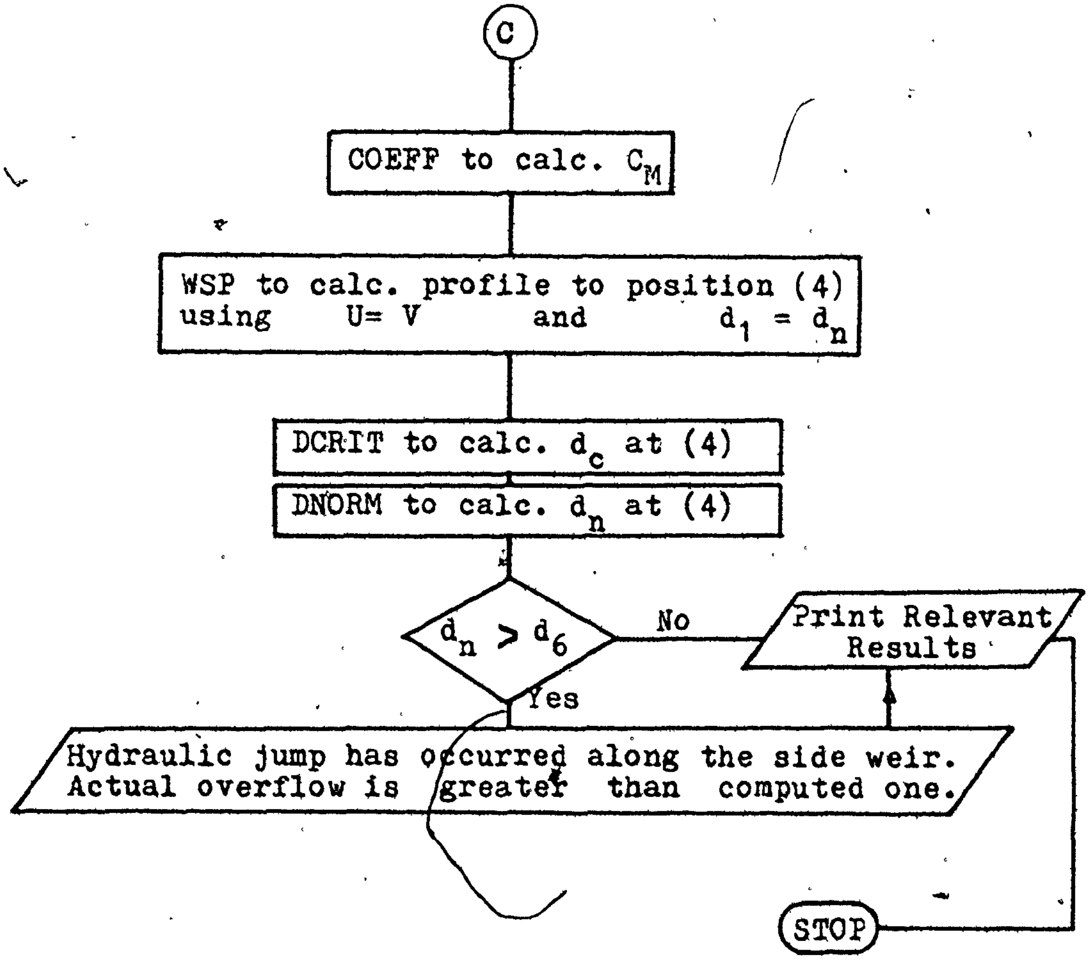


Fig.(4.2) Flow Diagram of Control Logic

4.4 Description of Subroutines

4.4.1 Subroutine DCRIT

This subroutine estimates the critical depth of flow for a given geometry of a rectangular, trapezoidal or triangular section. The technique for trapezoidal section is based on assuming an initial value of critical depth, calculating the square of the section factor Z_s and then comparing it with the constant Q^2/g. Otherwise, the critical depth can be obtained for rectangular section from:

$$d_c = (Q^2/gB^2)^{1/3} \qquad \ldots(4.5)$$

For trapezoidal section, the initial value of critical depth d_{1c} is obtained from Eq.(4.5). The square of the section factor is then calculated.

$$Z_s = \frac{A^3}{T}$$

$$= \frac{A^3}{B+2zd} \qquad \ldots(4.6)$$

Z_s and Q^2/g are then compared and the difference between them is considered a function of critical depth. The root of this function is sought by means of the gradient method as follows.

Difference between Z_s and $Q^2/g = f(d_c)$

$$f(d_c) = A^3/T - Q^2/g$$

$$d_{2c} = d_{1c} - f(d_c)/f'(d_c) \qquad \ldots(4.7)$$

where $f'(d_c) = \frac{d}{dd}(A^3/T - Q^2/g)$

$$= \frac{3A^2}{T} \cdot \frac{dA}{dd} - \frac{A^3}{T^2} \cdot \frac{dT}{dd} \qquad \ldots(4.8)$$

But $dA = T\ dd$

$$\frac{dA}{dd} = T$$

Also $T = B + 2zd$

$$\frac{dT}{dd} = 2z$$

Substituting for dA/dd and dT/dd in Eq.(4.8),

$$f'(d_c) = 3A^2 - 2zZ_s/T \qquad \ldots(4.9)$$

The flow diagram of this subroutine is presented in Fig.(4.3).

4.4.2 Subroutine DNORM

The normal depth of flow is calculated at both upstream and downstream ends of the side weir. The technique is similar to that used in subroutine DCRIT, based on assuming an initial value of normal depth, calculating the conveyance ($\frac{N}{n} \cdot A.R^{2/3}$) and comparing it with the constant ($Q/S_o^{1/2}$). The initial value of normal depth d_{1n} is obtained by assuming a very wide rectangular section where $B \gg d$, $A = Bd$ and $P = B + 2d = B$. Thus $R = A/P = B$

Recall Manning's Equation

$$Q = \frac{N}{n} A\ R^{2/3}\ S_o^{1/2}$$

$$= \frac{N}{n} B\ d\ d^{2/3}\ S_o^{1/2}$$

Collecting terms,

$$d = (Qn/(BNS_o^{1/2}))^{0.60} \qquad \ldots(4.10)$$

where Q is the normal discharge, N= 1.0 for Metric units and 1.486 for English units, S_o is the bed slope, and n is the Manning's roughness coefficient. The conveyance of the section and the constant are then calculated.

$$\text{conv} = \frac{N}{n} AR^{2/3} \qquad \ldots(4.11)$$

$$\text{const} = Q/S_o^{1/2} \qquad \ldots(4.12)$$

conv and const are then compared and if they are not equal a new value of normal depth d_{2n} is obtained from the relation:

$$d_{2n} = d_{1n} \left(\frac{\text{const}}{\text{conv}}\right)^{1/2} \qquad \ldots(4.13)$$

It should be noted that as the ratio const/conv tends to unity d_{2n} tends to d_{1n} until finally $d_{2n} = d_{1n}$ when the ratio const/conv is unity.

For triangular section, the normal depth is obtained directly from the relation:

$$d_n = \left(\frac{Q\, n\, 2^{2/3}(1+z^2)^{1/3}}{N\, z^{5/3}\, S_o^{1/2}} \right)^{3/8} \qquad \ldots(4.14)$$

which is derived from Manning's Equation. Fig.(4.4) shows the flow diagram of this subroutine.

4.4.3 Subroutine WSP

A procedure for calculating the water surface profile must form the basic element of the program. The procedure described by Prasad (1970) is adopted here with the use of the appropriate expression for dd/dx given by Eq. (4.1). Briefly restated, if the flow profile is described by d = f (x), then the depth at position i+1 may be calculated approximately from the depth at position i by the following iterative procedure:

1- Compute $(\frac{dd}{dx})_i$ from Eq.(4.1) in which d_i is given either as an initial condition or from a previous calculation.

2- Assume $(\frac{dd}{dx})_{i+1} = (\frac{dd}{dx})_i$ as a first approximation.

3- Calculate an approximate value of d_i+1 from the equation

$$d_{i+1} = d_i + 0.5\ ((\frac{dd}{dx})_i + (\frac{dd}{dx})_{i+1})\ \Delta x \qquad \ldots(4.15)$$

using the value of $(\frac{dd}{dx})_{i+1}$ from steps 2 or 4

4- Compute a new value of $(\frac{dd}{dx})_{i+1}$ form Eq.(4.1) using the approximate value of d_{i+1} obtained in step 3.

5- If the new value of $(\frac{dd}{dx})_{i+1}$ is not sufficiently close to the previously assumed value in step 2, repeat step 3 through 5. Otherwise, advance the solution by one integration step.

In the program, Eq.(4.15) is written as follows:

$$d_{i+1} = d_i + 0.5\ \mathrm{SIGN}\ ((\frac{dd}{dx})_i + (\frac{dd}{dx})_{i+1})\ \Delta x \quad \ldots(4.16)$$

where the value of SIGN is -1 for computation in an upstream direction and +1 for computation in a downstream direction. The value of SIGN is set by the main program.

For supercritical flow, the control section is upstream of the side weir beginning with the starting depth $d_1 = 0.93\ d_c$, where the 0.93 is the average value of the ratio d_1/d_c. Near the region of critical flow, the spacing between sections is reduced to one-fifth of the spacing normally used. The term dQ/dx is evaluated from the weir formula given in Eq.(3.11). The flow diagram of this subroutine is shown in Fig.(4.5).

4.4.4 Subroutine ENDCONT

The depth discharge relationship in the downstream channel is provided to the program in the form of data points. For a given depth of water, the corresponding discharge is estimated by means of Lagrange polynomial using 4 data points: the preceding and the following 3 data points as shown in Fig,(4.6a). Forsythe, Malcolm and Moler explained this type of nonlinear interpolation. The Lagrange polynomials are ($l_j(x)$, $j = 0,1,2,\ldots n$) of degree n with the property that,

$$l_j(x_i) = 1 \qquad \text{if } i = j$$
$$l_j(x_i) = 0 \qquad \text{if } i \neq j$$

It is easy to see that the nth degree polynomial that satisfies these conditions is:

$$l_j(x) = \frac{(x-x_0)(x-x_1)\ldots(x-x_{j-1})(x-x_{j+1})\ldots(x-x_n)}{(x_j-x_0)(x_j-x_1)\ldots(x_j-x_{j-1})(x_j-x_{j+1})\ldots(x_j-x_n)} \qquad (4.17)$$

Each factor in the numerator makes $l_j(x_i)$ zero for some $i \neq j$, while for $i = j$, corresponding factors in the denominator normalise the result so that $l_j(x_i) = 1$. The polynomial $l_j(x)\, y_i$ takes on the value y_i at the point x_i

and is zero at all points $x_i (i \neq j)$. The interpolating polynomial of degree n which passes through the (n+1) points (x_i , y_i) is given by:

$$y(x) = \sum_{j=0}^{n} l_j(x).y_j$$

For n = 3 i.e. 4 data points

$$y(x) = \frac{(x - x_1)(x - x_2)(x - x_3)y_0}{(x_0 - x_1)(x_0 - x_2)(x_0 - x_3)} +$$

$$\frac{(x - x_0)(x - x_2)(x - x_3)y_1}{(x_1 - x_0)(x_1 - x_2)(x_1 - x_3)} +$$

$$\frac{(x - x_0)(x - x_1)(x - x_3)y_2}{(x_2 - x_0)(x_2 - x_1)(x_2 - x_3)} +$$

$$\frac{(x - x_0)(x - x_1)(x - x_2)y_3}{(x_3 - x_0)(x_3 - x_1)(x_3 - x_2)} + \qquad \ldots(4.18)$$

Referring to Fig.(4.6a), one can set up the following relations:

$$x_0 - x_1 = - \Delta x$$

$$x_0 - x_2 = -2\Delta x$$

$$x_0 - x_3 = -3\Delta x$$

and

$$\frac{x - x_0}{\Delta x} = t$$

$$\frac{x-x_1}{\Delta x} = \frac{x-x_o-\Delta x}{\Delta x} = t-1$$

Similarly,

$$\frac{x-x_2}{\Delta x} = t-2$$

$$\frac{x-x_3}{\Delta x} = t-3$$

Substituting in the polynomial gives:

$$y(x) = \frac{-1}{6} y_o(t-1)(t-2)(t-3) + \frac{1}{2} t(t-2)(t-3) y_1$$

$$\frac{-1}{2} t(t-1)(t-3) y_2 + \frac{1}{6} t(t-1)(t-2) y_3 \qquad \ldots(4.19)$$

Collecting terms of t, t(t-1) and t(t-1)(t-2) results in:

$$y(x) = y_o + t(y_1-y_o) + \frac{1}{2} t(t-1)(y_o-2y_1+y_2)$$

$$+ \frac{1}{6} t(t-1)(t-2)(y_3-y_o+3y_1-3y_2) \qquad \ldots(4.20)$$

Applying this form of polynomial, the discharge Q(d) at any point is given by:

$$Q(d) = Q_o + t(Q_1-Q_o) + \frac{1}{2} t(t-1)(Q_o-2Q_1+Q_2)$$

$$+ \frac{1}{6} t(t-1)(t-2)(Q_3-Q_o+3Q_1-3Q_2) \qquad \ldots(4.21)$$

where Q_o, Q_1, Q_2 and Q_3 are data points that correspond to d_o, d_1, d_2 and d_3 respectively, and $t = (d-d_o)/\Delta d$ provided that the point (d,Q) lies between (d_o,Q_o) and (d_1,Q_1) as shown in Fig.(4.6b).

If the rating curve for the downstream channel is supplied to the program, then "normal" conditions will be assumed and the discharge Q(d) is calculated from Manning's equation. Fig.(4.7) shows the flow diagram of this subroutine.

4.4.5 Subroutine COEFF

This is subroutine to calculate the DeMarchi coefficient of discharge C_M. As previously described in Section (3.4), there are four relationships adopted in the computation. Depending on the magnitude of the Froude Number at the upstream end of the weir, the program uses the appropriate relationship. The flow diagram shown in Fig.(4.8) illustrates the procedure.

4.4.6 Subroutine DCONJ

Since the program will not compute the overflow accurately if a hydraulic jump forms along the weir, it is important to predict the formation of jump. The method developed in Section (3.6) is used here. As illustrated in the flow diagram, Fig.(4.9), the conjugate depth d_6 can be estimated by means of simple iterative procedure, given the depth of flow d_5 and the discharge Q_5 at a point along the weir. The main channel section may be triangular, rectangular or trapezoidal.

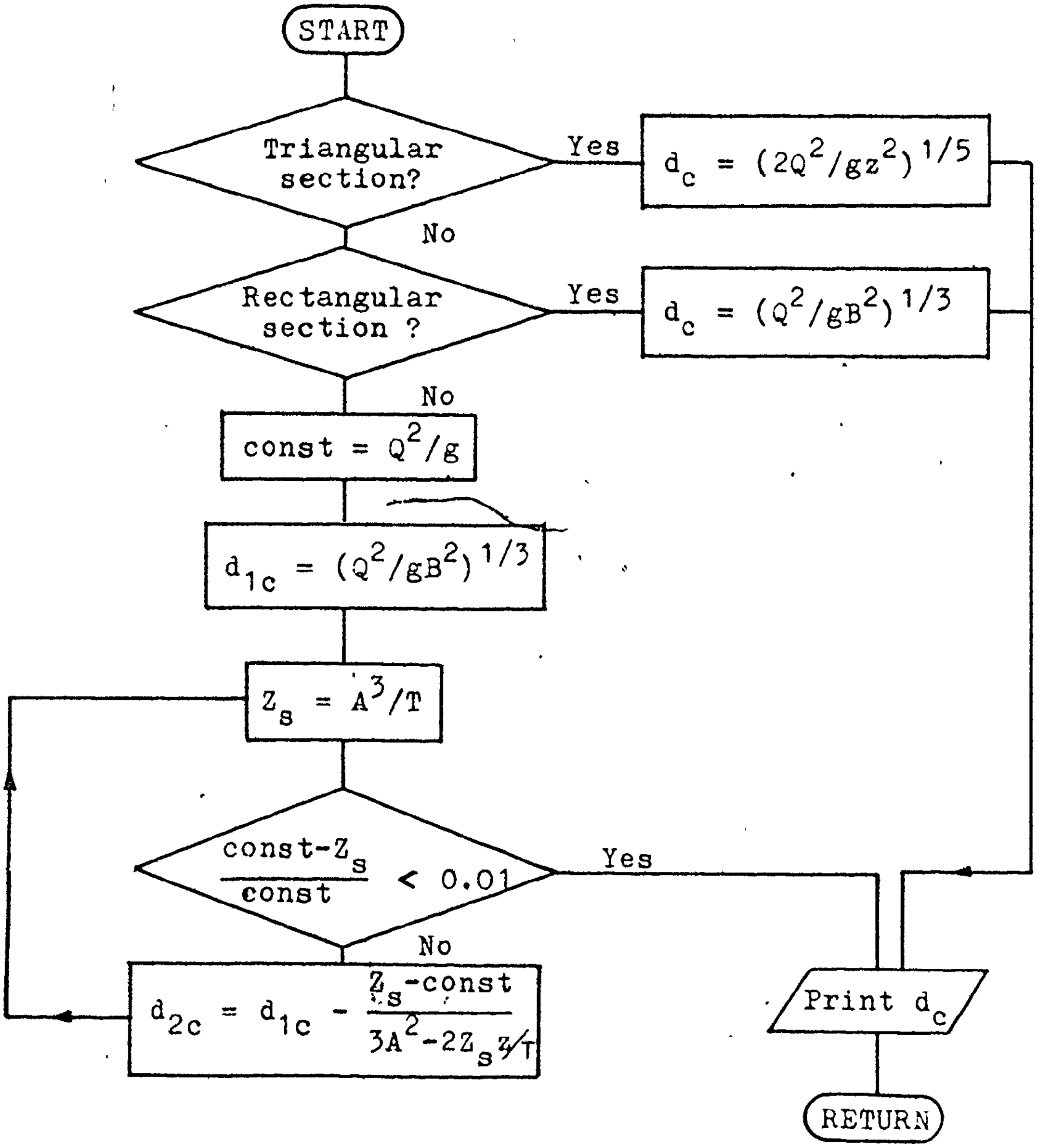


Fig.(4.3) Flow Diagram of Subroutine DCRIT

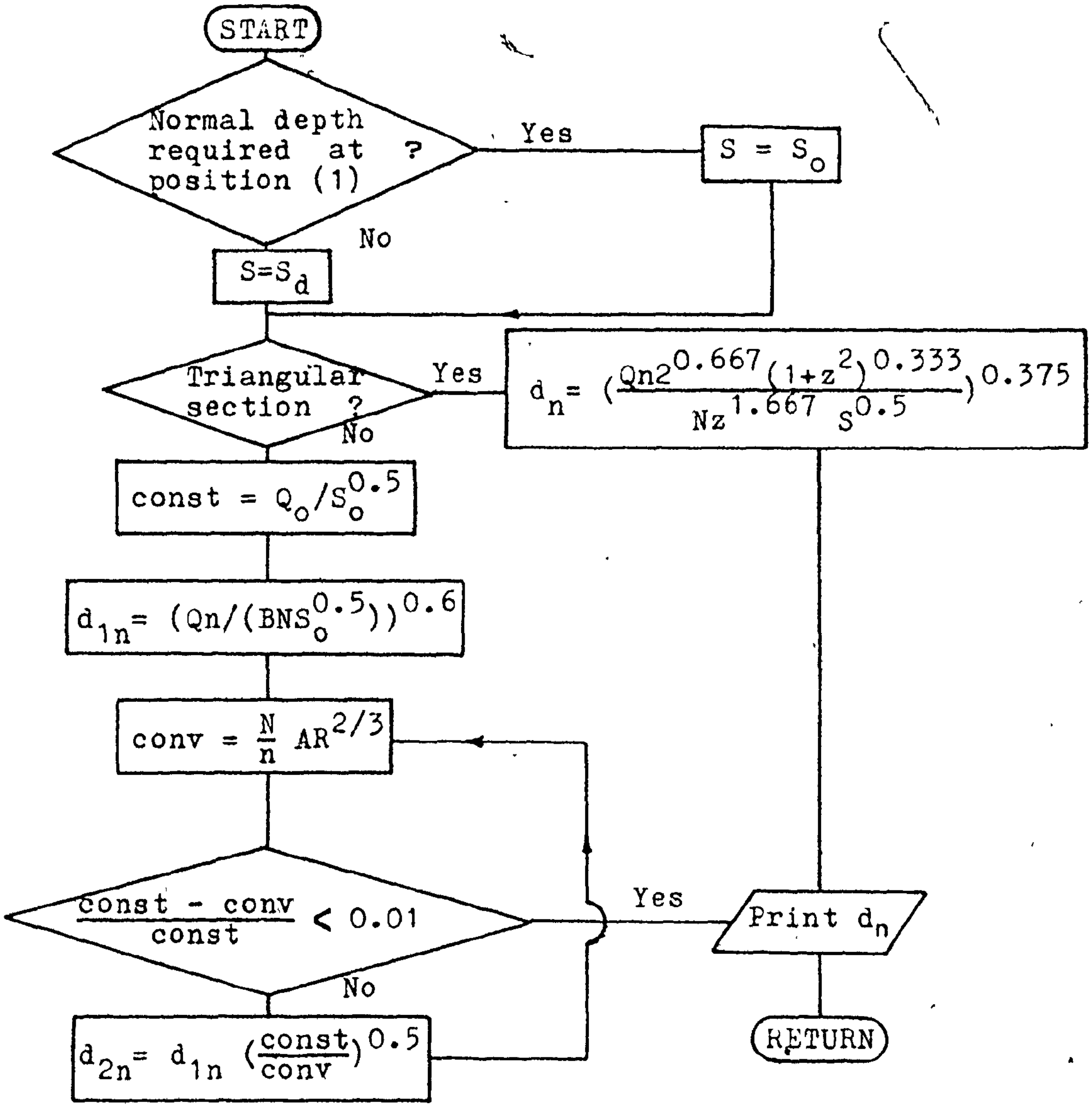


Fig.(4.4) Flow Diagram of Subroutine DNORM

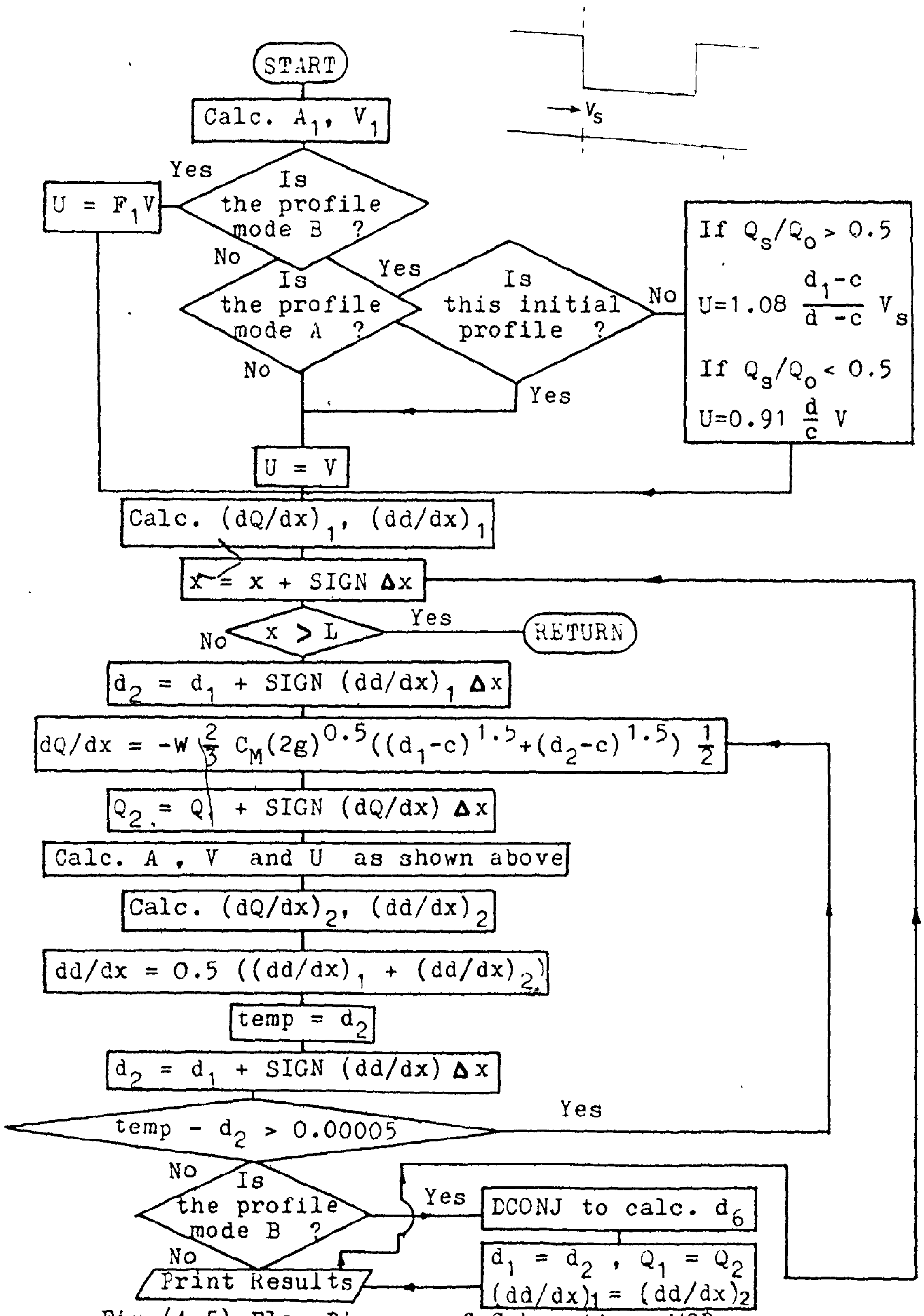


Fig.(4.5) Flow Diagram of Subroutine WSP

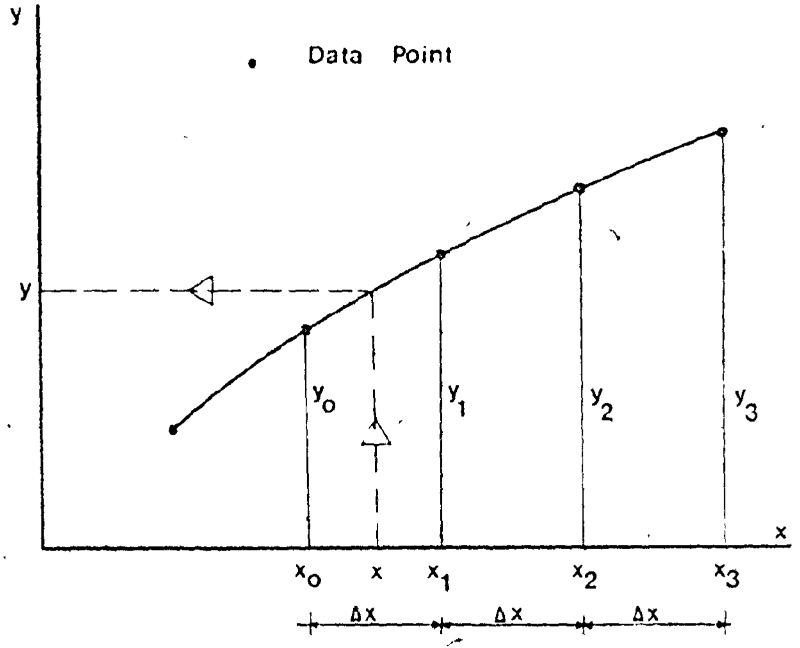


Fig.(4.6a) Nonlinear Interpolation for y

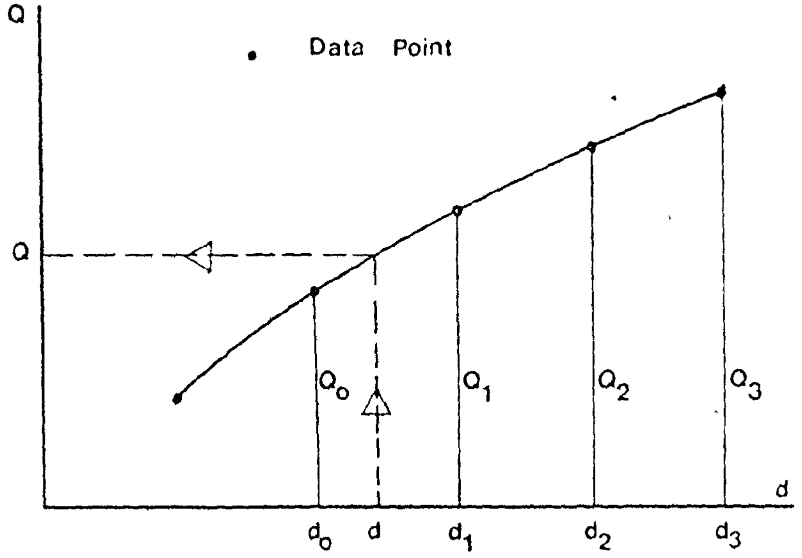


Fig.(4.6b) Nonlinear Interpolation for Q

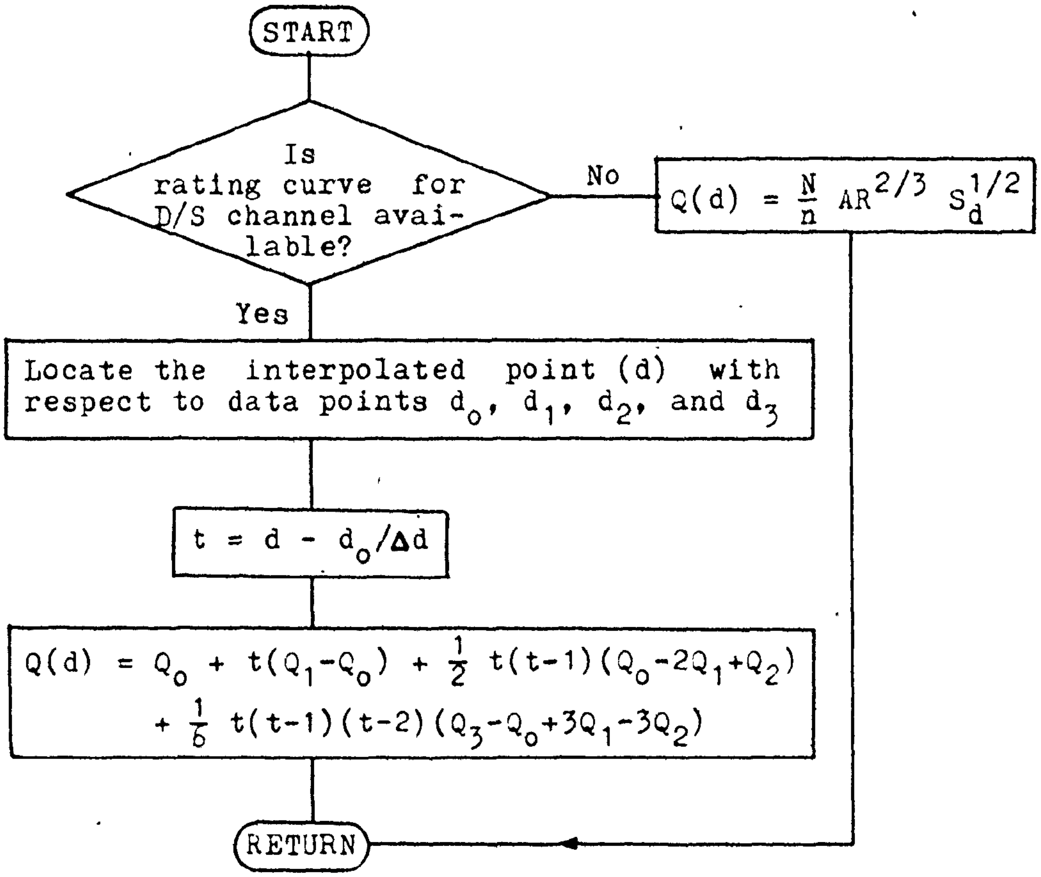


Fig.(4.7) Flow Diagram of Subroutine ENDCONT

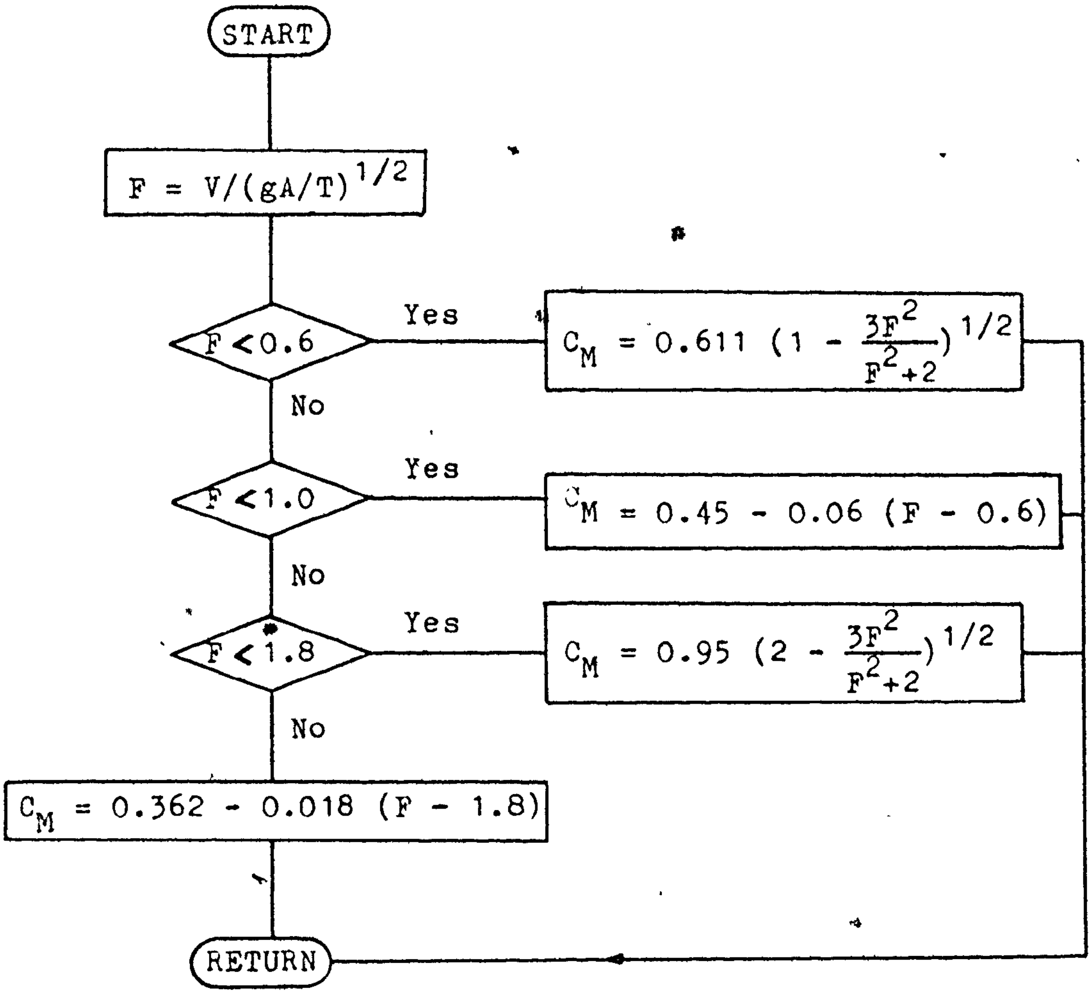


Fig.(4.8) Flow Diagram of Subroutine COEFF

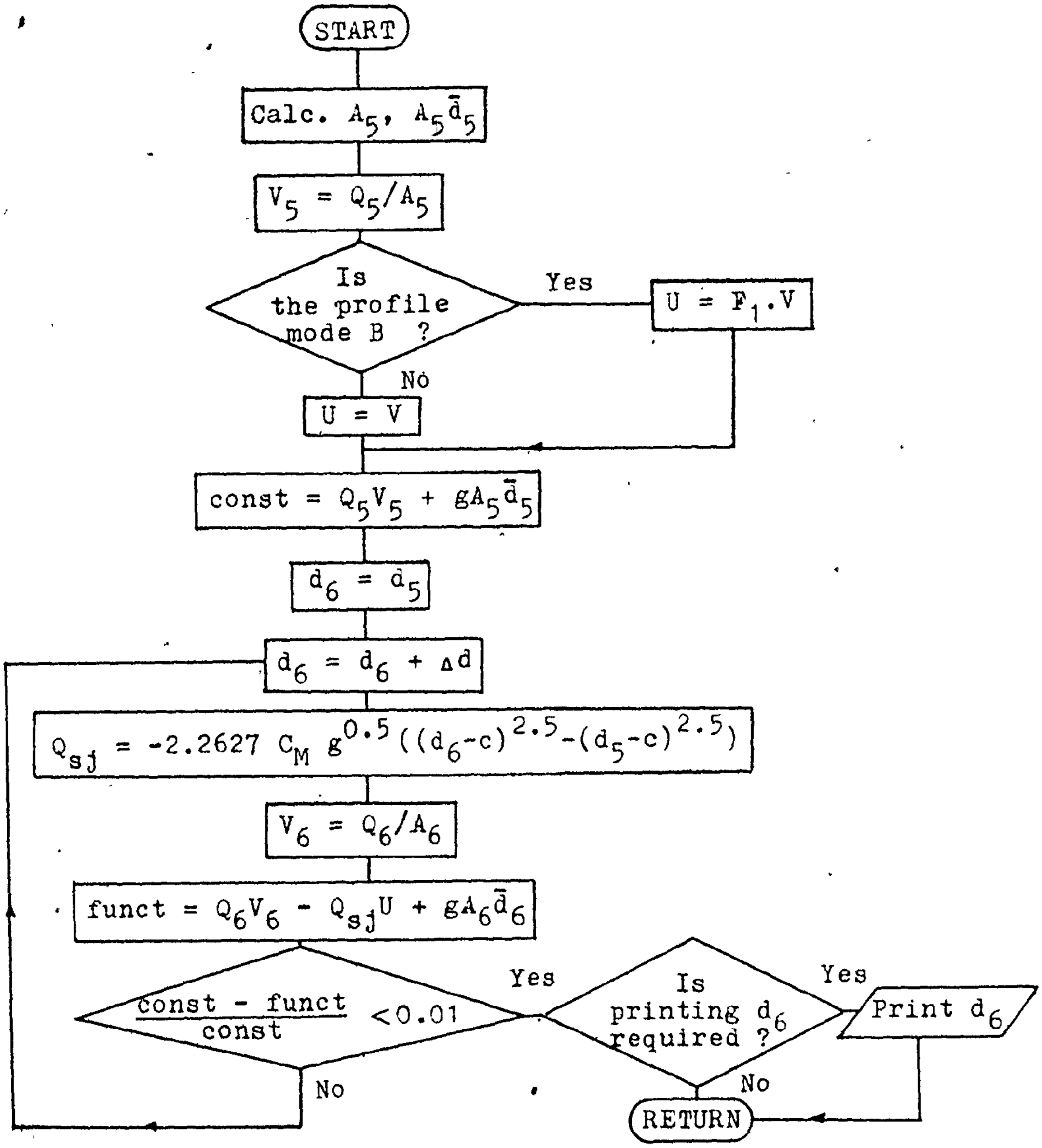


Fig.(4.9) Flow Diagram of Subroutine DCONJ

CHAPTER V

PROGRAM VALIDATION

5.1 Water Surface Profile

El-Khashab (1975) carried out a series of experiments to plot the water surface profile along the side weir. He used a prismatic rectangular channel 0.455 m wide with an average Manning's n of 0.012. The height of weir crest above the channel bed, c, varied from 0.10 to 0.25 m and the weir length, L, from 1.2 to 2.3 m. Table (5.1) presents the detailed data of 9 tests used here to verify the water surface profile computed by OVRFLO3. As can be seen from Figs. (5.1) to (5.9), the computed profiles are acceptable. The computer results are presented in Appendix E.

Test No.	Q_o (m^3/sec)	c (m)	L (m)	S_o	S_d Downstream
1V	0.083	0.25	2.3	0.0010	0.00017
2V	0.087	0.25	2.3	0.0010	0.00034
3V	0.096	0.20	2.3	0.0012	0.00012
4V	0.120	0.20	2.3	0.0015	0.00072
5V	0.0848	0.20	1.2	0.0015	0.00017
6V	0.250	0.17	2.3	0.0015	0.0015
7V	0.200	0.17	2.3	0.0015	0.0015
8V	0.1196	0.10	2.3	0.0010	0.0010
9V	0.154	0.10	2.3	0.0010	0.0010

Table(5.1) Data of Validation Tests of Water Surface Profile

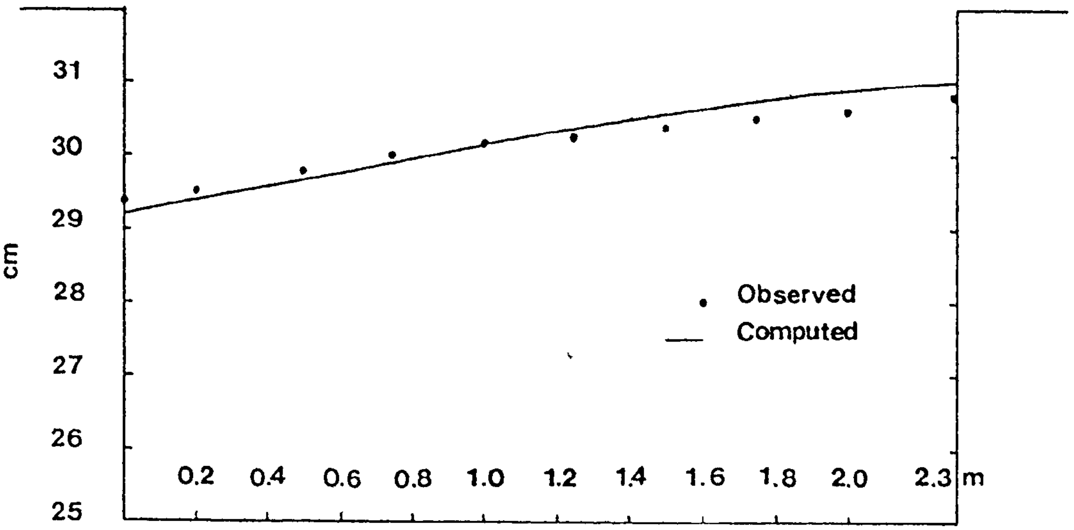


Fig.(5.1) Results of Test No.1V

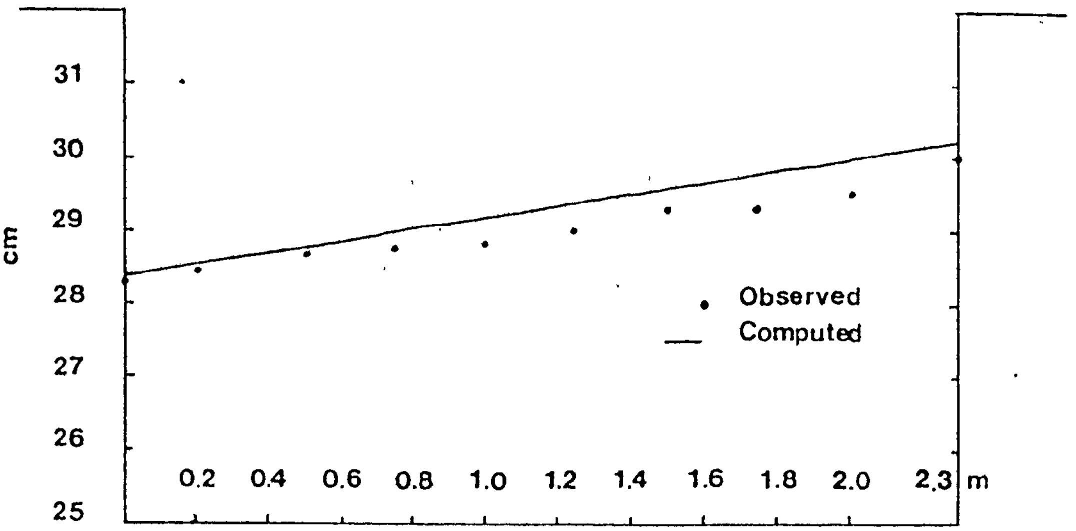


Fig.(5.2) Results of Test No.2V

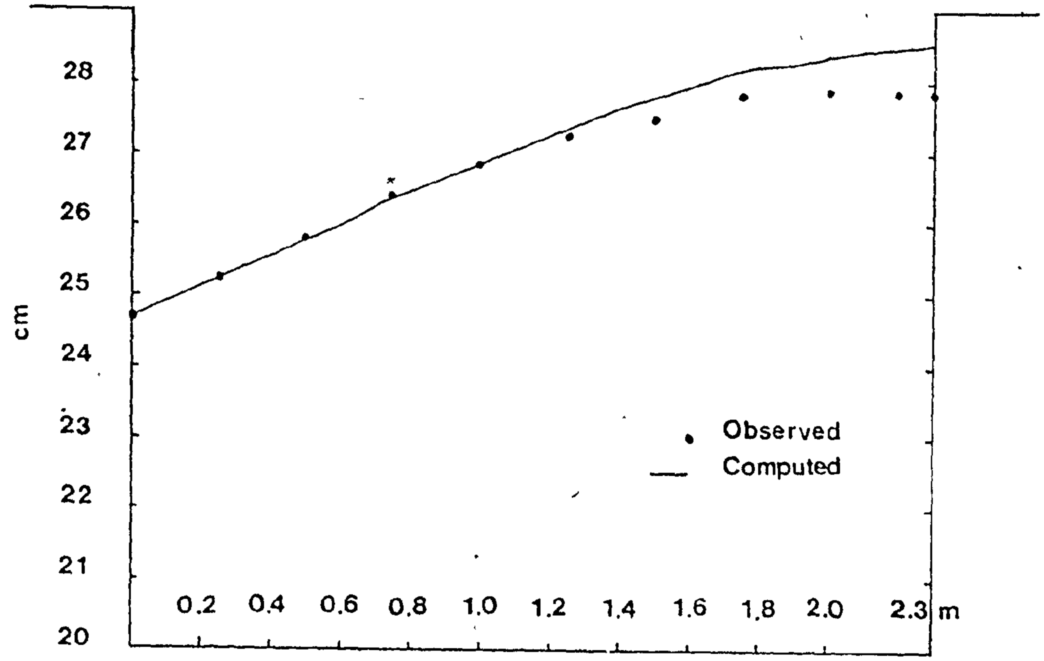


Fig.(5.3) Results of Test No.3V

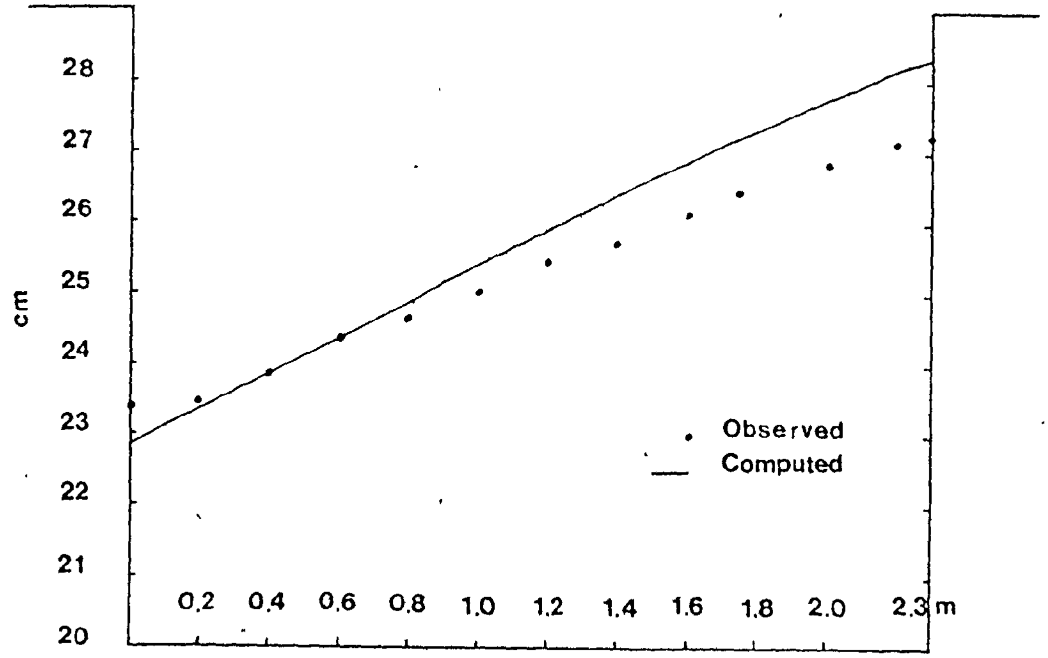


Fig.(5.4) Results of Test No.4V

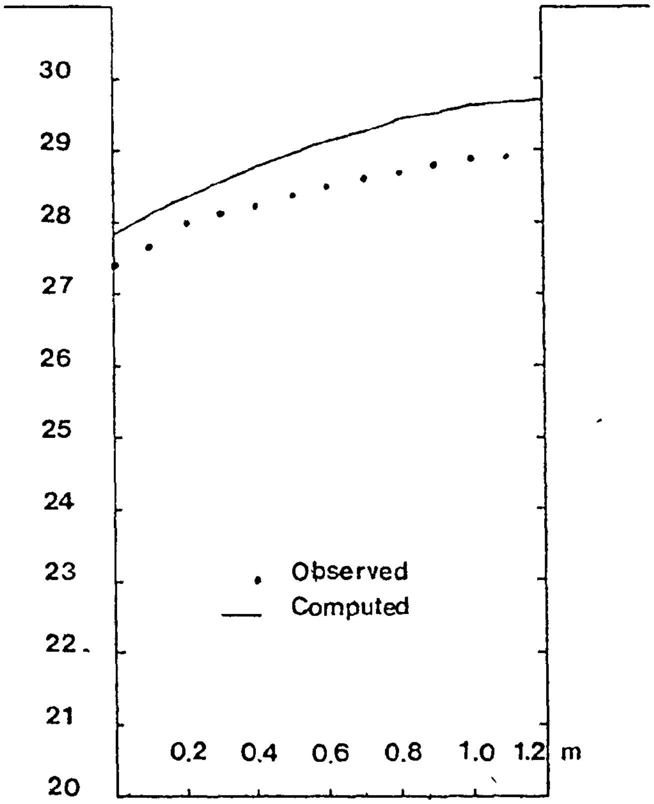


Fig.(5.5) Results of Test No.5V

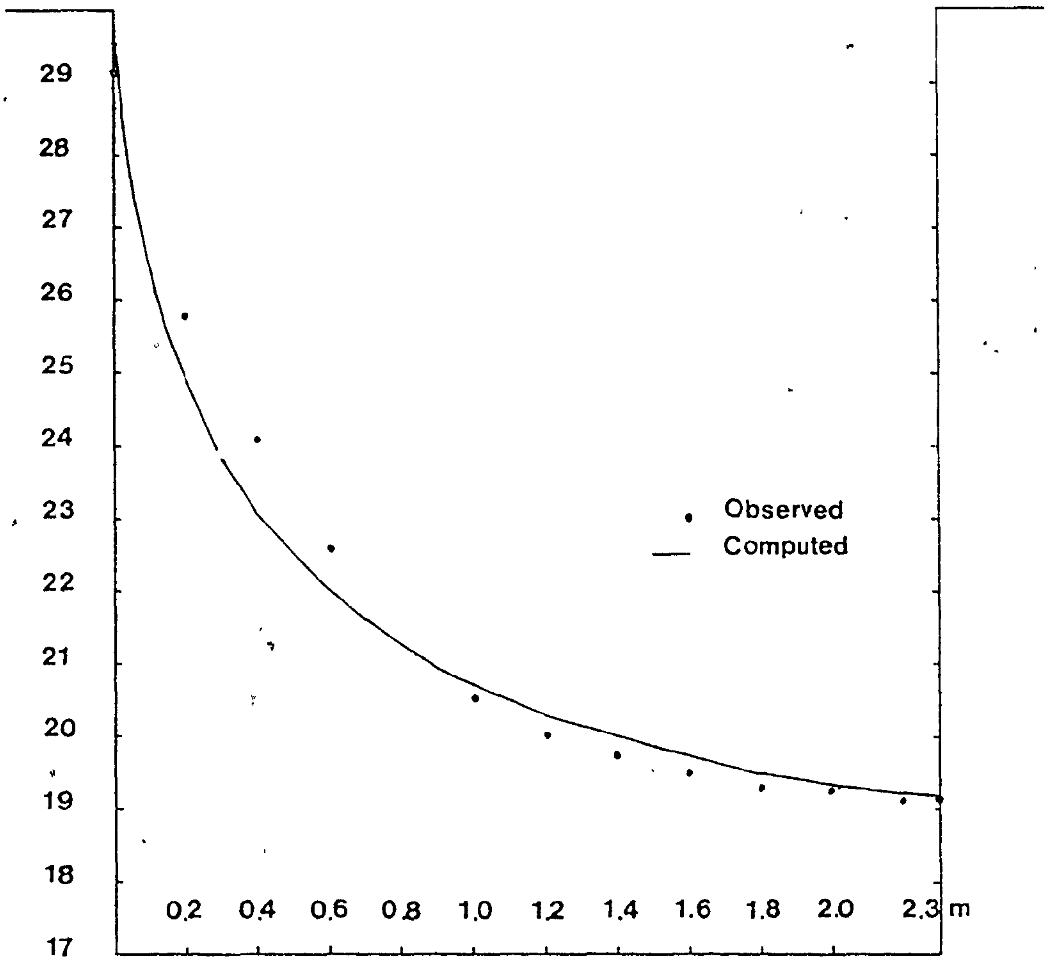


Fig.(5.6) Results of Test No.6V

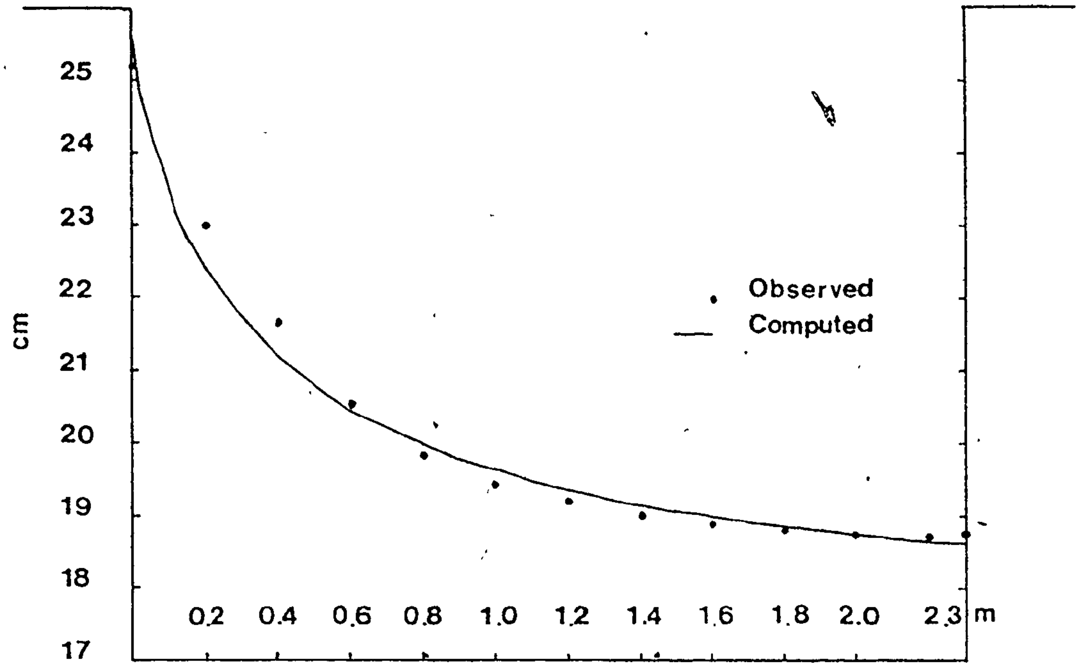


Fig.(5.7) Results of Test No.7V

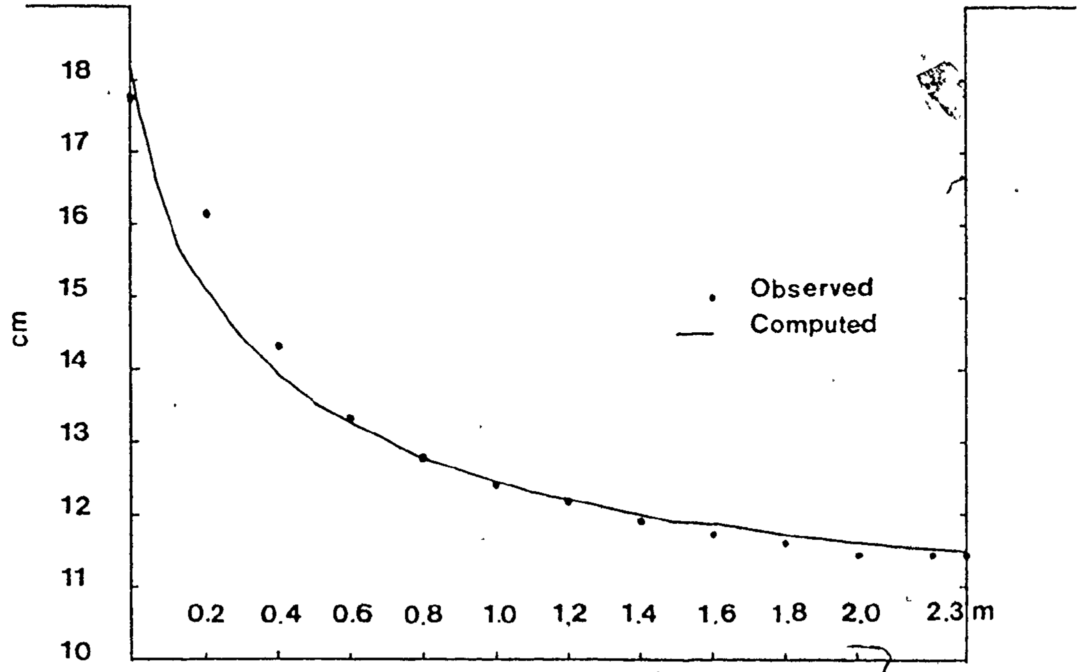


Fig.(5.8) Results of Test No.8V

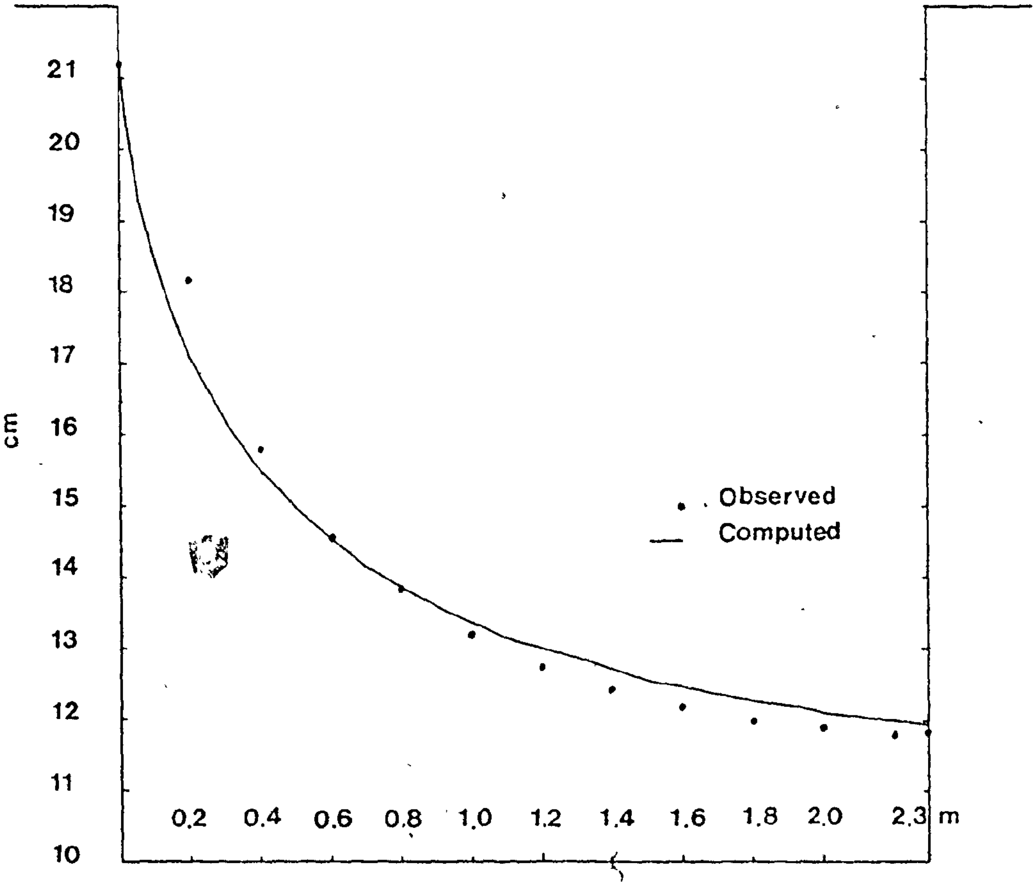


Fig.(5.9) Results of Test No.9V

5.2 Spill Flow

Another series of tests was carried out by El-Kashab to measure the discharge over the side weir, Q_s, see Table (5.2). The observed and computed ratios Q_s/Q_o of the Spill Flow Q_s to the approach channel flow Q_o were compared for each test and found to be accurate. Results of these tests are presented in Table (5.3) and Appendix E as well.

Test No.	Q_o (m^3/sec)	c (m)	L (m)	S_o	S_d
10V	0.116	0.20	2.3	0.0012	0.00036
11V	0.128	0.10	2.3	0.0015	0.00150
12V	0.116	0.10	2.3	0.0015	0.00150
13V	0.130	0.10	1.2	0.0015	0.00150

Table (5.2) Data of Validation Tests of Spill Flow

Test No.	Q_s/Q_o	
	Computed	Observed
10V	0.52	0.49
11V	0.27	0.27
12V	0.25	0.23
13V	0.22	0.20

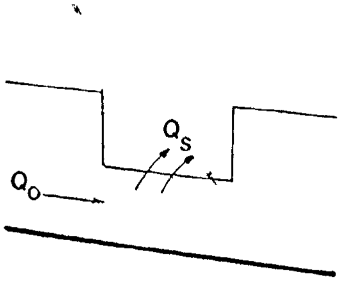


Table (5.3) Results of Validation Tests of Spill Flow

5.3 Comparison Between OVRFLO3, SWMM-EXTRAN and Observations

Although the verification tests on the EXTRAN Block of SWMM did not produce good results, it is useful to test both programs under the same conditions and compare their results to measured data. This will permit a decision on which program to use to model side weirs.

Olsson and Svensson (1979) conducted a series of experiments to measure the overflow from a channel with side weir for different flow situations upstream and along the side weir. The experiments were classified into 3 groups according to the flow profile along the weir. These groups are:

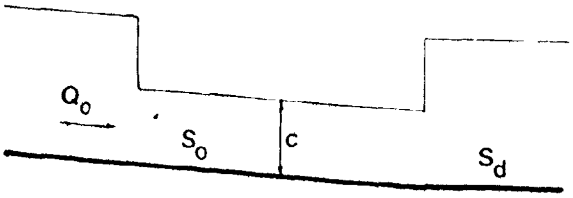
Group A - Supercritical profile on steep slope
Group B - Subcritical profile
Group C - Supercritical profile on mild slope

The main channel measured 0.15 m wide, 0.33 m high and 7.3 m long. The height of the weir crest varied from 0.0515 to 0.10 m whereas the weir length was kept constant at 0.57 m in all tests. The average value of Manning's n was 0.01. Table (5.4) shows the data of 17 tests used for comparing computed results to measurements in terms of the ratio Q_r/Q_o of the residual flow in the downstream channel Q_r to the flow in the approach channel Q_o. The discharge coefficients given in Table (5.4) were not used in OVRFLO3 since they are computed by the program. However, those values were used in EXTRAN since they were recommended by

Olsson and Svenssen. Results of these tests are given in Table (5.5) and it can be easily seen that OVRFLO3 produces results that are much closer to observations. The input and output files for EXTRAN are presented in Appendices B and C respectively, and those for OVRFLO3, in Appendix E.

Group	Test No.	Q_o (m^3/sec)	c (m)	S_o	S_d	C_w
A	1	0.0360	0.1000	0.0177	0.0177	0.40
	2	0.0450	0.1000	0.0200	0.0200	0.40
	3	0.0410	0.0515	0.0650	0.0650	0.35
	4	0.0160	0.0515	0.0515	0.0105	0.45
	5	0.0215	0.0515	0.0209	0.0209	0.40
	6	0.0180	0.0515	0.0138	0.0138	0.40
	7	0.0290	0.0515	0.0392	0.0392	0.40
B	8	0.0113	0.10	0.0017	0.0002	0.55
	9	0.0105	0.10	0.0013	0.0001	0.55
	10	0.0125	0.10	0.0020	0.0001	0.55
	11	0.0115	0.10	0.0020	0.0003	0.55
	12	0.0155	0.10	0.0030	0.0003	0.55
	13	0.0115	0.10	0.0016	0.0002	0.55
C	14	0.0480	0.1000	0.001	0.001	0.45
	15	0.0500	0.0515	0.009	0.009	0.45
	16	0.0290	0.1000	0.002	0.002	0.45
	17	0.0205	0.0515	0.001	0.001	0.45

Table (5.4) Data of Comparison Tests



Group	Test No.	% (Q_r/Q_o)		
		Computed		Observed
		OVRFLO3	EXTRAN	
A	1	90	98	90
	2	86	97	87
	3	91	99	90
	4	80	96	81
	5	88	97	86
	6	82	97	83
	7	91	98	90
B	8	37	85	41
	9	28	86	24
	10	25	84	16
	11	45	85	48
	12	38	80	35
	13	37	85	35
C	14	73	72	71
	15	53	83	58
	16	86	81	86
	17	70	72	68

Table (5.5) Results of Comparison Tests

CHAPTER VI

CONCLUSION

6.1 SIDWEIR Block of SWMM

SWMM is one of few urban runoff models widely used in Canada and U.S.A. Therefore, it is helpful to modify the current SWMM in such a way that it makes use of the new program OVRFLO3 in calculating the spill flow in a channel with side weir. This has been achieved by creating a new block in SWMM, called SIDWEIR, that includes the main OVRFLO3 program and its six subroutines. OVRFLO3 was adjusted to accept a set of input flows (i.e. inflow hydrograph) and produce two arrays, the spill flow and the depth at the upstream end of the side weir. These arrays are then stored on the disc file specified by the EXECUTIVE Block of SWMM. When using the EXTRAN Block at a side weir node, all necessary input stored on the disc file is read knowing the depth at the upstream end of the weir, the corresponding spill flow is estimated by simple interpolation. The SWMM user modeling side weirs at some nodes of the network follows this procedure:

1- Specify the disc file on which the output of SIDWEIR Block will be stored.

2- Call SIDWEIR Block in the same manner as any other block of SWMM.

3- Enter all the relevant data for running the SIDWEIR Block.

4- Call ENDPROGRAM or EXTRAN Block. If ENDPROGRAM is called, save the disc file specified in step 1 for future use. If EXTRAN is called, it will automatically use the information stored on the disc file specified in step 1 in order to calculate the spill flow from the channel where the side weir is located, providing that the appropriate I/O units are properly specified in the EXECUTIVE Block.

6.2 Conclusions

The following conclusions may be drawn from this study:

(i) Side weir diversion flow in the EXTRAN Block of SWMM is not accurately modelled. The expression used for describing the flow over weirs, Eq.(2.5), does not seem to be applied correctly by the program. Moreover, computed results showed considerable deviation from observations.

(ii) Program OVRFLO3 provides a satisfactory alternative for computing the overflow and the water surface profile along the side weir. The program is applicable to channels of rectangular, triangular or trapezoidal section. The coefficient of discharge is automatically computed by the program using newly proposed relationships. The formation of a hydraulic jump along the weir section is checked by means of a prediction method developed by the writer in Section (3.6). Satisfactory results were obtained when the computed profile and the overflow were compared to laboratory observations.

(iii) Simulation problems involving side weirs may now be modelled using the new block of SWMM namely SIDWEIR. This block, when given a set of inflows, will produce a rating curve relating the depth at the upstream end of the weir to the overflow. This rating curve is then used by EXTRAN to estimate the overflow at the side weir node knowing the depth at its upstream end.

6.3 Suggestions for Further Research

As in most research programs, the writer found problems not anticipated at the outset. These problems are suitable topics for further research:

(i) Derive a computational procedure for calculating the overflow from a hydraulic jump along the side weir. Experimental work would be necessary to support the derived computational procedure.

(ii) Elaborate the SIDWEIR Block to handle transverse weirs and oblique weir diversion structures. Ultimately produce a special diversion structure block.

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APPENDICES

APPENDIX A

HAND CALCULATIONS OF SWMM-EXTRAN VERIFICATION TESTS

A.1 Group A - Outfalls

Test No. 1A-Free Outfall
Single Pipe Flowing Under Pressure

Data: Input data are shown in Fig.(2.2) and listed in data file HS1EXDA in Appendix B.

(i) Continuity Check

Total input flow at node 200 and outflow at node 100 is 20 cfs; continutiy is satisfied.

(ii) Flow Depth at Outlet (node 100)

At the outlet of a system, the depth of flow is critical. The condition for critical depth is:

$$Z_c = \frac{Q}{\sqrt{g}} = \frac{20}{\sqrt{32.2}}$$

$$= 3.525$$

$$d_o^{2.5} = (2.0)^{2.5}$$

$$= 5.657$$

$$\frac{Z_c}{d_o^{2.5}} = 0.6231$$

From Tables of Chow, (A.7),

$$\frac{y_c}{d_o} = 0.803$$

Thus $y_c = 1.606$ ft

This is the depth fo flow at node 100

(iii) Velocity Check in Conduit 2000

At node 400 $\frac{R}{d_o} = 0.30426$

Thus R = 0.609 ft

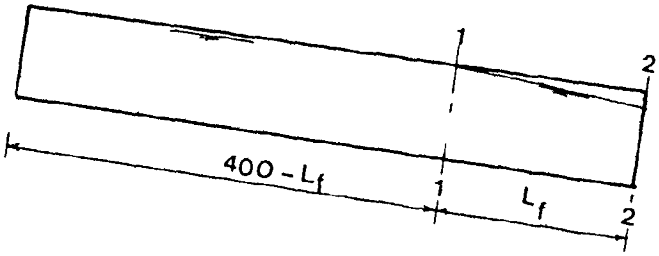

Fig.(A.1) Average Velocity in Conduit 2000

At node 100 $\frac{A}{d_o^2} = 0.676$

Then $A = 2.704 \text{ ft}^2$

$$V = \frac{Q}{A} = \frac{20}{2.704} = 7.397 \text{ fps}$$

From Fig.(A.1), the pipe is full upstream from section 1-1, then $V = \frac{Q}{A}$

$$V = \frac{20}{\frac{3.14(2)^2}{4}} = 6.366 \text{ fps}$$

$R = \frac{2}{4} = 0.5$ ft

Equating the energy at section 1-1 to that at 2-2

$$S_o \cdot L_f + 2 + \frac{(6.366)^2}{64.4} = 0 + 1.606 + \frac{(7.397)^2}{64.4} + S_f \cdot L_f \qquad (A.1)$$

where $S_f = \left(\frac{V_{ave.} n}{1.49 . R_{ave}^{2/3}}\right)^2$

$V_{ave} = \frac{1}{2}(6.366 + 7.397) = 6.882$ fps

$R_{ave} = \frac{1}{2}(0.50 + 0.609) = 0.555$ ft

$S_f = 7.905 \times 10^{-3}$

Substitute in Eq. (A.1)

$$L_f = \frac{0.1733}{(7.905-1.25)10^{-3}} = 26.04 \text{ ft}$$

Average velocity in conduit 2000 is then

$$\frac{26.04 \times 6.882 + (400-26.04)6.366}{400} = 6.40 \text{ fps}$$

% error in computing depth at node 100 $= \frac{1.606-1.61}{1.606} \times 100$

$= -0.25\%$

% error in computing velocity in conduit 2000

$= \frac{6.40-6.60}{6.40} \times 100$

$= -3.125\%$

(iv) Head Loss in Pipe

$h_L = S_f . L$

where $S_f = \left(\frac{V \ . \ n}{1.49 \ R^{2/3}}\right)^2$

$$R = \frac{0.555 \times 26.04 + 0.50 \ (400-26.04)}{400} = 0.504 \text{ ft}$$

$R^{2/3} = 0.633$

$$S_f = \left(\frac{6.40 \times 0.013}{1.49 \times 0.633}\right)^2 = 7.782 \times 10^{-3}$$

$$h_L = 7.782 \times 10^{-3} \times \cancel{4}00 = 3.11 \text{ ft}$$

Fig.(2.10) shows the hydraulic and energy grade lines (HGL and EGL) as calculated by hand computed by EXTRAN.

Test No.2A-Free Outfall
Continuous Pipes Flowing Under Pressure

Data: Input data are snown in Fig.(2.3) and listed in data file HS2EXDA in Appendix B.

(i) Continuity Check

Total input flow at node 500 and outflow at node 100 is 20 cfs; continuity is satisfied.

(ii) Flow Depth at Outlet (node 100)

At the outlet of a system, the depth of flow is critical since the outfall is free. The condition for a critical depth is

$$Z_c = \frac{Q}{g} = \frac{20}{32.2} = 3.525$$

$$d_o^{2.5} = (1.50)^{2.5} = 2.756$$

$$\frac{Z_c}{d_o^{2.5}} = 1.2790$$

From Tables of Chow, $\frac{y_c}{d_o} = 0.978$

Thus $y_c = 1.467$

Then depth of flow at node 100 = 1.467 ft

(iii) Velocity Check in Conduit 2000

At node 100 $\frac{R}{d_o} = 0.2745$

Thus $R = 0.412$ ft

At node 100 $\frac{A}{d_o^2} = 0.7810$

Thus $A = 1.757\ ft^2$

$V = \frac{Q}{A} = \frac{20}{1.757} = 11.382$ fps

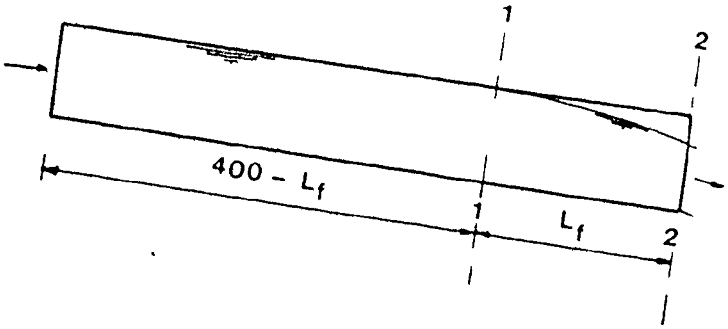

Fig.(A. 2) Average Velocity in Conduit 2000

From Fig. (A. 2), the pipe is full upstream from section 1-1, then

$$V = \frac{Q}{A} = \frac{20}{\frac{3.14(1.50)^2}{4}} = 11.318 \text{ fps}$$

$$R = \frac{1.5}{4} = 0.375 \text{ ft}$$

Equating the energy at section 1-1 to that at 2-2

$$S_o . L_f + 1.5 + \frac{(11.318)^2}{64.4} = 0 + 1.467 + \frac{(11.382)^2}{64.4} + S_f . L_f \quad (A.2)$$

where $S_f = \left(\frac{V_{ave} \,.\, n}{1.49 \, R_{ave}^{2/3}} \right)^2$

$V_{ave} = \frac{1}{2} (11.318 + 11.382) = 11.35$ fps

$R_{ave} = \frac{1}{2} (0.375 + 0.412) \simeq 0.394$ ft

$S_f = 0.034$

Substituting in Eq. (A.2) gives

$$L_f = \frac{0.0104}{(34-1.25)10^{-3}} = 0.32 \text{ ft}$$

Then average velocity in conduit 2000 is

$$\frac{11.35 x .32 - (400-.32)11.318}{400} = 11.318 \text{ fps}$$

% error in computing depth at outlet $= \frac{1.467-1.5}{1.467} \times 100$

$\simeq -2.25$ %

% error in computing velocity in conduit 2000

$= \frac{11.318-11.3}{11.318} \times 100$

$= 0.16$ %

(iv) Head Losses in Conduits

$$h_L = S_f . L = \left(\frac{V \,.\, n}{1.49 \, R^{2/3}} \right)^2 . L$$

Head loss h_L in each conduit can be easily calculated from the above equation. Results are put in Table (A.2) shown below.

Conduit	d_o ft	A ft^2	V fps	$R^{2/3}$	$S_f\ 10^3$	h_L ft
2000	1.50	1.767	11.32	0.52	36.075	14.43
3000	1.75	2.405	8.32	0.58	15.880	6.35
4000	2.00	3.142	6.37	0.63	7.783	3.11
5000	2.50	4.909	4.07	0.73	2.360	0.94

Table (A.2) Summary of Hand Calculations in Test No.2A

Fig. (2.11) shows the hydraulic and energy grade lines (HGL and EGL) as calculated by hand and computed by EXTRAN.

Test No. 3A-FreeOutfall
Simple Network with Free Surface in Pipes

Data: Input data are shown in Fig. (2.4) and listed in data file HS3EXDA in Appendix B.

(i) Continuity Check

Total input flows at nodes 600, 500 and 300 and outflow at node 100 is 3+2+1 = 6 cfs; continuity is satisfied.

(ii) Flow Depth at Outlet (node 100)

At the outlet of a system, the depth of flow is critical since the outfall is free. The condition for a critical depth is,

$$Z_c = \frac{Q}{g} = \frac{6}{32.2} = 1.057$$

$$d_o^{2.5} = (3.50)^{2.5} = 22.917$$

$$\frac{z_c}{d_o^{2.5}} = 0.0461$$

From Tables of Chow, $\frac{y_c}{d_o} = 0.21$

$y_c = 0.21 \times 3.5 = 0.735$ ft

This is the depth of flow at node 100

(iii) Velocity Check in Conduit 2000

$$\frac{R}{d_o} = 0.1259$$

Thus $R = 0.1259 \times 3.5 = 0.441$ ft

$$\frac{A}{d_o^2} = 0.1199$$

Thus $A = 0.1199 \times (3.50)^2 = 1.469$ ft^2

$V = \frac{6}{1.469} = 4.085$ fps at outlet

Normal Depth in conduit 2000 is obtained from Manning's Formula;

$$Q = \frac{1.49}{.013} \; A.R^{2/3}.S_o^{1/2}$$

$$AR^{2/3} = \frac{6 \times .013}{1.49 \times .05} = 1.047$$

$$d_o^{8/3} = (3.50)^{8/3} = 28.239$$

$$\frac{AR^{2/3}}{d_o^{8/3}} = 0.0371$$

From Tables of Chow, $\frac{y_n}{d_o} = 0.2334$

Thus $y_n = 0.817$ ft

$$\frac{A}{d_o^2} = 0.1394$$

Thus $A = 1.707$ ft^2

and $V = \frac{6}{1.707}$ 3.515 fps

$$\frac{R}{d_o} = 0.1382$$

Thus $R = 0.484$ ft

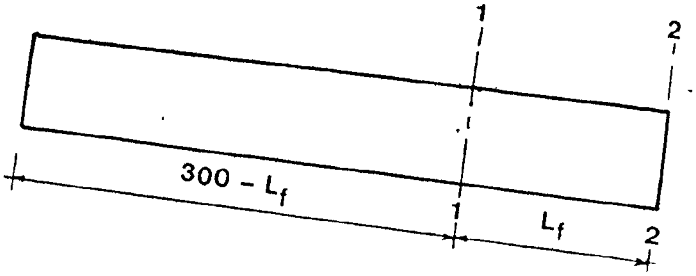

Fig.(A.3) Average Velocity in Conduit 2000

From Fig.(A.3), by equating the energy at section 1-1 to that at 2-2;

$$S_o \cdot L_f + .817 + \frac{(3.515)^2}{2x32.2} = 0 + .735 + \frac{(4.085)^2}{2x32.2} + S_f \cdot L_f \quad (A.3)$$

where $S_f = \left(\frac{V_{ave} \cdot n}{1.49\ R_{ave}^{2/3}}\right)^2$

$V_{ave} = \frac{1}{2}\ (4.085 + 3.515) = 3.8$ fps

$R_{ave} = \frac{1}{2}\ (0.441 + 0.484) = 0.4625$ ft

$S_f = 3.073 \times 10^{-3}$

Substituting in Eq. (A.3)

$$L_f = \frac{0.01473}{(3.073-2.50)10^{-3}} = 25.71 \text{ ft}$$

Average velocity in conduit 2000 is then

$$\frac{25.71 \times 3.80 + (300-25.71)3.515)}{300} = 3.54 \text{ fps}$$

% error in computing depth at node 100 = $\frac{0.735-0.73}{0.735} \times 100$

$= 0.68\%$

% error in computing velocity in conduit 2000

$= \frac{3.54-3.60}{3.54} \times 100$

$= -1.69\%$

(iv) Velocity Check in Other Conduits

Using Tables of Chow, velocities in conduits can be calculated. Table (A.3) presents such calculations. Hence, by comparing with computer results, % errors can be obtained as shown in Table (A.4).

Conduit	d_o ft	Q cfs	$AR^{2/3}$	$\frac{AR^{2/3}}{d_o^{8/3}}$	A/d_o^2	A ft^2	V fps
2000	3.5	6	1.047	.0371	.1390	1.703	3.52
3000	1.5	1	0.1745	.0592	.1936	0.436	2.29
4000	3.0	5	0.8725	.0466	.1632	1.469	3.40
5000	2.0	2	0.3490	.0550	.1836	0.734	2.72
6000	2.5	3	0.5235	.0455	.1597	0.998	3.01

Table (A.3) Summary of Hand Calculations in Test No. 3A

V Calculated	V Program	%error
3.52	3.6	-2.27
2.29	1.1	51.97
3.40	3.1	8.82
2.72	2.0	26.47
3.01	2.6	13.62

Table (A.4) Comparison Between Hand Calculations and Computer Results.

Test No. 4A
Simple Network Flowing Under Pressure

Input data are shown in Fig.(2.5) and listed in data file HS4EXDA in Appendix B. As can be seen from the output file in Appendix C, the system is totally unstable. Negative flows as well as very high appear in the summary of the output file.

A.2 Group B - Orifice Diversions

Test No. 1B-Orifice Diversion
Pipe Containing Orifice with Free Water Surface

Data: Input data are shown in Fig.(2.6) and listed in data file HS1EXDB in Appendix B.

(i) Continuity Check

Total input flow at node 500 = 67.143 cfs

Total outflows at nodes 100 and 300 = 67.13 cfs

$$\% \text{ error in satisfying continuity} = \frac{67.143-67.13}{67.143}$$

$$= 0.02\ \%$$

(ii) Check Flow Through Orifice

In order to get the water depth in the main pipe, Tables of Chow should be used.

$$V = \frac{1.49}{n} \cdot R^{2/3} \cdot S_o^{1/2}$$

$$Q = AV$$

$$= AR^{2/3} \cdot \frac{1.49}{.013} \cdot \left(\frac{0.20}{200}\right)^{1/2}$$

$$= 67.143 \text{ cfs}$$

Collecting terms,

$$AR^{2/3} = 18.525$$

$$d_o^{8/3} = (6.0)^{8/3}$$

$$= 118.869$$

$$\frac{AR^{2/3}}{d_o^{8/3}} = 0.1558$$

Thus $\frac{y}{d_o} = 0.50$

$y = 0.50 \times 6 = 3$ ft

$h = 3$ ft

Assume $C_o = 0.62$ and $A_o = 2$ ft^2. Substituting for C_o, A_o and h in Eq.(2.1); $Q_o = 17.236$ cfs.

Flow in conduit 2000 as computed by the program = 16.34 cfs

$$\% \text{ error in computing orifice discharge} = \frac{17.236-16.34}{17.236} \times 100$$

$$= 5.20\ \%$$

Test No. 2B-Orifice Diversion
Pipe Containing Orifice Flowing Under Pressure

Data: Input data are shown in Fig.(2.7) and listed in data file HS2EXDB in Appendix B.

(i) Continuity Check

Total input flow from node 500 and outflows at nodes 100 and 300 is 150 cfs; continuity is satisfied.

(ii) Check Flow Through Orifice

Unfortunately, one is unable to calculate the flow through orifice unless the head is known and in this test the pressure of flow at the location of the weir is unknown.

Test No. 1C-Weirs
Transverse Weir

Data: Input data are shown in Fig.(2.8) and listed in data file HS1EXDC in Appendix B.

(i) Continuity Check

Total input flow from node 400 and outflows at nodes

200 and 100 is 150 cfs; contiuity is satisfied.

(ii) Check Flow Over Weir

Eq.(2.2) is used to calculate the flow over transverse weir, with the exponent a = 3/2, $C_w = 0.45$ and L = 4.0 ft. That flow is the flow in conduit 2000. The rest of the flow continues in conduit 3000. Therefore, Q(2000) + Q(3000) = 150.0 cfs. Assume the water surface is horizontal just upstream from the weir. Therefore, the depth of water upstream from the weir should be equal to the depth of water in conduit 3000 at the same location. The approach velocity described in Eq.(2,2) is that in conduit 4000 where:

$$Q = 150 \text{ cfs}$$

$$= AV$$

$$= AR^{2/3} \cdot \frac{1.49}{.013} \left(\frac{0.75}{300}\right)^{1/2}$$

$$AR^{2/3} = 26.1744$$

$$= \frac{(4d)^{5/3}}{(4+2d)^{2/3}}$$

If d = 5.0 ft then $AR^{2/3} = 25.368$

d = 5.09ft then $AR^{2/3} = 25.910$

d = 5.13ft then $AR^{2/3} = 26.155$

$$V = \frac{Q}{A} = \frac{150}{4x5.13} = 7.31 \text{ fps}$$

Eq.(2.2) becomes

$$Q_s = Q(2000) = 0.45x4.0 \left[(h+.83)^{3/2} - (.83)^{3/2} \right]$$

$$h = \left(\frac{Q(2000)+1.36}{1.80}\right)^{2/3} - 0.83 \qquad \ldots(A.4)$$

For flow in conduit (3000),

$$Q(3000) = A.V = AR^{2/3} \cdot \frac{1.49}{n} \cdot S_o^{1/2}$$

Collecting terms,

$$AR^{2/3} = \frac{Q(3000)}{5.7308} \qquad \ldots(A.5)$$

Values for Q(2000) and Q(3000) are assigned in such a way that both equations (A.4) and (A.5) should end up with the same depth upstream from weir. Calculations are presented in Table (A.5) shown below. As can be seen, the depth upstream of weir is 4.94 ft and the corresponding flow over weir is 7.0 cfs. The program gives a value of 4.03 cfs.

$$\% \text{ error in computing flow over weir} = \frac{7.0-4.03}{7.0} \times 100$$

$$= 42.43\ \%$$

Eq.(A.4)			Eq.(A.5)		
Q(2000) cfs	h ft	d ft	Q(3000) cfs	$AR^{2/3}$	d ft
10	2.59	5.59	140	24.43	4.85
9	2.38	5.58	141	24.60	4.87
8	8.17	5.17	142	24.79	4.90
7	1.95	4.95	143	24.95	4.93
6	1.73	4.73	144	25.13	4.96
5	1.49	4.49	145	25.30	4.99
4	1.24	4.24	146	25.48	5.02
3	0.98	3.98	147	25.65	5.05
2	0.69	3.69	148	25.85	5.08

Table (A.5) Calculations for Depth Upstream of Weir in Test No. 1C

Test No. 2C-Weirs
<u>Side-Weir</u>

<u>Data</u>: Input data are shown in Fig.(2.9) and listed in data file HS2EXDC in Appendix B.

(i) <u>Continuity Check</u>

Total input flow from node 400 and outflows at nodes 200 and 100 is 150 cfs; continuity is satisfied.

(ii) <u>Check Flow Over Weir</u>

Eq.(2.2) is used to calculate the flow over side weir, with the exponent a = 5/3, where C_w = 0.45 and L = 5 ft. This flow is the flow in conduti 2000. The rest of the flow continues in conduit 3000. Therefore, Q(2000) +

Q(3000) = 150 cfs. As prescribed in Test No. 1C, the normal depth in the main channel is 5.13 ft and the approach velocity is 7.31 fps. Eq.(2.2) becomes:

$$Q_s = Q(2000) = 0.45 \times 5.0\ ((h+0.83)^{5/3} - (.83)^{5/3})$$

$$\text{or } h = \left(\frac{Q(2000)+1.65}{2.25}\right)^{3/5} - 0.83 \qquad \ldots(A.6)$$

Recall Eq.(A.5) $AR^{2/3} = \frac{Q(3000)}{5.7308}$

Assign values to Q(2000) and Q(3000) in order to get the right depth of water upstream of weir as previously done in Test No. 1C. From Table (A.6), the right depth upstream of weir is 4.85 ft and the corresponding flow over weir is 10 cfs. The program gives a value of 5.36 cfs.

$$\% \text{ error in computing flow over weir} = \frac{10-5.36}{10} \times 100$$

$$= 46.40\ \%$$

Eq.(A.6)			Eq.(A.5)		
Q(2000) cfs	h ft	d ft	Q(3000) cfs	$AR^{2/3}$	d ft
10	1.85	4.85	140	24.43	4.85
9	1.71	4.71	141	24.60	4.87
8	1.57	4.57	142	24.79	4.90
7	1.41	4.41	143	24.95	4.93
6	1.25	4.25	144	25.13	4.96
5	1.09	4.09	145	25.30	4.99

Table (A.6) Calculations for Depth U/S of Weir in Test No.2C

APPENDIX A. GEOMETRIC ELEMENTS FOR CIRCULAR CHANNEL SECTIONS

d_0 = diameter
y = depth of flow
A = water area
P = wetted perimeter
R = hydraulic radius
T = top width
D = hydraulic depth
$Z = A\sqrt{D}$ = section factor for critical-flow computation

$\frac{y}{d_0}$	$\frac{A}{d_0^2}$	$\frac{P}{d_0}$	$\frac{R}{d_0}$	$\frac{T}{d_0}$	$\frac{D}{d_0}$	$\frac{Z}{d_0^{2.5}}$	$\frac{AR^{2/3}}{d_0^{8/3}}$
0.01	0.0013	0.2003	0.0066	0.1990	0.0066	0.0001	0.0000
0.02	0.0037	0.2838	0.0132	0.2800	0.0134	0.0004	0.0002
0.03	0.0069	0.3482	0.0197	0.3412	0.0202	0.0010	0.0005
0.04	0.0105	0.4027	0.0262	0.3919	0.0268	0.0017	0.0009
0.05	0.0147	0.4510	0.0326	0.4359	0.0336	0.0027	0.0015
0.06	0.0192	0.4949	0.0389	0.4750	0.0406	0.0039	0.0022
0.07	0.0242	0.5355	0.0451	0.5103	0.0474	0.0053	0.0031
0.08	0.0294	0.5735	0.0513	0.5426	0.0542	0.0069	0.0040
0.09	0.0350	0.6094	0.0574	0.5724	0.0612	0.0087	0.0052
0.10	0.0409	0.6435	0.0635	0.6000	0.0682	0.0107	0.0065
0.11	0.0470	0.6761	0.0695	0.6258	0.0752	0.0129	0.0079
0.12	0.0534	0.7075	0.0754	0.6499	0.0822	0.0153	0.0095
0.13	0.0600	0.7377	0.0813	0.6726	0.0892	0.0179	0.0113
0.14	0.0668	0.7670	0.0871	0.6940	0.0964	0.0207	0.0131
0.15	0.0739	0.7954	0.0929	0.7141	0.1034	0.0238	0.0152
0.16	0.0811	0.8230	0.0986	0.7332	0.1106	0.0270	0.0173
0.17	0.0885	0.8500	0.1042	0.7513	0.1178	0.0304	0.0196
0.18	0.0961	0.8763	0.1097	0.7684	0.1252	0.0340	0.0220
0.19	0.1039	0.9020	0.1152	0.7846	0.1325	0.0378	0.0247
0.20	0.1118	0.9273	0.1206	0.8000	0.1398	0.0418	0.0273
0.21	0.1199	0.9521	0.1259	0.8146	0.1472	0.0460	0.0301
0.22	0.1281	0.9764	0.1312	0.8285	0.1546	0.0503	0.0333
0.23	0.1365	1.0003	0.1364	0.8417	0.1622	0.0549	0.0359
0.24	0.1449	1.0239	0.1416	0.8542	0.1696	0.0597	0.0394
0.25	0.1535	1.0472	0.1466	0.8660	0.1774	0.0646	0.0427
0.26	0.1623	1.0701	0.1516	0.8773	0.1850	0.0697	0.0464
0.27	0.1711	1.0928	0.1566	0.8879	0.1926	0.0751	0.0497
0.28	0.1800	1.1152	0.1614	0.8980	0.2004	0.0805	0.0536
0.29	0.1890	1.1373	0.1662	0.9075	0.2081	0.0862	0.0571
0.30	0.1982	1.1593	0.1709	0.9165	0.2162	0.0921	0.0610

Table(A.7) Tables of Ven T. Chow

APPENDIX A GEOMETRIC ELEMENTS FOR CIRCULAR CHANNEL SECTIONS (*continued*)

$\frac{y}{d_0}$	$\frac{A}{d_0^2}$	$\frac{P}{d_0}$	$\frac{R}{d_0}$	$\frac{T}{d_0}$	$\frac{D}{d_0}$	$\frac{Z}{d_0^{2.5}}$	$\frac{AR^{2/3}}{d_0^{8/3}}$
0 31	0 2074	1 1810	0 1755	0 9250	0 2242	0 0981	0 0650
0 32	0 2167	1 2025	0 1801	0 9330	0 2322	0 1044	0 0690
0 33	0 2260	1 2239	0 1848	0 9404	0 2404	0 1107	0 0736
0 34	0 2355	1 2451	0 1891	0 9474	0 2486	0 1172	0 0776
0 35	0 2450	1 2661	0 1935	0 9539	0 2568	0 1241	0 0820
0 36	0 2546	1 2870	0 1978	0 9600	0 2652	0 1310	0 0864
0 37	0 2642	1 3078	0 2020	0 9656	0 2736	0 1381	0 0909
0 38	0 2739	1 3284	0 2061	0 9708	0 2822	0 1453	0 0955
0 39	0 2836	1 3490	0 2102	0 9755	0 2908	0 1528	0 1020
0 40	0 2934	1 3694	0 2142	0 9798	0 2994	0 1603	0 1050
0 41	0 3032	1 3898	0 2181	0 9837	0 3082	0 1682	0 1100
0 42	0 3132	1 4101	0 2220	0 9871	0 3172	0 1761	0 1147
0 43	0 3229	1 4303	0 2257	0 9902	0 3262	0 1844	0 1196
0 44	0 3328	1 4505	0 2294	0 9928	0 3352	0 1927	0 1245
0 45	0 3428	1 4706	0 2331	0 9950	0 3446	0 2011	0 1298
0 46	0 3527	1 4907	0 2366	0 9968	0 3538	0 2098	0 1348
0 47	0 3627	1 5108	0 2400	0 9982	0 3634	0 2186	0 1401
0 48	0 3727	1 5308	0 2434	0 9992	0 3730	0 2275	0 1452
0 49	0 3827	1 5508	0 2467	0 9998	0 3828	0 2366	0 1505
0 50	0 3927	1 5708	0 2500	1 0000	0 3928	0 2459	0 1558
0 51	0 4027	1 5908	0 2531	0 9998	0 4028	0 2553	0 1610
0 52	0 4127	1 6108	0 2562	0 9992	0 4130	0 2650	0 1664
0 53	0 4227	1 6308	0 2591	0 9982	0 4234	0 2748	0 1715
0 54	0 4327	1 6509	0 2620	0 9968	0 4340	0 2848	0 1772
0 55	0 4426	1 6710	0 2649	0 9950	0 4448	0 2949	0 1825
0 56	0 4526	1 6911	0 2676	0 9928	0 4558	0 3051	0 1878
0 57	0 4625	1 7113	0 2703	0 9902	0 4670	0 3158	0 1933
0 58	0 4724	1 7315	0 2728	0 9871	0 4786	0 3262	0 1987
0 59	0 4822	1 7518	0 2753	0 9837	0 4902	0 3373	0 2041
0 60	0 4920	1 7722	0 2776	0 9798	0 5022	0 3484	0 2092
0 61	0 5018	1 7926	0 2797	0 9755	0 5144	0 3600	0 2146
0 62	0 5115	1 8132	0 2818	0 9708	0 5270	0 3710	0 2199
0 63	0 5212	1 8338	0 2839	0 9656	0 5398	0 3830	0 2252
0 64	0 5308	1 8546	0 2860	0 9600	0 5530	0 3945	0 2302
0 65	0 5404	1 8755	0 2881	0 9539	0 5666	0 4066	0 2358

Table(A.7) Tables of Ven T. Chow (continued)

APPENDIX A. GEOMETRIC ELEMENTS FOR CIRCULAR CHANNEL SECTIONS (*continued*)

$\frac{y}{d_0}$	$\frac{A}{d_0^2}$	$\frac{P}{d_0}$	$\frac{R}{d_0}$	$\frac{T}{d_0}$	$\frac{D}{d_0}$	$\frac{Z}{d_0^{2.5}}$	$\frac{AR^{2/3}}{d_0^{8/3}}$
0.66	0.5499	1.8965	0.2899	0.9474	0.5804	0.4188	0.2407
0.67	0.5594	1.9177	0.2917	0.9404	0.5948	0.4309	0.2460
0.68	0.5687	1.9391	0.2935	0.9330	0.6096	0.4437	0.2510
0.69	0.5780	1.9606	0.2950	0.9250	0.6250	0.4566	0.2560
0.70	0.5872	1.9823	0.2962	0.9165	0.6408	0.4694	0.2608
0.71	0.5964	2.0042	0.2973	0.9075	0.6572	0.4831	0.2653
0.72	0.6054	2.0264	0.2984	0.8980	0.6742	0.4964	0.2702
0.73	0.6143	2.0488	0.2995	0.8879	0.6918	0.5100	0.2751
0.74	0.6231	2.0714	0.3006	0.8773	0.7104	0.5248	0.2794
0.75	0.6318	2.0944	0.3017	0.8660	0.7296	0.5392	0.2840
0.76	0.6404	2.1176	0.3025	0.8542	0.7498	0.5540	0.2888
0.77	0.6489	2.1412	0.3032	0.8417	0.7710	0.5695	0.2930
0.78	0.6573	2.1652	0.3037	0.8285	0.7934	0.5850	0.2969
0.79	0.6655	2.1895	0.3040	0.8146	0.8170	0.6011	0.3008
0.80	0.6736	2.2143	0.3042	0.8000	0.8420	0.6177	0.3045
0.81	0.6815	2.2395	0.3044	0.7846	0.8685	0.6347	0.3082
0.82	0.6893	2.2653	0.3043	0.7684	0.8970	0.6524	0.3118
0.83	0.6969	2.2916	0.3041	0.7513	0.9276	0.6707	0.3151
0.84	0.7043	2.3186	0.3038	0.7332	0.9606	0.6897	0.3182
0.85	0.7115	2.3462	0.3033	0.7141	0.9964	0.7098	0.3212
0.86	0.7186	2.3746	0.3026	0.6940	1.0354	0.7307	0.3240
0.87	0.7254	2.4038	0.3017	0.6726	1.0784	0.7528	0.3264
0.88	0.7320	2.4341	0.3008	0.6499	1.1264	0.7771	0.3286
0.89	0.7380	2.4655	0.2996	0.6258	1.1800	0.8016	0.3307
0.90	0.7445	2.4981	0.2980	0.6000	1.2408	0.8285	0.3324
0.91	0.7504	2.5322	0.2963	0.5724	1.3110	0.8586	0.3336
0.92	0.7560	2.5681	0.2944	0.5426	1.3932	0.8917	0.3345
0.93	0.7612	2.6061	0.2922	0.5103	1.4918	0.9292	0.3350
0.94	0.7662	2.6467	0.2896	0.4750	1.6130	0.9725	0.3353
0.95	0.7707	2.6906	0.2864	0.4359	1.7682	1.0242	0.3349
0.96	0.7749	2.7389	0.2830	0.3919	1.9770	1.0888	0.3340
0.97	0.7785	2.7934	0.2787	0.3412	2.2820	1.1752	0.3322
0.98	0.7816	2.8578	0.2735	0.2800	2.7916	1.3050	0.3291
0.99	0.7841	2.9412	0.2665	0.1990	3.9400	1.5554	0.3248
1.00	0.7854	3.1416	0.2500	0.0000	∞	∞	0.3117

Table(A.7) Tables of Ven T. Chow (continued)

APPENDIX B

IBM

FORTRAN CODING FORM

PROGRAM EXTRAN - HSIEXDA

PROGRAMMER H. MITRI

DATE July, 17, 80

PUNCHING INSTRUCTIONS GRAPHIC PUNCH

PAGE 1 / 16

FORTRAN STATEMENT

```
0
    1  2  3   4
EXTENDED TRANSPORT
QUANTITY
TEST NO.1A - FREE OUTFALL
SINGLE PIPE FLOWING UNDER PRESSURE
  300 20.0 0.0     2   1   0   0   1   6   1   0   0   1
    0
      200        100
     2000
  0.0
 2000  200  100    1          2.0     400.0          0.013
99999
  200     200.00    100.50
  100     200.00    100.00
99999
99999
99999
99999
99999
  100
99999
99999
    1
```

IBM

FORTRAN CODING FORM

PROGRAM EXTRAN – HSIEXDA

PROGRAMMER H. MITRI

DATE July, 17, 80

PUNCHING INSTRUCTIONS GRAPHIC PUNCH

2 1/6

FORTRAN STATEMENT

```
 200
0.0       20.0
2.0       20.0
ENDPROGRAM
```

IBM

FORTRAN CODING FORM

PROGRAM EXTRAN - HS2EXDA

PROGRAMMER H. MITRI

DATE July, 17, 80

PUNCHING INSTRUCTIONS GRAPHIC PUNCH

3 / 13

FORTRAN STATEMENT

```
0
    1   2   3   4
EXTENDED TRANSPORT
QUANTITY
TEST NO. 2A - FREE OUTFALL
CONTINUOUS PIPES FLOWING UNDER PRESSURE
 600 20.0 0.0     5   4    0    0    1    6    1    0    0    1
    0
       500        400       300       200       100
      5000       4000      3000      2000
  0.0
 5000  500  400      1      2.50      400.0          0.013
 4000  400  300      1      2.00      400.0          0.013
 3000  300  200      1      1.75      400.0          0.013
 2000  200  100      1      1.50      400.0          0.013
99999
  500      200.00      102.00
  400      200.00      101.50
  300      200.00      101.00
  200      200.00      100.50
  100      200.00      100.00
99999
99999
99999
```

2

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IBM

FORTRAN CODING FORM

EXTRAN-HS2EXDA

H. MITRI

July, 17, 80

4

```
99999
99999
  100
99999
99999
    1
  500
0.0          20.0
4.0          20.0
ENDPROGRAM
```

IBM FORTRAN CODING FORM

EXTRAN - 1153EXDA

KAMTRI

July, 18, 80

```
C
   1   2   3   4
EXTENDED TRANSPORT
QUANTITY
TEST NO 3A - FREE OUTFALL
SIMPLE NETWORK WITH FREE WATER SURFACE IN PIPES
 100  20  0.0     6     5     0     0     1     6     3     0     0     1
   0
      600         500         400         300         200         100
     6000        5000        4000        3000        2000
  0.0
 6000  600  400     1        2.50      300.0           0.013
 5000  500  400     1        2.00      100.0           0.013
 4000  400  200     1        3.00      300.0           0.013
 3000  300  200     1        1.50      100.0           0.013
 2000  200  100     1        3.50      300.0           0.013
99999
  600      200.00      102.25
  500      200.00      101.75
  400      200.00      101.50
  300      200.00      101.00
  200      200.00      100.75
  100      200.00      100.00
99999
```

IBM

FORTRAN CODING FORM

EXTRAN - HS3EXDA
H MITRL
July, 18, 80

```
99999
99999
99999
99999
  100
99999
99999
    1
  600   500   300
0.0         3.0        2 0        1.0
E.0         3.0        2.0        1.0
ENDPROGRAM
```

IBM

FORTRAN CODING FORM

PROGRAM EXTRAN - HS4EXDA

PROGRAMMER H MITKI

DATE July, 21, 80

FORTRAN STATEMENT

```
C
   1   2    3    4
EXTENDED TRANSPORT
QUANTITY
TEST NO:4A - FREE OUTFALL
SIMPLE NETWORK FLOWING UNDER PRESSURE
  100 20.0 0.0     6     5     0     0     1     6     3     C     0     1
    0
      1 600        500         400         300         200         100
        6000       5000        4000        3000        2000
  0.0
 6000  600  400    1           2.50        300.0             0.013
 5000  500  .00    1           2.00        100.0             0.013
 4000  400  200    1           3.00        500.0             0 013
 3000  300  200    1           1.50        100.0             0.013
 2000  200  100    1           3.50        500.0             0.013
99999
  600     200.00   102.25
  500     200.00   101.75
  400     200.00   101.50
  300     200.00   101.00
  200     200 00   100.75
  100     200.00   100.00
99999
```

IBM

FORTRAN CODING FORM

PROGRAM EXTRAN - HS4EXDA

PROGRAMMER H.MITRI

DATE July, 21, 80

PUNCHING INSTRUCTIONS GRAPHIC PUNCH

FORTRAN STATEMENT

```
99999
99999
99999
99999
  100
99999
99999
    1
  600 500  300
0.0        30.0      20.0      10.0
2.0        30.0      20.0      10.0
ENDPROGRAM
```

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FORTRAN CODING FORM

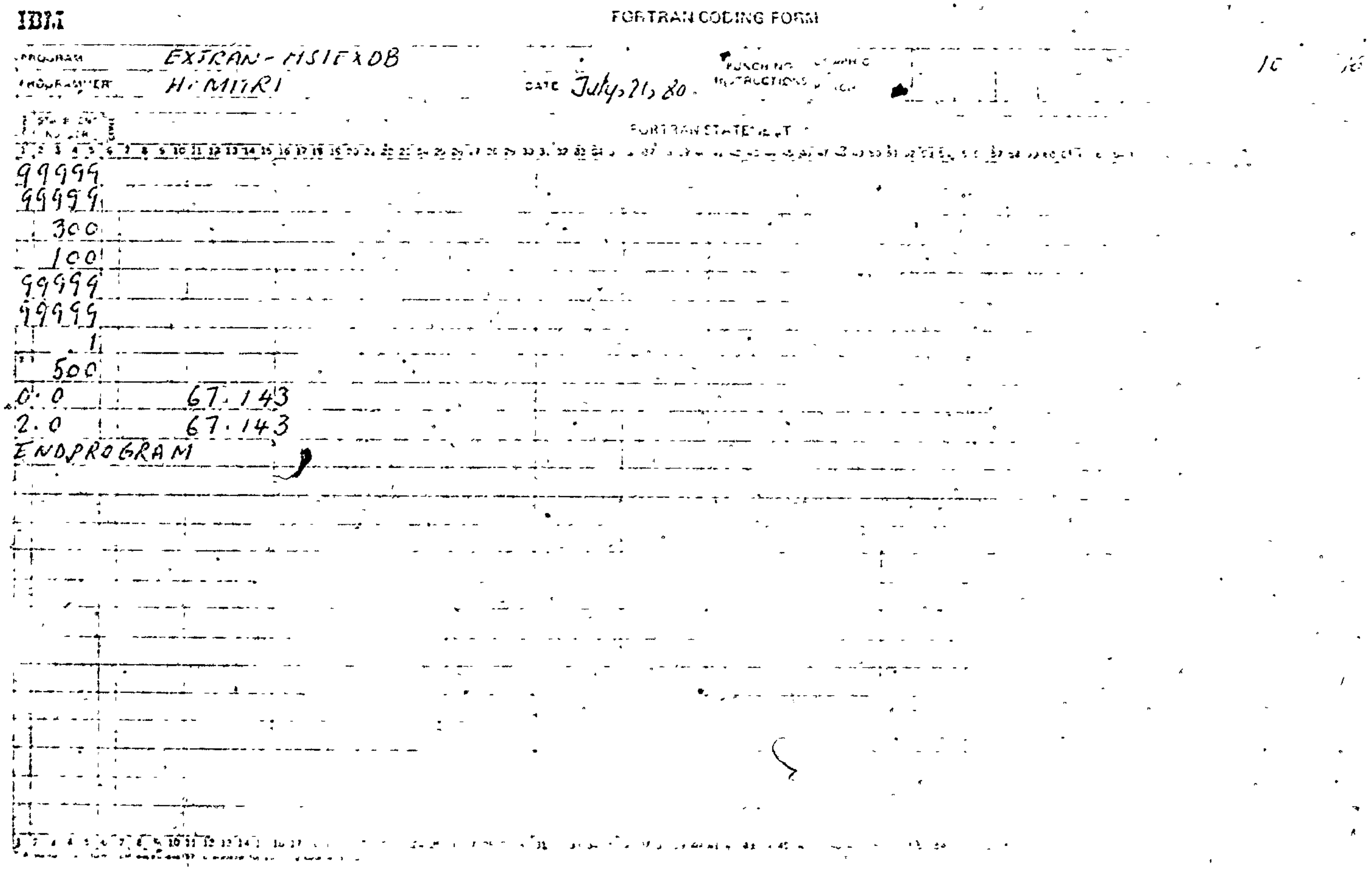
EXTRAN - HSIEXDB

H. MITRI

DATE July, 21, 80

9

```
0
  1  2  3  4
EXTENDED TRANSPORT
QUANTITY
TEST NO.1B - ORIFICE DIVERSION STRUCTURE
PIPE CONTAINING ORIFICE FLOWING WITH FREE SURFACE
   300  20.0  0.0     5    3    0    0    1    6    1    0    0    1
    0
        500      400      300      200      100
       5000      4000     2000
  0.0
 5000   500   400    1     6.0     200.0     0.013
 4000   400   300    1     5.0     200.0     0.013
 2000   200   100    1     4.0     100.0     0.013
99999
  500     200.00     100.40
  400     200.00     100.20
  300     200.00     100.00
  200     200.00      98.00
  100     200 00      95.20
99999
99999
  400   200   2.0   0.62    100.20
99999
```



IBM

FORTRAN CODING FORM

PROGRAM EXTRAN-MSIFXDB

PROGRAMMER H. MIIRI

DATE July, 21, 80.

PUNCHING INSTRUCTIONS

FORTRAN STATEMENT

```
99999
99999
  300
  100
99999
99999
    1
  500
0.0        67.143
2.0        67.143
ENDPROGRAM
```

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IBM FORTRAN CODING FORM

PROGRAM EXTRAN - 1152EXDB
PROGRAMMER H MAZI
DATE July, 22, 80

FORTRAN STATEMENT

```
   1   2   3   4
EXTENDED TRANSPORT
QUANTITY
TEST NO.2B - ORIFICE DIVERSION STRUCTURE
PIPE CONTAINING ORIFICE FLOWING UNDER PRESSURE
 300 20.0 0.0      5    3    0    0    1    6    1    0    0    1
   0
      500       400       300       200       100
     5000      4000      2000
  0.0
 5000  500  400    .1       6.0       200.0            0.013
 4000  400  300    1        5.0       200.0            0.013
 2000  200  100    1        4.0       100.0            0.013
99999
  500    200.00    100.40
  400    200.00    100.20
  300    200.00    100.00
  200    200.00     96.00
  100    200.00     95.20
99999
99999
  400  2.0  2.0 0.62   100.20
99999
```

IBM

FORTRAN CODING FORM

PROGRAM EXTRAN-HS2EXDB

PROGRAMMER H. MITRI

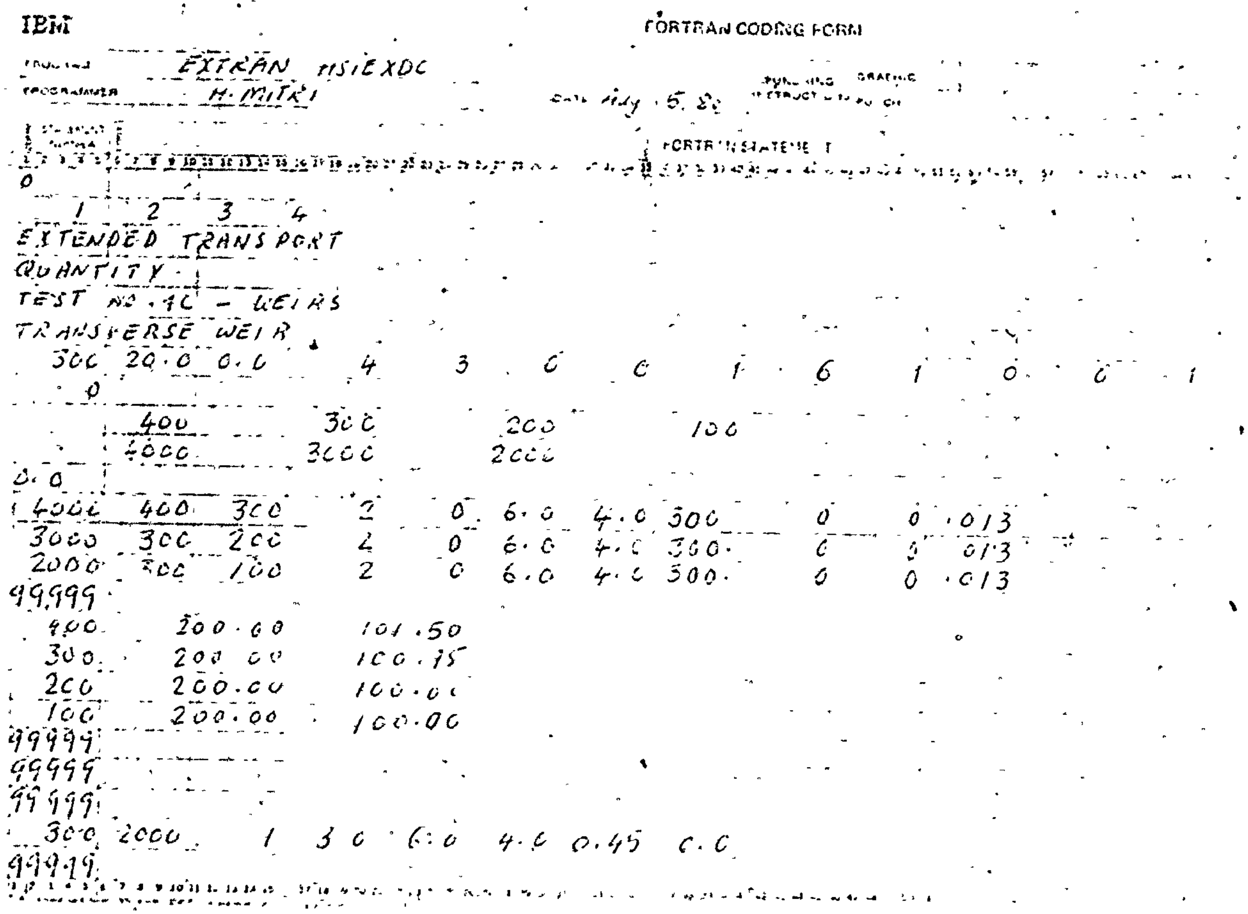
DATE July, 22, 80

PUNCHING INSTRUCTIONS GRAPHIC PUNCH

12

FORTRAN STATEMENT

```
99999
99999
  300
  100
99999
99999
    1
  500
0.0          150.0
2.0          150.0
ENDPROGRAM
```



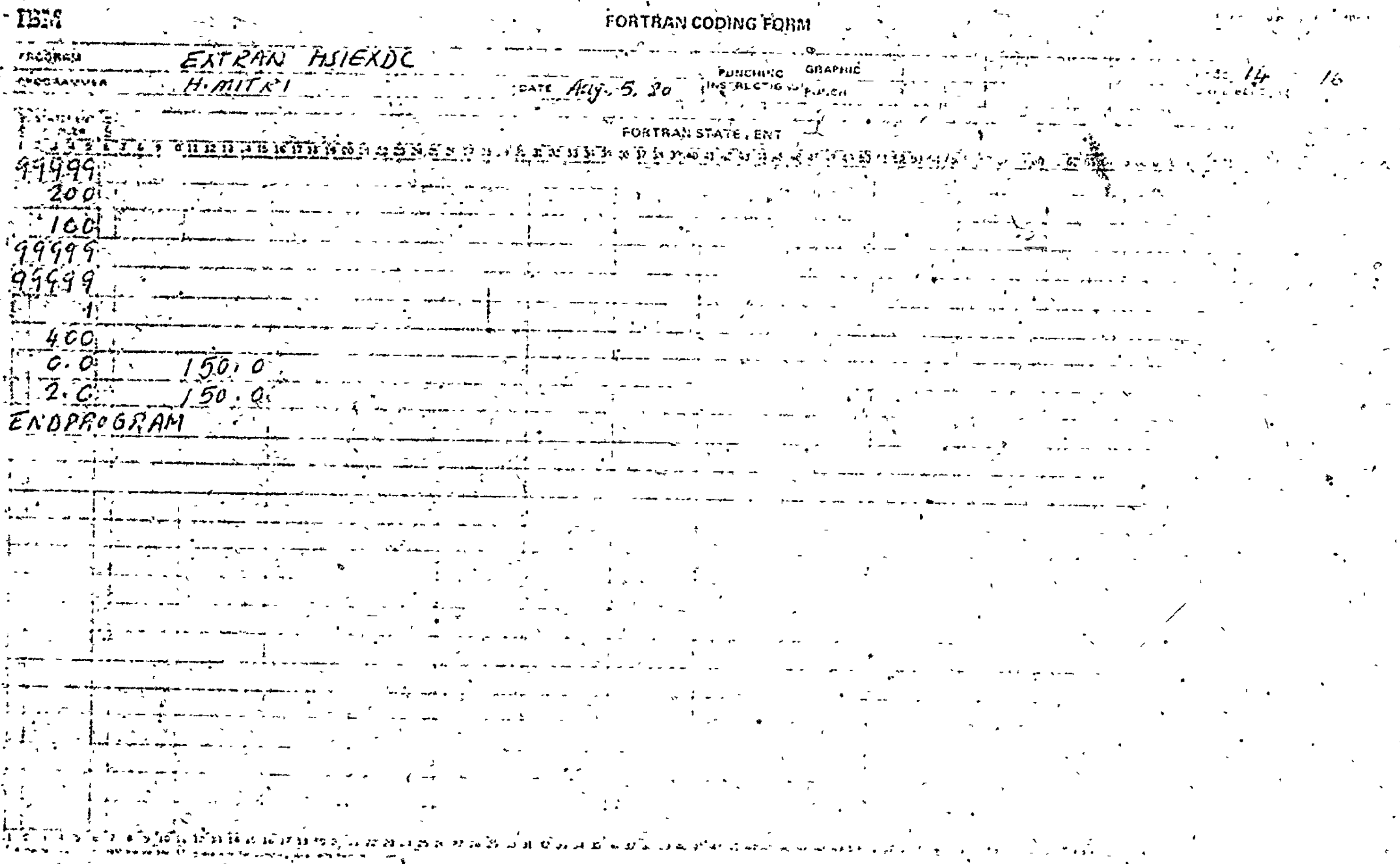
IBM FORTRAN CODING FORM

PROGRAM EXTRAN MSIEXDC
PROGRAMMER H. MITRI DATE Aug. 5. 82

15

FORTRAN STATEMENT

```
0
 1  2  3  4
EXTENDED TRANSPORT
QUANTITY
TEST NO.4C - WEIRS
TRANSVERSE WEIR
  300 20.0 0.0     4     3   0    0    1   6    1    0    0   1
   0
       400        300         200        100
       4000       3000        2000
0.0
 4000  400  300     2     0  6.0  4.0 300      0     0 .013
 3000  300  200     2     0  6.0  4.0 300.     0     0 .013
 2000  200  100     2     0  6.0  4.0 500.     0     0 .013
99999
  400     200.00    101.50
  300     200.00    100.15
  200     200.00    100.00
  100     200.00    100.00
99999
99999
99999
  300  2000     1  3 0  6.0  4.0 0.45  0.0
99999
```



IBM

FORTRAN CODING FORM

PROGRAM EXTRAN ASIEXDC

PROGRAMMER H.MITRI

DATE Aug. 5, 80

PUNCHING INSTRUCTIONS GRAPHIC PUNCH

14 16

STATEMENT NUMBER

CONT.

FORTRAN STATEMENT

```
99999
  200
  100
99999
99999
    1
  400
  0.0     150.0
  2.0     150.0
ENDPROGRAM
```

IBM

FORTRAN CODING FORM

PROGRAM EXTRAN HS2EXDC

PROGRAMMER H. MITRI

DATE Aug., 6, 80

PUNCHING INSTRUCTIONS GRAPHIC PUNCH

15 16

STATEMENT NUMBER

FORTRAN STATEMENT

```
0
    1   2   3   4
EXTENDED TRANSPORT
QUANTITY
TEST. NO. 2C - WEIRS
SIDE WEIR
  300 20.0 0.0        4    3    0    0    1    6    1    0    0    1
    0
        400        300        200        100
        4000       3000       2000
0.0
 4000  400  300   2    0  6.0  4.0 300.    0    0 .013
 3000  300  200   2    0  6.0  4.0 300.    0    0 .013
 2000  300  100   2    0  6.0  4.0 300.    0    0 .013
99999
  400   200.00    101.50
  300   200.00    100.75
  200   200.00    100.00
  100   200.00    100.00
99999
99999
99999
  300 2000    3  3.0  6.0  5.0  0.45  0.0
99999
```

IBM

FORTRAN CODING FORM

PROGRAM EXTRAN HS2EXDC

PROGRAMMER H. MITRI

DATE Aug. 6, 80.

PUNCHING INSTRUCTIONS GRAPHIC PUNCH

FORTRAN STATEMENT

```
99999
  200
  100
99999
99999
    1
  400
  0.0     150.0
  2.0     150.0
ENDPROGRAM
```

COPIE DE QUALITEE INFERIEURE

```
1     FPS
      0
      1   2   3   4
      EXTENDED TRANSPORT
      QUANTITY
      TEST NO.1 - SIDE WEIR
      COMPARISON OF RESULTS WITH OBSERVATIONS
      180    5    0    4    3    0    0    1    6    1    0    0    1
      0
      400     300     200     100
      4000    3000    2000
      0
      4000    400     300     2    0    2    .49213    100    0    0    .01
      3000    300     200     2    0    2    .49213    100    0    0    .01
      2000    300     100     2    0    2    .49213    100    0    0    .01
      99999
      400     110     103.54
      300     110     101.77
      200     110     100
      100     110     100
      99999
      99999
      99999
      300     2000    3    .3281    2    1.87008    .4    0
      99999
      99999
      200
      100
      99999
      99999
      1
      400
      0    1.2713
      1    1.2713
      ENDPROGRAM

      FPS
      0
      1   2   3   4
      EXTENDED TRANSPORT
      QUANTITY
      TEST NO.2 - SIDE WEIR
      COMPARISON OF RESULTS WITH OBSERVATIONS
      180    5    0    4    3    0    0    1    6    1    0    0    1
      0
      400     300     200     100
      4000    3000    2000
      0
      4000    400     300     2    0    2    .49213    100    0    0    .01
      3000    300     200     2    0    2    .49213    100    0    0    .01
      2000    300     100     2    0    2    .49213    100    0    0    .01
      99999
      400     110     104
      300     110     102
      200     110     100
      100     110     100
      99999
      99999
      99999
      300     2000    3    .3281    2    1.87008    .4    0
      99999
      99999
      200
      100


      99999
      99999
      1
      400
      0    1.5892
      1    1.5892
      ENDPROGRAM

      FPS
      0
      1   2   3   4
      EXTENDED TRANSPORT
      QUANTITY
      TEST NO.3 - SIDE WEIR
      COMPARISON OF RESULTS WITH OBSERVATIONS
      180    5    0    4    3    0    0    1    6    1    0    0    1
      0
      400     300     200     100
      4000    3000    2000
      0
      4000    400     300     2    0    2    .49213    100    0    0    .01
      3000    300     200     2    0    2    .49213    100    0    0    .01
      2000    300     100     2    0    2    .49213    100    0    0    .01
      99999
      400     120     113
      300     120     106.5
      200     120     100
      100     120     100
      99999
      99999
      99999
      300     2000    3    .169     2    1.87008    .35    0
      99999
      99999
      200
      100
      99999
      99999
      1
      400
      0    1.4479
      1    1.4479
      ENDPROGRAM

      FPS
      0
      1   2   3   4
      EXTENDED TRANSPORT
      QUANTITY
      TEST NO.4 - SIDE WEIR
      COMPARISON OF RESULTS WITH OBSERVATIONS
      180    5    0    4    3    0    0    1    6    1    0    0    1
      0
      400     300     200     100
      4000    3000    2000
      0
      4000    400     300     2    0    2    .49213    100    0    0    .01
      3000    300     200     2    0    2    .49213    100    0    0    .01
      2000    300     100     2    0    2    .49213    100    0    0    .01
      99999
      400     110     102.1
      300     110     101.05
```

COPIE DE QUALITEE INFERIEURE

```
99999
99999
99999
300    2000    3    .169    2    1.87008    .45    0
99999
99999
200
100
99999
99999
1
400
0    .565
1    .565
ENDPROGRAM

FPS
0
1   2   3   4
EXTENDED TRANSROPT
QUANTITY
TEST NC.5 - SICE WEIR
COMPARISON OF RESULTS WITH CBSERVATIONS
180   5   0   4   3   0   0   1   6   1   0   0   1
0
400     300     200     100
4000    3000    2000
0
4000    400    300    2    0    2    .49213    100    0    0    .01
3000    300    200    2    0    2    .49213    100    0    0    .01
2000    300    100    2    0    2    .49213    100    0    0    .01
99999
400     110    104.18
300     110    102.09
200     110    100
100     110    100
99999
99999
99999
300    2000    3    .169    2    1.87008    .4    0
99999
99999
200
100
99999
99999
1
400
0    .7593
1    .7593
ENDPROCRAM

FPS
0
1   2   3   4
EXTENDED TRANSPORT
QUANTITY
TEST NC.6 - SICE WEIR
COMPARISON OF RESULTS WITH CBSERVATIONS
180   5   0   4   3   0   0   1   6   1   0   0   1
0
400     300     200     100


4000    3000    2000
0
4000    400    300    2    0    2    .49213    100    0    0    .01
3000    300    200    2    0    2    .49213    100    0    0    .01
2000    300    100    2    0    2    .49213    100    0    0    .01
99999
400     110    102.76
300     110    101.38
200     110    100
100     110    100
99999
99999
99999
300    2000    3    .169    2    1.87008    .4    0
99999
99999
200
100
99999
99999
1
400
0    .6357
1    .6357
ENDPROGRAM

FPS
0
1   2   3   4
EXTENDED TRANSPORT
QUANTITY
TEST NO.7 - SICE WEIR
COMPARISON OF RESULTS WITH CBSERVATICNS
180   5   0   4   2   0   0   1   6   1   0   0   1
0
400     300     200     100
4000    3000    2000
0
4000    400    300    2    0    2    .49213    100    0    0    .01
3000    300    200    2    0    2    .49213    100    0    0    .01
2000    300    100    2    0    2    .49213    100    0    0    .01
99999
400     110    107.84
300     110    103.92
200     110    100
100     110    100
99999
99999
99999
300    2000    3    .169    2    1.87008    .4    0
99999
99999
200
100
99999
99999
1
400
0    1.2241
1    1.2241
ENDPROGRAM

FPS
```

```
0
1   2   3   4
EXTENDED TRANSPORT
QUANTITY
TEST NO.8 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
180    5    0    4    3    0    0    1    6    1    0    0    1
3
400     300     200     100
4000    3000    2000
0
4000    400     300     2    0    2    .49213    100    0    0    .01
3000    300     200     2    0    2    .49213    100    0    0    .01
2000    300     100     2    0    2    .49213    100    0    0    .01
99999
400     110     100.19
300     110     100.02
200     110     100
100     110     100
99999
99999
99999
300     2000    3    .3281    2    1.87008    .55    0
99999
99999
200
100
99999
99999
1
400
0    .3991
1    .3991
ENDPROGRAM

FPS
0
1   2   3   4
EXTENDED TRANSPORT
QUANTITY
TEST NO.9 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
180    5    0    4    3    0    0    1    6    1    0    0    1
0
400     300     200     100
4000    3000    2000
0
4000    400     300     2    0    2    .49213    100    0    0    .01
3000    300     200     2    0    2    .49213    100    0    0    .01
2000    300     100     2    0    2    .49213    100    0    0    .01
99999
400     110     100.14
300     110     100.01
200     110     100
100     110     100
99999
99999
99999
300     2000    3    .3281    2    1.87008    .55    0
99999
99999
200
100
99999


99999
1
400
0    .3708
1    .3708
ENDPROGRAM

FPS
0
1   2   3   4
EXTENDED TRANSPORT
QUANTITY
TEST NO.10 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
180    5    0    4    3    0    0    1    6    1    0    0    1
0
400     300     200     100
4000    3000    2000
0
4000    400     300     2    0    2    .49213    100    0    0    .01
3000    300     200     2    0    2    .49213    100    0    0    .01
2000    300     100     2    0    2    .49213    100    0    0    .01
99999
400     110     100.20
300     110     100.01
200     110     100
100     110     100
99999
99999
99999
300     2000    3    .3281    2    1.87008    .55    0
99999
99999
200
100
99999
99999
1
400
0    .4414
1    .4414
ENDPROGRAM

FPS
0
1   2   3   4
EXTENDED TRANSPORT
QUANTITY
TEST NO.11 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
180    5    0    4    3    0    0    1    6    1    0    0    1
0
400     300     200     100
4000    3000    2000
0
4000    400     300     2    0    2    .49213    100    0    0    .01
3000    300     200     2    0    2    .49213    100    0    0    .01
2000    300     100     2    0    2    .49213    100    0    0    .01
99999
400     111     100.23
300     110     100.03
200     110     100
100     110     100
```

```
99999
99999
99999
300    2000    3    .3281     2    1.87008    .55    0
99999
99999
200
100
99999
99999
1
400
0    .4061
1.   .4061
ENDPROGRAM

FPS
0
1    2    3    4
EXTENDED TRANSPORT
QUANTITY
TEST NO.12 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
180    5    0    4    3    0    0    1    6    1    0    0    1
0
400     300     200     100
4000    3000    2000
0
4000    400    300    2    0    2    .49213    100    0    0    .01
3000    300    200    2    0    2    .49213    100    0    0    .01
2000    300    100    2    0    2    .49213    100    0    0    .01
99999
400     110    100.33
300     110    100.03
200     110    100
100     110    100
99999
99999
99999
300    2000    3    .3281     2    1.87008    .55    0
99999
99999
200
100
99999
99999
1
400
0    .5474
1    .5474
ENDPROGRAM

FPS
0
1    2    3    4
EXTENDED TRANSPORT
QUANTITY
TEST NO.13 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
180    5    0    4    3    0    0    1    6    1    0    0    1
0
400     300     200     100
4000    3000    2000


0
4000    400    300    2    0    2    .49213    100    0    0    .01
3000    300    200    2    0    2    .49213    100    0    0    .01
2000    300    100    2    0    2    .49213    100    0    0    .01
99999
400     110    100.18
300     110    100.02
200     110    100
100     110    100
99999
99999
99999
300    2000    3    .3281     2    1.87008    .55    0
99999
99999
200
100
99999
99999
1
400
0    .4061
1    .4061
ENDPROGRAM

FPS
0
1    2    3    4
EXTENDED TRANSPORT
QUANTITY
TEST NO.14 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
180    6    0    4    3    0    0    1    6    1    0    0    1
0
400     300     200     100
4000    3000    2000
0
4000    400    300    2    0    2    .49213    100    0    0    .01
3000    300    200    2    0    2    .49213    100    0    0    .01
2000    300    100    2    0    2    .49213    100    0    0    .01
99999
400     110    100.2
300     110    100.1
200     110    100
100     110    100
99999
99999
99999
300    2000    3    .3291     2    1.87008    .45    0
99999
99999
200
100
99999
99999
1
400
0    1.6951
1    1.6951
ENDPROGRAM

FPS
```

COPIE DE QUALITEE INFERIEURE

```
1   2   3   4
EXTENDED TRANSPORT
QUANTITY
TEST NO.15 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
180    5    0    4    3    0    0    1    6    1    0    0    1
0
400     300     200     100
4000    3000    2000
0
4000    400     300     2     0     2     .49213    100    0    0    .01
3000    300     200     2     0     2     .49213    100    0    0    .01
2000    300     100     2     0     2     .49213    100    0    0    .01
99999
400     110     101.8
300     110     100.9
200     110     100
100     110     100
99999
99999
99999
300     2000    3     .169     2     1.87008     .45     0
99999
99999
200
100
99999
99999
1
400
0     1.7657
1     1.7657
ENDPROGRAM

FPS
0
1   2   3   4
EXTENDED TRANSPORT
QUANTITY
TEST NO.16 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
180    5    0    4    3    0    0    1    6    1    0    0    1
0
400     300     200     100
4000    3000    2000
0
4000    400     300     2     0     2     .49213    100    0    0    .01
3000    300     200     2     0     2     .49213    100    0    0    .01
2000    300     100     2     0     2     .49213    100    0    0    .01
99999
400     110     100.4
300     110     100.2
200     110     100
100     110     100
99999
99999
99999
300     2000    3     .3281     2     1.87008     .45     0
99999
99999
200
100
99999
99999


1
400
0     1.0241
1     1.0241
ENDPROGRAM

FPS
0
1   2   3   4
EXTENDED TRANSPORT
QUANTITY
TEST NO.17 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
180    5    0    4    3    0    0    1    6    1    0    0    1
0
400     300     200     100
4000    3000    2000
0
4000    400     300     2     0     2     .49213    100    0    0    .01
3000    300     200     2     0     2     .49213    100    0    0    .01
2000    300     100     2     0     2     .49213    100    0    0    .01
99999
400     110     100.2
300     110     100.1
200     110     100
100     110     100
99999
99999
99999
300     2000    3     .169     2     1.87008     .45     0
99999
99999
200
100
99999
99999
1
400
0     .724
1     .724
ENDPROGRAM
```

APPENDIX C

COPIE DE QUALITEE INFERIEURE

```
TEST NO.1A - FREE OUTFALL
SINGLE PIPE FLOWING UNDER PRESSURE
 * * * * * * * * * * * * * * * * *T-I-M-E  H-I-S-T-O-R-Y  O-F  F-L-O-W  A-N-D  V-E-L-O-C-I-T-Y * * * * * * * * * * * * * * * * *
                                                Q(CFS), VEL(FPS), HLOS(FT)

  TIME       CONDUIT 2000        CONDUIT
  0.  0        2.75   0.0
  0.  2       18.74   5.9
  0.  4       19.99   6.6
  0.  6       20.00   6.6
  0.  8       20.00   6.6
  0. 10       20.00   6.6
  0. 12       20.00   6.6
  0. 14       20.00   6.6
  0. 16       20.00   6.6
  0. 18       20.00   6.6
  0. 20       20.00   6.6
  0. 22       20.00   6.6
  0. 24       20.00   6.6
  0. 26       20.00   6.6
  0. 28       20.08   6.6
  0. 30       20.00   6.6
  0. 32       20.00   6.6
  0. 34       20.00   6.6
  0. 36       20.00   6.6
  0. 38       20.00   6.6
  0. 40       20.00   6.6
  0. 42       20.00   6.6
  0. 44       20.00   6.6
  0. 46       20.00   6.6
  0. 48       20.00   6.6
  0. 50       20.00   6.6
  0. 52       20.00   6.6
  0. 54       20.00   6.6
  0. 56       20.00   6.6
  0. 58       20.00   6.6
  1.  0       20.00   6.6
  1.  2       20.00   6.6
  1.  4       20.00   6.6
  1.  6       20.00   6.6
  1.  8       20.00   6.6
  1. 10       20.00   6.6
  1. 12       20.00   6.6
  1. 14       20.00   6.6
  1. 16       20.00   6.6
  1. 18       20.00   6.6
  1. 20       20.00   6.6
  1. 22       20.00   6.6
  1. 24       20.00   6.6
  1. 26       20.00   6.6
  1. 28       20.00   6.6
  1. 30       20.00   6.6
  1. 32       20.00   6.6
  1. 34       20.00   6.6
  1. 36       20.00   6.6
  1. 38       20.00   6.6
```

COPIE DE QUALITEE INFERIEURE

```
TEST NO.2A - FREE OUTFALL
CONTINUOUS PIPES FLOWING UNDER PRESSURE
 * * * * * * * * * * * * * * * * * * * T I M E  H I S T O R Y  O F  F L O W  A N D  V E L O C I T Y * * * * * * * * * * * * * * *
                                        Q(CFS), VEL(FPS), HLOS(FT)

  TIME      CONDUIT 5000       CONDUIT 4000       CONDUIT 3000       CONDUIT 2000       CONDUIT
 0.  0       2.33  0.0          0.66  0.0          0.00  0.0          0.00  0.0
 0.  2      22.38  5.4          8.30  3.5           .31   .7           .00   .1
 0.  4      18.16  3.6         12.73  4.2          9.83  4.4          2.11  1.8
 0.  6      17.81  3.6         13.71  4.4          9.80  4.1          6.83  3.9
 0.  8      17.74  3.6         13.71  4.3         10.70  4.4          8.86  5.1
 0. 10      18.01  3.7         14.44  4.6         11.77  4.8         10.13  5.8
 0. 12      18.24  3.7         15.09  4.8         12.70  5.2         11.21  6.4
 0. 14      18.43  3.7         15.63  4.9         13.49  5.6         12.13  6.9
 0. 16      18.66  3.8         16.69  5.1         14.16  5.8         12.91  7.3
 0. 18      18.75  3.9         16.49  5.2         14.75  6.1         13.61  7.7
 0. 20      18.87  3.8         16.84  5.3         15.26  6.3         14.21  8.1
 0. 22      18.98  3.9         17.15  5.4         15.71  6.5         14.75  8.4
 0. 24      19.08  3.9         17.42  5.5         16.12  6.7         15.23  8.6
 0. 26      19.17  3.9         17.67  5.6         16.48  6.8         15.66  8.9
 0. 28      19.25  3.9         17.88  5.7         16.80  7.0         16.06  9.1
 0. 30      19.32  3.9         18.08  5.7         17.10  7.1         16.41  9.3
 0. 32      19.38  3.9         18.26  5.8         17.36  7.2         16.74  9.5
 0. 34      19.44  4.0         18.42  5.9         17.60  7.3         17.03  9.6
 0. 36      19.49  4.0         18.56  5.9         17.79  7.4         17.19  9.7
 0. 38      19.52  4.0         18.65  5.9         17.93  7.4         17.33  9.8
 0. 40      19.55  4.0         18.73  6.0         18.06  7.5         17.54  9.9
 0. 42      19.58  4.0         18.83  6.0         18.22  7.6         17.77 10.0
 0. 44      19.62  4.0         18.94  6.0         18.38  7.6         17.97 10.1
 0. 46      19.66  4.0         19.03  6.1         18.52  7.7         18.15 10.3
 0. 48      19.69  4.0         19.12  6.1         18.66  7.7         18.32 10.3
 0. 50      19.72  4.0         19.26  6.1         18.78  7.8         18.47 10.4
 0. 52      19.74  4.0         19.27  6.1         18.89  7.8         18.60 10.5
 0. 54      19.77  4.0         19.34  6.2         18.99  7.9         18.73 10.6
 0. 56      19.79  4.0         19.40  6.2         19.08  7.9         18.84 10.7
 0. 58      19.81  4.0         19.46  6.2         19.16  8.0         18.95 10.7
 1.  0      19.82  4.0         19.50  6.2         19.24  8.0         19.04 10.8
 1.  2      19.84  4.0         19.55  6.2         19.31  8.0         19.13 10.8
 1.  4      19.86  4.0         19.59  6.2         19.37  8.1         19.21 10.9
 1.  6      19.87  4.0         19.63  6.2         19.43  8.1         19.28 10.9
 1.  8      19.88  4.0         19.66  6.3         19.48  8.1         19.35 10.9
 1. 10      19.89  4.1         19.69  6.3         19.53  8.1         19.41 11.0
 1. 12      19.90  4.1         19.72  6.3         19.57  8.1         19.46 11.0
 1. 14      19.91  4.1         19.75  6.3         19.61  8.2         19.51 11.0
 1. 16      19.92  4.1         19.77  6.3         19.65  8.2         19.55 11.1
 1. 18      19.93  4.1         19.79  6.3         19.68  8.2         19.59 11.1
 1. 20      19.93  4.1         19.81  6.3         19.71  8.2         19.63 11.1
 1. 22      19.94  4.1         19.83  6.3         19.74  8.2         19.67 11.1
 1. 24      19.94  4.1         19.84  6.3         19.76  8.2         19.70 11.1
 1. 26      19.95  4.1         19.86  6.3         19.78  8.2         19.72 11.2
 1. 28      19.95  4.1         19.87  6.3         19.80  8.2         19.75 11.2
 1. 30      19.96  4.1         19.88  6.3         19.82  8.2         19.77 11.2
 1. 32      19.96  4.1         19.89  6.3         19.84  8.2         19.79 11.2
 1. 34      19.97  4.1         19.90  6.3         19.85  8.3         19.81 11.2
 1. 36      19.97  4.1         19.91  6.3         19.87  8.3         19.83 11.2
 1. 38      19.97  4.1         19.92  6.3         19.88  8.3         19.84 11.2
 1. 40      19.97  4.1         19.93  6.3         19.89  8.3         19.85 11.2
 1. 42      19.98  4.1         19.93  6.3         19.90  8.3         19.87 11.2
 1. 44      19.98  4.1         19.94  6.3         19.91  8.3         19.88 11.3
 1. 46      19.98  4.1         19.95  6.3         19.92  8.3         19.89 11.3
 1. 48      19.98  4.1         19.95  6.4         19.92  8.3         19.90 11.3
 1. 50      19.98  4.1         19.96  6.4         19.93  8.3         19.91 11.3
 1. 52      19.99  4.1         19.96  6.4         19.94  8.3         19.92 11.3
 1. 54      19.99  4.1         19.96  6.4         19.94  8.3         19.93 11.3
 1. 56      19.99  4.1         19.97  6.4         19.95  8.3         19.93 11.3
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(Cont) 2A

1. 58	19.99	4.1	19.97	6.4	19.95	8.3	19.94	11.3
2. 0	19.99	4.1	19.97	6.4	19.96	8.3	19.95	11.3
2. 2	19.99	4.1	19.98	6.4	19.96	8.3	19.95	11.3
2. 4	19.99	4.1	19.98	6.4	19.97	8.3	19.96	11.3
2. 6	19.99	4.1	19.98	6.4	19.97	8.3	19.96	11.3
2. 8	19.99	4.1	19.98	6.4	19.97	8.3	19.96	11.3
2. 10	19.99	4.1	19.98	6.4	19.97	8.3	19.97	11.3
2. 12	19.99	4.1	19.98	6.4	19.98	8.3	19.97	11.3
2. 14	20.00	4.1	19.99	6.4	19.98	8.3	19.97	11.3
2. 16	20.00	4.1	19.99	6.4	19.98	8.3	19.98	11.3
2. 18	20.00	4.1	19.99	6.4	19.98	8.3	19.98	11.3
2. 20	20.00	4.1	19.99	6.4	19.98	8.3	19.98	11.3
2. 22	20.00	4.1	19.99	6.4	19.99	8.3	19.98	11.3
2. 24	20.00	4.1	19.99	6.4	19.99	8.3	19.98	11.3
2. 26	20.00	4.1	19.99	6.4	19.99	8.3	19.99	11.3
2. 28	20.00	4.1	19.99	6.4	19.99	8.3	19.99	11.3
2. 30	20.00	4.1	19.99	6.4	19.99	8.3	19.99	11.3
2. 32	20.00	4.1	19.99	6.4	19.99	8.3	19.99	11.3
2. 34	20.00	4.1	19.99	6.4	19.99	8.3	19.99	11.3
2. 36	20.00	4.1	20.00	6.4	19.99	8.3	19.99	11.3
2. 38	20.00	4.1	20.00	6.4	19.99	8.3	19.99	11.3
2. 40	20.00	4.1	20.00	6.4	19.99	8.3	19.99	11.3
2. 42	20.00	4.1	20.00	6.4	19.99	8.3	19.99	11.3
2. 44	20.00	4.1	20.00	6.4	19.99	8.3	19.99	11.3
2. 46	20.00	4.1	20.00	6.4	20.00	8.3	19.99	11.3
2. 48	20.00	4.1	20.00	6.4	20.00	8.3	19.99	11.3
2. 50	20.00	4.1	20.00	6.4	20.00	8.3	20.00	11.3
2. 52	20.00	4.1	20.00	6.4	20.00	8.3	20.00	11.3
2. 54	20.00	4.1	20.00	6.4	20.00	8.3	20.00	11.3
2. 56	20.00	4.1	20.00	6.4	20.00	8.3	20.00	11.3
2. 58	20.00	4.1	20.00	6.4	20.00	8.3	20.00	11.3
3. 0	20.00	4.1	20.00	6.4	20.00	8.3	20.00	11.3
3. 2	20.00	4.1	20.00	6.4	20.00	8.3	20.00	11.3
3. 4	20.00	4.1	20.00	6.4	20.00	8.3	20.00	11.3
3. 6	20.00	4.1	20.00	6.4	20.00	8.3	20.00	11.3
3. 8	20.00	4.1	20.00	6.4	20.00	8.3	20.00	11.3
3. 10	20.00	4.1	20.00	6.4	20.00	8.3	20.00	11.3
3. 12	20.00	4.1	20.00	6.4	20.00	8.3	20.00	11.3
3. 14	20.00	4.1	20.00	6.4	20.00	8.3	20.00	11.3
3. 16	20.00	4.1	20.00	6.4	20.00	8.3	20.00	11.3
3. 18	20.00	4.1	20.00	6.4	20.00	8.3	20.00	11.3

COPIE DE QUALITEE INFERIEURE

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TEST NO.3A - FREE OUTFALL
SIMPLE SEWAGE NETWORK WITH FREE WATER SURFACE IN PIPES
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*--T-I-M-E--H-I-S-T-O-R-Y--O-F--F-L-O-W--A-N-D--V-E-L-O-C-I-T-Y-*-*-*-*-*-*-*-*-*-*-*-*-*-*
                                                  Q(CFS), VEL(FPS), HLOS(FT)
  TIME       CONDUIT 6000         CONDUIT 5000         CONDUIT 4000         CONDUIT 3000         CONDUIT 2000         CONDUIT
  0.  0       .17   0.0          1.35   0.0           0.00   0.0            .54   0.0           0.00   0.0
  0.  2      3.53   3.1          1.90   2.4           2.26   2.4            .81   2.3            .76   1.6
  0.  4      2.91   2.5          1.99   1.8           5.13   3.5            .86   1.4           4.27   3.2
  0.  6      2.99   2.5          2.02   2.0           5.23   3.4            .96   1.1           5.84   3.6
  0.  8      3.01   2.6          2.00   2.0           4.97   3.1           1.00   1.1           5.95   3.6
  0. 10      3.00   2.6          2.00   2.0           4.98   3.1           1.00   1.1           5.97   3.6
  0. 12      3.00   2.6          2.00   2.0           4.99   3.1           1.00   1.1           5.99   3.6
  0. 14      3.00   2.6          2.00   2.0           5.00   3.1           1.00   1.1           5.99   3.6
  0. 16      3.00   2.6          2.00   2.0           5.00   3.1           1.00   1.1           6.00   3.6
  0. 18      3.00   2.6          2.00   2.0           5.00   3.1           1.00   1.1           6.00   3.6
  0. 20      3.00   2.6          2.00   2.0           5.00   3.1           1.00   1.1           6.00   3.6
  0. 22      3.00   2.6          2.00   2.0           5.00   3.1           1.00   1.1           6.00   3.6
  0. 24      3.00   2.6          2.00   2.0           5.00   3.1           1.00   1.1           6.00   3.6
  0. 26      3.00   2.6          2.00   2.0           5.00   3.1           1.00   1.1           6.00   3.6
  0. 28      3.00   2.6          2.00   2.0           5.00   3.1           1.00   1.1           6.00   3.6
  0. 30      3.00   2.6          2.00   2.0           5.00   3.1           1.00   1.1           6.00   3.6
  0. 32      3.00   2.6          2.00   2.0           5.00   3.1           1.00   1.1           6.00   3.6
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COPIE DE QUALITEE INFERIEURE

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TEST NO.4A - FREE OUTFALL
SIMPLE NETWORK FLOWING UNDER PRESSURE
-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*- T-I-M-E- H-I-S-T-O-R-Y -O-F -F-L-O-W- -A-N-D- -V-E-L-O-C-I-T-Y-*-*-*-*-*-*-*-*-*-*-*-*-*-*
                                          Q(CFS), VEL(FPS), HLOS(FT)
 TIME        CONDUIT 6000        CONDUIT 5000        CONDUIT 4000        CONDUIT 3000        CONDUIT 2000        CONDUIT
 0.  0       12.67   0.0         81.21   0.0          0.64   0.0         31.17   0.0          0.00   0.0
 0.  2       26.68   6.4         17.77  30.5         57.21   7.0          9.23   5.1         56.97   7.1
 0.  4       33.66   5.2          3.76  10.5         61.09   9.5         10.79   5.8         74.59   8.0
 0.  6       24.28   5.8         25.57   -.7         58.16   7.4         11.97   6.3         62.11   7.3
 0.  8       31.54   4.2         -1.19  19.8         64.53   9.9         16.95   7.9         75.62   7.5
 0. 10       28.76   3.7         15.18  11.8         63.76  10.6          1.62   4.1         78.63   6.3
 0. 12       32.96   4.2          5.62  20.7         67.40  11.4         -2.93   1.9         73.68   7.2
 0. 14       29.33   7.6         22.67   7.9         46.08   5.5         -1.64   1.5         44.19   7.3
 0. 16       40.03   5.8         40.61   3.0         41.45   3.2         -3.06   -.0         63.92   7.6
 0. 18       31.79   8.3        -10.76  13.8         47.81   5.2         13.46   7.3         52.23   9.1
 0. 20       32.43   6.7         12.92   9.3         52.48   7.6         -1.05   -.2         50.15   7.4
 0. 22       26.87   5.1         16.01  18.4         51.34   8.5         13.92  11.7         73.98   7.8
 0. 24       30.66   2.4         32.57  18.2         71.17  11.6         -2.66   -.7         78.02   7.6
 0. 26       31.93   9.1         14.52  13.6         55.02   6.7         -1.22   2.0         52.22   8.2
 0. 28       29.14   4.0          6.48  19.6         65.35   8.8         -3.28   -.1         58.26   6.9
 0. 30       41.58   5.9         41.64   2.6         36.84   9.9         16.64   7.8         75.51   7.9
 0. 32       32.57   8.4         27.76  12.1         50.26   6.5          5.64   3.9         53.63   7.7
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TEST NO.18 - ORIFICE DIVERSION STRUCTURE
PIPE CONTAINING ORIFICE FLOWING WITH FREE SURFACE
                                     T I M E   H I S T O R Y   O F   F L O W   A N D   V E L O C I T Y
                                                 Q(CFS), VEL(FPS), HLOS(FT)
 TIME      CONDUIT 5000        CONDUIT 4086        CONDUIT 2060        CONDUIT
 0.  0     57.99  3.6           0.00  0.0            .02  0.0
 0.  2     66.72  6.5          54.67  5.3          14.52  4.1
 0.  4     67.00  5.4          49.07  5.6          16.11  4.2
 0.  6     65.83  5.5          50.77  5.5          16.26  4.2
 0.  8     67.10  5.5          50.84  5.5          16.30  4.2
 0. 10     67.14  5.5          50.83  5.5          16.31  4.2
 0. 12     67.14  5.5          50.83  5.5          16.31  4.2
 0. 14     67.14  5.5          50.82  5.5          16.31  4.2
 0. 16     67.14  5.5          50.82  5.5          16.31  4.2
 0. 18     67.14  5.5          50.82  5.5          16.31  4.2
 0. 20     67.14  5.5          50.82  5.5          16.31  4.2
 0. 22     67.14  5.5          50.82  5.5          16.32  4.2
 0. 24     67.14  5.5          50.82  5.5          16.32  4.2
 0. 26     67.14  5.5          50.82  5.5          16.32  4.2
 0. 28     67.14  5.5          50.82  5.5          16.32  4.2
 0. 30     67.14  5.5          50.82  5.5          16.32  4.2
 0. 32     67.14  5.5          50.82  5.5          16.32  4.2
 0. 34     67.14  5.5          50.82  5.5          16.32  4.2
 0. 36     67.14  5.5          50.82  5.5          16.32  4.2
 0. 38     67.14  5.5          50.81  5.5          16.32  4.2
 0. 40     67.14  5.5          50.81  5.5          16.32  4.2
 0. 42     67.14  5.5          50.81  5.4          16.32  4.2
 0. 44     67.14  5.5          50.81  5.4          16.32  4.2
 0. 46     67.14  5.5          50.81  5.4          16.32  4.2
 0. 48     67.14  5.5          50.81  5.4          16.33  4.2
 0. 50     67.14  5.5          50.81  5.4          16.33  4.2
 0. 52     67.14  5.5          50.81  5.4          16.33  4.2
 0. 54     67.14  5.5          50.81  5.4          16.33  4.2
 0. 56     67.14  5.5          50.81  5.4          16.33  4.2
 0. 58     67.14  5.5          50.81  5.4          16.33  4.2
 1.  0     67.14  5.5          50.81  5.4          16.33  4.2
 1.  2     67.14  5.5          50.81  5.4          16.33  4.2
 1.  4     67.14  5.5          50.80  5.4          16.33  4.2
 1.  6     67.14  5.5          50.80  5.4          16.33  4.2
 1.  8     67.14  5.5          50.80  5.4          16.33  4.2
 1. 10     67.14  5.5          50.80  5.4          16.33  4.2
 1. 12     67.14  5.5          50.80  5.4          16.33  4.2
 1. 14     67.14  5.5          50.80  5.4          16.34  4.2
 1. 16     67.14  5.5          50.80  5.4          16.34  4.2
 1. 18     67.14  5.5          50.80  5.4          16.34  4.2
 1. 20     67.14  5.5          50.80  5.4          16.34  4.2
 1. 22     67.14  5.5          50.80  5.4          16.34  4.2
 1. 24     67.14  5.5          50.80  5.4          16.34  4.2
 1. 26     67.14  5.5          50.80  5.4          16.34  4.2
 1. 28     67.14  5.5          50.80  5.4          16.34  4.2
 1. 30     67.14  5.5          50.80  5.4          16.34  4.2
 1. 32     67.14  5.5          50.79  5.4          16.34  4.2
 1. 34     67.14  5.5          50.79  5.4          16.34  4.2
 1. 36     67.14  5.5          50.79  5.4          16.34  4.2
 1. 38     67.14  5.5          50.79  5.4          16.34  4.2
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TEST NO.29 - ORIFICE DIVERSION STRUCTURE
PIPE CONTAINING ORIFICE FLOWING UNDER PRESSURE
* * * * * * * * * * * * * * * * T-I-M-E  H-I-S-T-O-R-Y  O-F  F-L-O-W  A-N-D  V-E-L-O-C-I-T-Y * * * * * * * * * * * * * * * *
                                                          Q(CFS), VEL(FPS), HLOS(FT)

  TIME      CONDUIT 5000          CONDUIT 4000          CONDUIT 2000          CONDUIT
  0.  0    311.54   0.0            0.00   0.0              .02   0.0
  0.  2     71.36   3.5           44.46   7.5            16.92   4.6
  0.  4    196.72   4.0          125.11   5.6            18.07   4.9
  0.  6    132.73   7.7          135.11   9.0            21.01   4.3
  0.  8    153.51   6.7          129.85   8.1            20.10   4.6
  0. 10    149.67   6.9          129.03   8.3            20.48   4.5
  0. 12    150.01   6.9          129.50   8.3            20.47   4.5
  0. 14    150.00   6.9          129.52   8.3            20.47   4.5
  0. 16    150.00   6.9          129.53   8.3            20.47   4.5
  0. 18    150.00   6.9          129.53   8.3            20.47   4.5
  0. 20    150.00   6.9          129.53   8.3            20.47   4.5
  0. 22    150.00   6.9          129.53   8.3            20.47   4.5
  0. 24    150.00   6.9          129.53   8.3            20.47   4.5
  0. 26    150.00   6.9          129.53   8.3            20.47   4.5
  0. 28    150.00   6.9          129.53   8.3            20.47   4.5
  0. 30    150.00   6.9          129.53   8.3            20.47   4.5
  0. 32    150.00   6.9          129.53   8.3            20.47   4.5
  0. 34    150.00   6.9          129.53   8.3            20.47   4.5
  0. 36    150.00   6.9          129.53   8.3            20.47   4.5
  0. 38    150.00   6.9          129.53   8.3            20.47   4.5
  0. 40    150.00   6.9          129.53   8.3            20.47   4.5
  0. 42    150.00   6.9          129.53   8.3            20.47   4.5
  0. 44    150.00   6.9          129.53   8.3            20.47   4.5
  0. 46    150.00   6.9          129.53   8.3            20.47   4.5
  0. 48    150.00   6.9          129.53   8.3            20.47   4.5
  0. 50    150.00   6.9          129.53   8.3            20.47   4.5
  0. 52    150.00   6.9          129.53   8.3            20.47   4.5
  0. 54    150.00   6.9          129.53   8.3            20.47   4.5
  0. 56    150.00   6.9          129.53   8.3            20.47   4.5
  0. 58    150.00   6.9          129.53   8.3            20.47   4.5
  1.  0    150.00   6.9          129.53   8.3            20.47   4.5
  1.  2    150.00   6.9          129.53   8.3            20.47   4.5
  1.  4    150.00   6.9          129.53   8.3            20.47   4.5
  1.  6    150.00   6.9          129.53   8.3            20.47   4.5
  1.  8    150.00   6.9          129.53   8.3            20.47   4.5
  1. 10    150.00   6.9          129.53   8.3            20.47   4.5
  1. 12    150.00   6.9          129.53   8.3            20.47   4.5
  1. 14    150.00   6.9          129.53   8.3            20.47   4.5
  1. 16    150.00   6.9          129.53   8.3            20.47   4.5
  1. 18    150.00   6.9          129.53   8.3            20.47   4.5
  1. 20    150.00   6.9          129.53   8.3            20.47   4.5
  1. 22    150.00   6.9          129.53   8.3            20.47   4.5
  1. 24    150.00   6.9          129.53   8.3            20.47   4.5
  1. 26    150.00   6.9          129.53   8.3            20.47   4.5
  1. 28    150.00   6.9          129.53   8.3            20.47   4.5
  1. 30    150.00   6.9          129.53   8.3            20.47   4.5
  1. 32    150.00   6.9          129.53   8.3            20.47   4.5
  1. 34    150.00   6.9          129.53   8.3            20.47   4.5
  1. 36    150.00   6.9          129.53   8.3            20.47   4.5
  1. 38    150.00   6.9          129.53   8.3            20.47   4.5
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COPIE DE QUALITEE INFERIEURE

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TEST NO.10 - WEIRS
TRANSVERSE WEIR
* * * * * * * * * * * * * * * * * T I M E  H I S T O R Y  O F  F L O W  A N D  V E L O C I T Y * * * * * * * * * * * * * * * * *
                                              Q(CFS), VEL(FPS), HLOS(FT)
 TIME      CONDUIT 4000          CONDUIT 3000         CONDUIT 2000         CONDUIT
 0.  0     34.88   0.0             0.00   0.0           0.00   0.0
 0.  2    151.35   8.0           146.16   8.1           2.46   2.0
 0.  4    150.17   7.8           145.57   8.9           3.81   2.7
 0.  6    150.00   7.8           145.91   8.9           4.00   2.7
 0.  8    150.00   7.8           145.97   8.9           4.02   2.7
 0. 10    150.00   7.8           145.97   8.9           4.03   2.7
 0. 12    150.00   7.8           145.97   8.9           4.03   2.7
 0. 14    150.00   7.8           145.97   8.9           4.03   2.7
 0. 16    150.00   7.8           145.97   8.9           4.03   2.7
 0. 18    150.00   7.8           145.97   8.9           4.03   2.7
 0. 20    150.00   7.8           145.97   8.9           4.03   2.7
 0. 22    150.00   7.8           145.97   8.9           4.03   2.7
 0. 24    150.00   7.8           145.97   8.9           4.03   2.7
 0. 26    150.00   7.8           145.97   8.9           4.03   2.7
 0. 28    150.00   7.8           145.97   8.9           4.03   2.7
 0. 30    150.00   7.8           145.97   8.9           4.03   2.7
 0. 32    150.00   7.8           145.97   8.9           4.03   2.7
 0. 34    150.00   7.8           145.97   8.9           4.03   2.7
 0. 36    150.00   7.8           145.97   8.9           4.03   2.7
 0. 38    150.00   7.8           145.97   8.9           4.03   2.7
 0. 40    150.00   7.8           145.97   8.9           4.03   2.7
 0. 42    150.00   7.8           145.97   8.9           4.03   2.7
 0. 44    150.00   7.8           145.97   8.9           4.03   2.7
 0. 46    150.00   7.8           145.97   8.9           4.03   2.7
 0. 48    150.00   7.8           145.97   8.9           4.03   2.7
 0. 50    150.00   7.8           145.97   8.9           4.03   2.7
 0. 52    150.00   7.8           145.97   8.9           4.03   2.7
 0. 54    150.00   7.8           145.97   8.9           4.03   2.7
 0. 56    150.00   7.8           145.97   8.9           4.03   2.7
 0. 58    150.00   7.8           145.97   8.9           4.03   2.7
 1.  0    150.00   7.8           145.97   8.9           4.03   2.7
 1.  2    150.00   7.8           145.97   8.9           4.03   2.7
 1.  4    150.00   7.8           145.97   8.9           4.03   2.7
 1.  6    150.00   7.8           145.97   8.9           4.03   2.7
 1.  8    150.00   7.8           145.97   8.9           4.03   2.7
 1. 10    150.00   7.8           145.97   8.9           4.03   2.7
 1. 12    150.00   7.8           145.97   8.9           4.03   2.7
 1. 14    150.00   7.8           145.97   8.9           4.03   2.7
 1. 16    150.00   7.8           145.97   8.9           4.03   2.7
 1. 18    150.00   7.8           145.97   8.9           4.03   2.7
 1. 20    150.00   7.8           145.97   8.9           4.03   2.7
 1. 22    150.00   7.8           145.97   8.9           4.03   2.7
 1. 24    150.00   7.8           145.97   8.9           4.03   2.7
 1. 26    150.00   7.8           145.97   8.9           4.03   2.7
 1. 28    150.00   7.8           145.97   8.9           4.03   2.7
 1. 30    150.00   7.8           145.97   8.9           4.03   2.7
 1. 32    150.00   7.8           145.97   8.9           4.03   2.7
 1. 34    150.00   7.8           145.97   8.9           4.03   2.7
 1. 36    150.00   7.8           145.97   8.9           4.03   2.7
 1. 38    150.00   7.8           145.97   8.9           4.03   2.7
```

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TEST NO.2C  - WEIRS
SIDE WEIR
 * * * * * * * * * * * * * * * * *  T I M E  H I S T O R Y  O F  F L O W  A N D  V E L O C I T Y  * * * * * * * * * * * * * * * *
                                                   Q(CFS), VEL(FPS), HLOS(FT)

 TIME       CONDUIT 4000          CONDUIT 3000          CONDUIT 2000          CONDUIT
 0.  0       34.88   0.0            0.00   0.0            0.60   0.0
 0.  2      150.98   8.0          145.54   8.1            3.42   2.5
 0.  4      150.14   7.8          144.36   8.9            5.11   3.0
 0.  6      150.00   7.8          144.60   8.9            5.33   3.0
 0.  8      150.00   7.8          144.64   8.9            5.35   3.0
 0. 10      150.00   7.8          144.64   8.9            5.36   3.0
 0. 12      150.00   7.8          144.64   8.9            5.36   3.0
 0. 14      150.00   7.8          144.64   8.9            5.36   3.0
 0. 16      150.00   7.8          144.64   8.9            5.36   3.0
 0. 18      150.00   7.8          144.64   8.9            5.36   3.0
 0. 20      150.00   7.8          144.64   8.9            5.36   3.0
 0. 22      150.00   7.8          144.64   8.9            5.36   3.0
 0. 24      150.00   7.8          144.64   8.9            5.36   3.0
 0. 26      150.00   7.8          144.64   8.9            5.36   3.0
 0. 28      150.00   7.8          144.64   8.9            5.36   3.0
 0. 30      150.00   7.8          144.64   8.9            5.36   3.0
 0. 32      150.00   7.8          144.64   8.9            5.36   3.0
 0. 34      150.00   7.8          144.64   8.9            5.36   3.0
 0. 36      150.00   7.8          144.64   8.9            5.36   3.0
 0. 38      150.00   7.8          144.64   8.9            5.36   3.0
 0. 40      150.00   7.8          144.64   8.9            5.36   3.0
 0. 42      150.00   7.8          144.64   8.9            5.36   3.0
 0. 44      150.00   7.8          144.64   8.9            5.36   3.0
 0. 46      150.00   7.8          144.64   8.9            5.36   3.0
 0. 48      150.00   7.8          144.64   8.9            5.36   3.0
 0. 50      150.00   7.8          144.64   8.9            5.36   3.0
 0. 52      150.00   7.8          144.64   8.9            5.36   3.0
 0. 54      150.00   7.8          144.64   8.9            5.36   3.0
 0. 56      150.00   7.8          144.64   8.9            5.36   3.0
 0. 58      150.00   7.8          144.64   8.9            5.36   3.0
 1.  0      150.00   7.8          144.64   8.9            5.36   3.0
 1.  2      150.00   7.8          144.64   8.9            5.36   3.0
 1.  4      150.00   7.8          144.64   8.9            5.36   3.0
 1.  6      150.00   7.8          144.64   8.9            5.36   3.0
 1.  8      150.00   7.8          144.64   8.9            5.36   3.0
 1. 10      150.00   7.8          144.64   8.9            5.36   3.0
 1. 12      150.00   7.8          144.64   8.9            5.36   3.0
 1. 14      150.00   7.8          144.64   8.9            5.36   3.0
 1. 16      150.00   7.8          144.64   8.9            5.36   3.0
 1. 18      150.00   7.8          144.64   8.9            5.36   3.0
 1. 20      150.00   7.8          144.64   8.9            5.36   3.0
 1. 22      150.00   7.8          144.64   8.9            5.36   3.0
 1. 24      150.00   7.8          144.64   8.9            5.36   3.0
 1. 26      150.00   7.8          144.64   8.9            5.36   3.0
 1. 28      150.00   7.8          144.64   8.9            5.36   3.0
 1. 30      150.00   7.8          144.64   8.9            5.36   3.0
 1. 32      150.00   7.8          144.64   8.9            5.36   3.0
 1. 34      150.00   7.8          144.64   8.9            5.36   3.0
 1. 36      150.00   7.8          144.64   8.9            5.36   3.0
 1. 38      150.00   7.8          144.64   8.9            5.36   3.0
```

```
 TEST NO.2 - SIDE WEIR
 COMPARISON OF RESULTS WITH OBSERVATIONS
 * * * * * * * * * * * * * * * *   T I M E   H I S T O R Y   O F   F L O W   A N D   V E L O C I T Y   * * * * * * * * * * * * * * *
                                                    Q(CFS), VEL(FPS), HLOS(FT)
   TIME       CONDUIT 4000        CONDUIT 3000        CONDUIT 2000        CONDUIT
   0. 0        .10   0.0          0.00   0.0          0.00   0.0
   0. 1       1.42   6.5           .94   4.3          0.00   0.0
   0. 1       1.35   5.7          1.34   5.8           .01   1.1
   0. 2       1.27   5.8          1.27   5.8           .02   1.6
   0. 2       1.27   5.8          1.2    5.8           .02   1.5
   0. 3       1.27   5.8          1.25   5.8           .02   1.5
   0. 3       1.27   5.8          1.25   5.8           .02   1.6
   0. 4       1.27   5.8          1.25   5.8           .02   1.6
   0. 4       1.27   5.8          1.25   5.8           .02   1.6
   0. 5       1.27   5.8          1.25   5.8           .02   1.6
   0. 5       1.27   5.8          1.25   5.8           .02   1.6
   0. 6       1.27   5.8          1.25   5.8           .02   1.6
   0. 6       1.27   5.8          1.25   5.8           .02   1.6
   0. 7       1.27   5.8          1.25   5.8           .02   1.6
   0. 7       1.27   5.8          1.25   5.8           .02   1.5
   0. 8       1.27   5.8          1.25   5.8           .02   1.6
   0. 8       1.27   5.8          1.25   5.8           .02   1.6
   0. 9       1.27   5.8          1.25   5.8           .02   1.6
   0. 9       1.27   5.8          1.25   5.8           .02   1.5
   0. 10      1.27   5.8          1.25   5.8           .02   1.6
   0. 10      1.27   5.8          1.25   5.8           .02   1.5
   0. 11      1.27   5.8          1.25   5.8           .02   1.6
   0. 11      1.27   5.8          1.25   5.8           .02   1.6
   0. 12      1.27   5.8          1.25   5.8           .02   1.6
   0. 12      1.27   5.8          1.25   5.8           .02   1.6
   0. 13      1.27   5.8          1.25   5.8           .02   1.6
   0. 13      1.27   5.8          1.25   5.8           .02   1.6
   0. 14      1.27   5.8          1.25   5.8           .02   1.6
   0. 14      1.27   5.8          1.25   5.8           .02   1.6
   0. 15      1.27   5.8          1.25   5.8           .02   1.6
```

```
TEST NO.2 - SIDE-WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
 * * * * * * * * * * * * * * * * *  T I M E   H I S T O R Y   O F   F L O W   A N D   V E L O C I T Y  * * * * * * * * * * * * * * *
                                                  Q(CFS), VEL(FPS), HLOS(FT)

    TIME       CONDUIT 4000          CONDUIT 3000          CONDUIT 2000         CONDUIT
    0.  0       .14   0.0           0.00   0.0           0.00   0.0
    0.  1      1.81   6.1           1.32   5.5            .00    .0
    0.  1      1.65   6.3           1.65   6.4            .04   1.9
    0.  2      1.59   6.3           1.57   6.3            .05   2.3
    0.  2      1.58   6.3           1.55   6.3            .04   2.2
    0.  3      1.59   6.3           1.55   6.3            .04   2.2
    0.  3      1.59   6.3           1.55   6.3            .04   2.2
    0.  4      1.59   6.3           1.55   6.3            .04   2.2
    0.  4      1.59   6.3           1.55   6.3            .04   2.2
    0.  5      1.59   6.3           1.55   6.3            .04   2.2
    0.  5      1.59   6.3           1.55   6.3            .04   2.2
    0.  6      1.59   6.3           1.55   6.3            .04   2.2
    0.  6      1.59   6.3           1.55   6.3            .04   2.2
    0.  7      1.59   6.3           1.55   6.3            .04   2.2
    0.  7      1.59   6.3           1.55   6.3            .04   2.2
    0.  8      1.59   6.3           1.55   6.3            .04   2.2
    0.  8      1.59   6.3           1.55   6.3            .04   2.2
    0.  9      1.59   6.3           1.55   6.3            .04   2.2
    0.  9      1.59   6.3           1.55   6.3            .04   2.2
    0. 10      1.59   6.3           1.55   6.3            .04   2.2
    0. 10      1.59   6.3           1.55   6.3            .04   2.2
    0. 11      1.59   6.3           1.55   6.3            .04   2.2
    0. 11      1.59   6.3           1.55   6.3            .04   2.2
    0. 12      1.59   6.3           1.55   6.3            .04   2.2
    0. 12      1.59   6.3           1.55   6.3            .04   2.2
    0. 13      1.59   6.3           1.55   6.3            .04   2.2
    0. 13      1.59   6.3           1.55   6.3            .04   2.2
    0. 14      1.59   6.3           1.55   6.3            .04   2.2
    0. 14      1.59   6.3           1.55   6.3            .04   2.2
    0. 15      1.59   6.3           1.55   6.3            .04   2.2
```

```
TEST NO.3 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
* * * * * * * * * * * * * * * * T I M E   H I S T O R Y   O F   F L O W   A N D   V E L O C I T Y * * * * * * * * * * * * * * * *
                                        Q(CFS), VEL(FPS), HLOS(FT)

  TIME         CONDUIT 4000         CONDUIT 3000         CONDUIT 2000         CONDUIT
  0.  0           .36   0.0         0.00   0.0           0.00   0.0
  0.  1          1.57  10.0         1.66   9.8            .01   1.5
  0.  1          1.44   9.9         1.44   9.9            .02   2.5
  0.  2          1.45   9.9         1.43   9.9            .02   2.5
  0.  2          1.45   9.9         1.43   9.9            .02   2.5
  0.  3          1.45   9.9         1.43   9.9            .02   2.5
  0.  3          1.45   9.9         1.43   9.9            .02   2.5
  0.  4          1.45   9.9         1.43   9.9            .02   2.5
  0.  4          1.45   9.9         1.43   9.9            .02   2.5
  0.  5          1.45   9.9         1.43   9.9            .02   2.5
  0.  5          1.45   9.9         1.43   9.9            .02   2.5
  0.  6          1.45   9.9         1.43   9.9            .02   2.5
  0.  6          1.45   9.9         1.43   9.9            .02   2.5
  0.  7          1.45   9.9         1.43   9.9            .02   2.5
  0.  7          1.45   9.9         1.43   9.9            .02   2.5
  0.  8          1.45   9.9         1.43   9.9            .02   2.5
  0.  8          1.45   9.9         1.43   9.9            .02   2.5
  0.  9          1.45   9.9         1.43   9.9            .02   2.5
  0.  9          1.45   9.9         1.43   9.9            .02   2.5
  0. 10          1.45   9.9         1.43   9.9            .02   2.5
  0. 10          1.45   9.9         1.43   9.9            .02   2.5
  0. 11          1.45   9.9         1.43   9.9            .02   2.5
  0. 11          1.45   9.9         1.43   9.9            .02   2.5
  0. 12          1.45   9.9         1.43   9.9            .02   2.5
  0. 12          1.45   9.9         1.43   9.9            .02   2.5
  0. 13          1.45   9.9         1.43   9.9            .02   2.5
  0. 13          1.45   9.9         1.43   9.9            .02   2.5
  0. 14          1.45   9.9         1.43   9.9            .02   2.5
  0. 14          1.45   9.9         1.43   9.9            .02   2.5
  0. 15          1.45   9.9         1.43   9.9            .02   2.5
```

```
TEST NO.4 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
* * * * * * * * * * * * * * * * T I M E   H I S T O R Y   O F   F L O W   A N D   V E L O C I T Y * * * * * * * * * * * * * * *
                                              Q(CFS), VEL(FPS), HLOS(FT)

    TIME          CONDUIT 4000          CONDUIT 3000          CONDUIT 2000          CONDUIT
    0.  0          .33   0.0           0.00   0.0            0.00   0.0
    0.  1          .55   3.7            .21   2.4            0.00   0.0
    0.  1          .64   4.0            .54   3.9             .00    .7
    0.  2          .59   4.0            .58   4.0             .01   1.1
    0.  2          .57   4.0            .55   3.9             .02   1.4
    0.  3          .57   4.0            .55   3.9             .02   1.4
    0.  3          .57   4.0            .55   3.9             .02   1.4
    0.  4          .57   4.0            .55   3.9             .02   1.4
    0.  4          .57   4.0            .55   3.9             .02   1.4
    0.  5          .57   4.0            .55   3.9             .02   1.4
    0.  5          .57   4.0            .55   3.9             .02   1.4
    0.  6          .57   4.0            .55   3.9             .02   1.4
    0.  6          .57   4.0            .55   3.9             .02   1.4
    0.  7          .57   4.0            .55   3.9             .02   1.4
    0.  7          .57   4.0            .55   3.9             .02   1.4
    0.  8          .57   4.0            .55   3.9             .02   1.4
    0.  9          .57   4.0            .55   3.9             .02   1.4
    0.  9          .57   4.0            .55   3.9             .02   1.4
    0.  9          .57   4.0            .55   3.9             .02   1.4
    0. 10          .57   4.0            .55   3.9             .02   1.4
    0. 10          .57   4.0            .55   3.9             .02   1.4
    0. 11          .57   4.0            .55   3.9             .02   1.4
    0. 11          .57   4.0            .55   3.9             .02   1.4
    0. 12          .57   4.0            .55   3.9             .02   1.4
    0. 12          .57   4.0            .55   3.9             .02   1.4
    0. 13          .57   4.0            .55   3.9             .02   1.4
    0. 13          .57   4.0            .55   3.9             .02   1.4
    0. 14          .57   4.0            .55   3.9             .02   1.4
    0. 14          .57   4.0            .55   3.9             .02   1.4
    0. 15          .57   4.0            .55   3.9             .02   1.4
```

```
TEST NO.5 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
* * * * * * * * * * * * * * * * * *   T I M E   H I S T O R Y   O F   F L O W   A N D   V E L O C I T Y  * * * * * * * * * * * * *
                                                         Q(CFS), VEL(FPS), HLOS(FT)
  TIME      CONDUIT 4000          CONDUIT 3000          CONDUIT 2000          CONDUIT
  0.  0      .07   0.0            0.00   0.0            0.00   0.0
  0.  1      .85   5.2             .51   4.2             .00   0.5
  0.  1      .82   5.5             .81   5.6             .01   1.1
  0.  2      .76   5.5             .76   5.5             .02   1.5
  0.  2      .76   5.5             .74   5.5             .02   1.6
  0.  3      .76   5.5             .74   5.5             .02   1.6
  0.  3      .76   5.5             .74   5.5             .02   1.6
  0.  4      .76   5.5             .74   5.5             .02   1.6
  0.  4      .76   5.5             .74   5.5             .02   1.6
  0.  5      .76   5.5             .74   5.5             .02   1.6
  0.  5      .76   5.5             .74   5.5             .02   1.6
  0.  6      .76   5.5             .74   5.5             .02   1.6
  0.  6      .76   5.5             .74   5.5             .02   1.6
  0.  7      .76   5.5             .74   5.5             .02   1.6
  0.  7      .76   5.5             .74   5.5             .02   1.6
  0.  8      .76   5.5             .74   5.5             .02   1.6
  0.  8      .76   5.5             .74   5.5             .02   1.6
  0.  9      .76   5.5             .74   5.5             .02   1.6
  0.  9      .76   5.5             .74   5.5             .02   1.6
  0. 10      .76   5.5             .74   5.5             .02   1.6
  0. 10      .76   5.5             .74   5.5             .02   1.6
  0. 11      .76   5.5             .74   5.5             .02   1.6
  0. 11      .76   5.5             .74   5.5             .02   1.6
  0. 12      .76   5.5             .74   5.5             .02   1.6
  0. 12      .76   5.5             .74   5.5             .02   1.6
  0. 13      .76   5.5             .74   5.5             .02   1.6
  0. 13      .76   5.5             .74   5.5             .02   1.6
  0. 14      .76   5.5             .74   5.5             .02   1.6
  0. 14      .76   5.5             .74   5.5             .02   1.6
  0. 15      .76   5.5             .74   5.5             .02   1.6
```

```
TEST NO.6 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
* * * * * * * * * * * * * * *  T I M E  H I S T O R Y  O F  F L O W  A N D  V E L O C I T Y  * * * * * * * * * * * * * * *
                                                    Q(CFS), VEL(FPS), FLOS(FT)

  TIME        CONDUIT 4000         CONDUIT 3000         CONDUIT 2000         CONDUIT
  0.  0        .04   0.0           0.00   0.0           0.00   0.0
  0.  1        .66   4.2            .30   3.0           0.00   0.0
  0.  1        .71   4.5            .65   4.5            .02   1.8
  0.  2        .65   4.5            .65   4.5            .02   1.5
  0.  2        .64   4.5            .63   4.5            .02   1.5
  0.  3        .64   4.5            .62   4.5            .02   1.5
  0.  3        .64   4.5            .62   4.5            .02   1.5
  0.  4        .64   4.5            .62   4.5            .02   1.5
  0.  4        .64   4.5            .62   4.5            .02   1.5
  0.  5        .64   4.5            .62   4.5            .02   1.5
  0.  5        .64   4.5            .62   4.5            .02   1.5
  0.  6        .64   4.5            .62   4.5            .02   1.5
  0.  6        .64   4.5            .62   4.5            .02   1.5
  0.  7        .64   4.5            .62   4.5            .02   1.5
  0.  7        .64   4.5            .62   4.5            .02   1.5
  0.  8        .64   4.5            .62   4.5            .02   1.5
  0.  8        .64   4.5            .62   4.5            .02   1.5
  0.  9        .64   4.5            .62   4.5            .02   1.5
  0.  9        .64   4.5            .62   4.5            .02   1.5
  0. 10        .64   4.5            .62   4.5            .02   1.5
  0. 10        .64   4.5            .62   4.5            .02   1.5
  0. 11        .64   4.5            .62   4.5            .02   1.5
  0. 11        .64   4.5            .62   4.5            .02   1.5
  0. 12        .64   4.5            .62   4.5            .02   1.5
  0. 12        .64   4.5            .62   4.5            .02   1.5
  0. 13        .64   4.5            .62   4.5            .02   1.5
  0. 13        .64   4.5            .62   4.5            .02   1.5
  0. 14        .64   4.5            .62   4.5            .02   1.5
  0. 14        .64   4.5            .62   4.5            .02   1.5
  0. 15        .64   4.5            .62   4.5            .02   1.5
```

```
TEST NO.7 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
* * * * * * * * * * * * * *  T I M E  H I S T O R Y  O F  F L O W  A N D  V E L O C I T Y  * * * * * * * * * * * * * * * *
                                          Q(CFS), VEL(FPS), FLOS(FT)

 TIME        CONDUIT 4000        CONDUIT 3000        CONDUIT 2000        CONDUIT
 0.  0        .16   0.0          0.00   6.0          0.00  0.0
 0.  1       1.20   7.3          1.02   6.8           .02   .7
 0.  1       1.02   7.4          1.03   7.5           .02  1.8
 0.  2       1.02   7.5          1.00   7.5           .02  2.0
 0.  2       1.02   7.5          1.00   7.5           .02  2.0
 0.  3       1.02   7.5          1.00   7.5           .02  2.0
 0.  3       1.02   7.5          1.00   7.5           .02  2.0
 0.  4       1.02   7.5          1.00   7.5           .02  2.0
 0.  4       1.02   7.5          1.00   7.5           .02  2.0
 0.  5       1.02   7.5          1.00   7.5           .02  2.0
 0.  5       1.02   7.5          1.00   7.5           .02  2.0
 0.  6       1.02   7.5          1.00   7.5           .02  2.0
 0.  6       1.02   7.5          1.00   7.5           .02  2.0
 0.  7       1.02   7.5          1.00   7.5           .02  2.0
 0.  7       1.02   7.5          1.00   7.5           .02  2.0
 0.  8       1.02   7.5          1.00   7.5           .02  2.0
 0.  8       1.02   7.5          1.00   7.5           .02  2.0
 0.  9       1.02   7.5          1.00   7.5           .02  2.0
 0.  9       1.02   7.5          1.00   7.5           .02  2.0
 0. 10       1.02   7.5          1.00   7.5           .02  2.0
 0. 10       1.02   7.5          1.00   7.5           .02  2.0
 0. 11       1.02   7.5          1.00   7.5           .02  2.0
 0. 11       1.02   7.5          1.00   7.5           .02  2.0
 0. 12       1.02   7.5          1.00   7.5           .02  2.0
 0. 12       1.02   7.5          1.00   7.5           .02  2.0
 0. 13       1.02   7.5          1.00   7.5           .02  2.0
 0. 13       1.02   7.5          1.00   7.5           .02  2.0
 0. 14       1.02   7.5          1.00   7.5           .02  2.0
 0. 14       1.02   7.5          1.00   7.5           .02  2.0
 0. 15       1.02   7.5          1.00   7.5           .02  2.0
```

QUALITEE INFERIEURE

```
TEST NO.8 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
 * * * * * * * * * * * * * * * T I M E  H I S T O R Y  O F  F L O W  A N D  V E L O C I T Y  * * * * * * * * * * * * * * * *
                                         Q(CFS), VEL(FPS), FLOS(FT)

  TIME       CONDUIT 4000        CONDUIT 3000         CONDUIT 2000        CONDUIT
  0.  0       .00   0.0          0.00   0.0           0.00   0.0
  0.  1       .26   2.0           .01    .2           0.00   0.0
  0.  1       .42   2.4           .12    .1           0.00   0.0
  0.  2       .43   2.2           .25   1.6            .00    .0
  0.  2       .37   1.7           .30   1.6            .00    .2
  0.  3       .39   1.7           .33   1.8            .01    .4
  0.  3       .40   1.7           .33   1.8            .03    .6
  0.  4       .40   1.7           .33   1.8            .04    .8
  0.  4       .40   1.7           .34   1.9            .05    .9
  0.  5       .40   1.7           .34   1.9            .05    .9
  0.  5       .40   1.7           .34   1.9            .06    .9
  0.  5       .40   1.7           .34   1.9            .06    .9
  0.  6       .40   1.7           .34   1.9            .06    .9
  0.  7       .40   1.7           .34   1.9            .06    .9
  0.  7       .40   1.7           .34   1.9            .06    .9
  0.  8       .40   1.7           .34   1.9            .06    .9
  0.  8       .40   1.7           .34   1.9            .06    .9
  0.  9       .40   1.7           .34   1.9            .06    .9
  0.  9       .40   1.7           .34   1.9            .06    .9
  0. 10       .40   1.7           .34   1.9            .06    .9
  0. 10       .40   1.7           .34   1.9            .06    .9
  0. 11       .40   1.7           .34   1.9            .06    .9
  0. 11       .40   1.7           .34   1.9            .06    .9
  0. 12       .40   1.7           .34   1.9            .06    .9
  0. 12       .40   1.7           .34   1.9            .06    .9
  0. 13       .40   1.7           .34   1.9            .06    .9
  0. 13       .40   1.7           .34   1.9            .06    .9
  0. 14       .40   1.7           .34   1.9            .06    .9
  0. 14       .40   1.7           .34   1.9            .06    .9
  0. 15       .40   1.7           .34   1.9            .06    .9
```

COPIE DE QUALITEE INFERIEURE

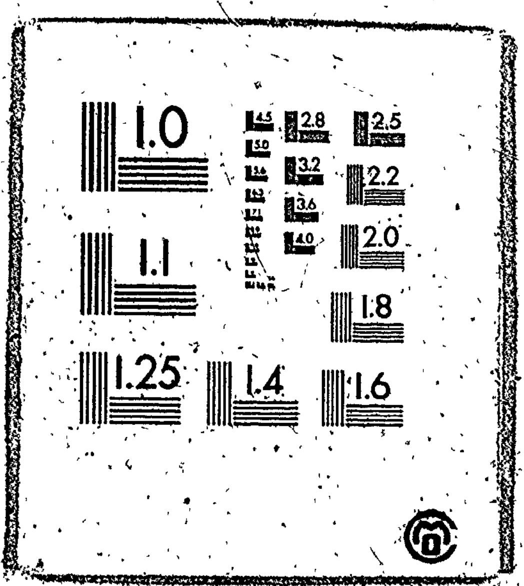
```
TEST NO.9 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
* * * * * * * * * * * * * * * *  T I M E   H I S T O R Y   O F   F L O W   A N D   V E L O C I T Y  * * * * * * * * * * * * * * * *
                                         Q(CFS), VEL(FPS), HLOS(FT)

  TIME        CONDUIT 4000           CONDUIT 3000           CONDUIT 2000           CONDUIT
 0.  0        .00   0.0              0.00   0.0             0.00   0.0
 0.  1        .22   1.8               .00    .2             0.00   0.0
 0.  1        .39   2.3               .09   1.0             0.00   0.0
 0.  2        .40   2.1               .22   1.5              .00    .0
 0.  2        .35   1.7               .27   1.7              .00    .1
 0.  3        .35   1.5               .29   1.7              .01    .3
 0.  3        .36   1.6               .30   1.8              .02    .5
 0.  4        .37   1.6               .31   1.8              .03    .7
 0.  4        .37   1.6               .31   1.8              .04    .8
 0.  5        .37   1.6               .32   1.8              .04    .8
 0.  5        .37   1.6               .32   1.8              .05    .8
 0.  6        .37   1.6               .32   1.8              .05    .9
 0.  6        .37   1.6               .32   1.8              .05    .9
 0.  7        .37   1.6               .32   1.8              .05    .9
 0.  7        .37   1.5               .32   1.8              .05    .9
 0.  8        .37   1.6               .32   1.8              .05    .9
 0.  8        .37   1.6               .32   1.8              .05    .9
 0.  9        .37   1.5               .32   1.8              .05    .9
 0.  9        .37   1.6               .32   1.8              .05    .9
 0. 10        .37   1.6               .32   1.8              .05    .9
 0. 10        .37   1.6               .32   1.8              .05    .9
 0. 11        .37   1.6               .32   1.8              .05    .9
 0. 11        .37   1.6               .32   1.8              .05    .9
 0. 12        .37   1.5               .32   1.8              .05    .9
 0. 12        .37   1.6               .32   1.8              .05    .9
 0. 13        .37   1.6               .32   1.8              .05    .9
 0. 13        .37   1.6               .32   1.8              .05    .9
 0. 14        .37   1.6               .32   1.8              .05    .9
 0. 14        .37   1.5               .32   1.8              .05    .9
 0. 15        .37   1.6               .32   1.8              .05    .9
```

```
TEST NO.10 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
* * * * * * * * * * * * * * *  T I M E   H I S T O R Y   O F   F L O W   A N D   V E L O C I T Y  * * * * * * * * * * * * * * * *
                                                          Q(CFS), VEL(FPS), HLOS(FT)

   TIME        CONDUIT 4000          CONDUIT 3000          CONDUIT 2000          CONDUIT
   0.  0        .00   0.0            0.00   0.0            0.00   0.0
   0.  1        .30   2.1             .01    .2            0.00   0.0
   0.  1        .43   2.5             .14   1.2            0.00   0.0
   0.  2        .46   2.2             .29   1.7             .00    .1
   0.  2        .40   [illegible]     .33   1.8             .01    .3
   0.  3        .43   1.8             .34   1.8             .02    .6
   0.  3        .44   1.8             .35   1.9             .04    .4
   0.  4        .44   1.8             .36   1.9             .06    .9
   0.  4        .44   1.7             .36   1.9             .06    .9
   0.  5        .44   1.7             .36   1.9             .07   1.0
   0.  5        .44   1.7             .36   1.9             .07   1.0
   0.  5        .44   1.7             .36   1.9             .07   1.0
   0.  6        .44   1.7             .36   1.9             .07   1.0
   0.  7        .44   1.7             .36   1.9             .07   1.0
   0.  7        .44   1.7             .37   1.9             .07   1.0
   0.  8        .44   1.7             .37   1.9             .07   1.0
   0.  8        .44   1.7             .37   1.9             .07   1.0
   0.  9        .44   1.7             .37   1.9             .07   1.0
   0.  9        .44   1.7             .37   1.9             .07   1.0
   0. 10        .44   1.7             .37   1.9             .07   1.0
   0. 10        .44   1.7             .37   1.9             .07   1.0
   0. 11        .44   1.7             .37   1.9             .07   1.0
   0. 11        .44   1.7             .37   1.9             .07   1.0
   0. 12        .44   1.7             .37   1.9             .07   1.0
   0. 12        .44   1.7             .37   1.9             .07   1.0
   0. 13        .44   1.7             .37   1.9             .07   1.0
   0. 13        .44   1.7             .37   1.9             .07   1.0
   0. 14        .44   1.7             .37   1.9             .07   1.0
   0. 14        .44   1.7             .37   1.9             .07   1.0
   0. 15        .44   1.7             .37   1.9             .07   1.0
```

3 OF / DE 3



```
TEST NO.11 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
* * * * * * * * * * * * * * *  T I M E   H I S T O R Y   O F   F L O W   A N D   V E L O C I T Y * * * * * * * * * * * * * * *
                                   Q(CFS), VEL(FPS), FLOS(FT)

 TIME      CONDUIT 4000       CONDUIT 3000       CONDUIT 2000       CONDUIT
 0.  0      .00   0.0          0.00   0.0          0.00   0.0
 0.  1      .27   2.1           .01    .3          0.00   0.0
 0.  1      .45   2.5           .13   1.2          0.00   0.0
 0.  2      .44   2.2           .27   1.7           .00    .1
 0.  2      .38   1.8           .31   1.8           .00    .2
 0.  3      .42   1.7           .33   1.8           .01    .5
 0.  3      .42   1.7           .34   1.9           .03    .7
 0.  4      .41   1.7           .35   1.9           .04    .8
 0.  4      .42   1.7           .35   1.9           .05    .9
 0.  5      .41   1.7           .35   1.9           .05    .9
 0.  5      .41   1.7           .35   1.9           .05    .9
 0.  5      .41   1.7           .35   1.9           .06    .9
 0.  6      .41   1.7           .35   1.9           .06    .9
 0.  7      .41   1.7           .35   1.9           .06    .9
 0.  7      .41   1.7           .35   1.9           .06    .9
 0.  8      .41   1.7           .35   1.9           .06    .9
 0.  9      .41   1.7           .35   1.9           .06    .9
 0.  9      .41   1.7           .35   1.9           .06    .9
 0.  9      .41   1.7           .35   1.9           .06    .9
 0. 10      .41   1.7           .35   1.9           .06    .9
 0. 10      .41   1.7           .35   1.9           .06    .9
 0. 11      .41   1.7           .35   1.9           .06    .9
 0. 11      .41   1.7           .35   1.9           .06    .9
 0. 12      .41   1.7           .35   1.9           .06    .9
 0. 12      .41   1.7           .35   1.9           .06    .9
 0. 13      .41   1.7           .35   1.9           .06    .9
 0. 13      .41   1.7           .35   1.9           .06    .9
 0. 14      .41   1.7           .35   1.9           .06    .9
 0. 14      .41   1.7           .35   1.9           .06    .9
 0. 15      .41   1.7           .35   1.9           .06    .9
```

RE

```
TEST NO.12 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
* * * * * * * * * * * * * * * * T I M E - H I S T O R Y  O F  F L O W  A N D  V E L O C I T Y * * * * * * * * * * * * * * * *
                                                 Q(CFS), VEL(FPS), FLOS(FT)

 TIME       CONDUIT 4000          CONDUIT 3000          CONDUIT 2000          CONDUIT
 0.  0       .01   0.0             0.00   0.0            0.00   0.0
 0.  1       .43   2.6              .02    .4            0.00   0.0
 0.  1       .45   2.9              .25   1.6             .00   0.1
 0.  2       .53   2.1              .39   2.0             .00    .3
 0.  2       .52   2.1              .41   2.0             .03    .7
 0.  3       .54   2.1              .42   2.0             .07   1.0
 0.  3       .55   2.1              .43   2.0             .09   1.1
 0.  4       .55   2.1              .44   2.1             .10   1.2
 0.  4       .55   2.1              .44   2.1             .10   1.2
 0.  5       .55   2.1              .44   2.1             .11   1.2
 0.  5       .55   2.1              .44   2.1             .11   1.2
 0.  6       .55   2.1              .44   2.1             .11   1.2
 0.  6       .55   2.1              .44   2.1             .11   1.2
 0.  7       .55   2.1              .44   2.1             .11   1.2
 0.  7       .55   2.1              .44   2.1             .11   1.2
 0.  8       .55   2.1              .44   2.1             .11   1.2
 0.  8       .55   2.1              .44   2.1             .11   1.2
 0.  9       .55   2.1              .44   2.1             .11   1.2
 0.  9       .55   2.1              .44   2.1             .11   1.2
 0. 10       .55   2.1              .44   2.1             .11   1.2
 0. 10       .55   2.1              .44   2.1             .11   1.2
 0. 11       .55   2.1              .44   2.1             .11   1.2
 0. 11       .55   2.1              .44   2.1             .11   1.2
 0. 12       .55   2.1              .44   2.1             .11   1.2
 0. 12       .55   2.1              .44   2.1             .11   1.2
 0. 13       .55   2.1              .44   2.1             .11   1.2
 0. 13       .55   2.1              .44   2.1             .11   1.2
 0. 14       .55   2.1              .44   2.1             .11   1.2
 0. 14       .55   2.1              .44   2.1             .11   1.2
 0. 15       .55   2.1              .44   2.1             .11   1.2
```

```
TEST NO.13 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
* * * * * * * * * * * * * * * * * *   T I M E   H I S T O R Y   O F   F L O W   A N D   V E L O C I T Y   * * * * * * * * * * * * * * * *
                                                        Q(CFS), VEL(FPS), FLOS(FT)

 TIME        CONDUIT 4000          CONDUIT 3000          CONDUIT 2000          CONDUIT
 0.  0        .00   0.0            0.00   0.0            0.00   0.0
 0.  1        .27   2.0             .01    .2            0.00   0.0
 0.  1        .44   2.4             .12   1.2            0.00   0.0
 0.  2        .44   2.1             .26   1.7             .00    .1
 0.  2        .38   1.7             .31   1.8             .00    .2
 0.  3        .39   1.7             .32   1.8             .01    .5
 0.  3        .41   1.7             .34   1.8             .03    .7
 0.  4        .41   1.7             .34   1.9             .04    .8
 0.  4        .41   1.7             .34   1.9             .05    .9
 0.  5        .41   1.7             .35   1.9             .06    .9
 0.  5        .41   1.7             .35   1.9             .06    .9
 0.  6        .41   1.7             .35   1.9             .06    .9
 0.  6        .41   1.7             .35   1.9             .06    .9
 0.  7        .41   1.7             .35   1.9             .06    .9
 0.  7        .41   1.7             .35   1.9             .06    .9
 0.  8        .41   1.7             .35   1.9             .06    .9
 0.  8        .41   1.7             .35   1.9             .06    .9
 0.  9        .41   1.7             .35   1.9             .06    .9
 0.  9        .41   1.7             .35   1.9             .06    .9
 0. 10        .41   1.7             .35   1.9             .06    .9
 0. 10        .41   1.7             .35   1.9             .06    .9
 0. 11        .41   1.7             .35   1.9             .06    .9
 0. 11        .41   1.7             .35   1.9             .06    .9
 0. 12        .41   1.7             .35   1.9             .06    .9
 0. 12        .41   1.7             .35   1.9             .06    .9
 0. 13        .41   1.7             .35   1.9             .06    .9
 0. 13        .41   1.7             .35   1.9             .06    .9
 0. 14        .41   1.7             .35   1.9             .06    .9
 0. 14        .41   1.7             .35   1.9             .06    .9
 0. 15        .41   1.7             .35   1.9             .06    .9
```

```
TEST NO.14 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
* * * * * * * * * * * * * * * *  T I M E   H I S T O R Y   O F   F L O W   A N D   V E L O C I T Y  * * * * * * * * * * * * * * *
                                                  Q(CFS), VEL(FPS), PLOS(FT)

 TIME        CONDUIT 4000          CONDUIT 3000          CONDUIT 2000          CONDUIT
 0.  0       -.02   0.3            0.00   0.0            0.00   0.0
 0.  1       1.73   3.8             .40   1.5             .02   0.0
 0.  1       1.67   3.3            1.06   3.0             .34   2.2
 0.  2       1.65   3.3            1.14   3.3             .35   2.2
 0.  2       1.69   2.9            1.19   3.0             .43   2.2
 0.  3       1.69   2.9            1.21   3.1             .46   2.2
 0.  3       1.70   2.9            1.21   3.1             .47   2.2
 0.  4       1.70   2.9            1.22   3.1             .48   2.2
 0.  4       1.72   2.9            1.22   3.1             .48   2.2
 0.  5       1.70   2.9            1.22   3.1             .48   2.2
 0.  5       1.70   2.9            1.22   3.1             .48   2.2
 0.  6       1.70   2.9            1.22   3.1             .48   2.2
 0.  6       1.70   2.9            1.22   3.1             .48   2.2
 0.  7       1.70   2.9            1.22   3.1             .48   2.2
 0.  7       1.70   2.9            1.22   3.1             .48   2.2
 0.  8       1.70   2.9            1.22   3.1             .48   2.2
 0.  8       1.70   2.9            1.22   3.1             .48   2.2
 0.  9       1.70   2.9            1.22   3.1             .48   2.2
 0.  9       1.70   2.9            1.22   3.1             .48   2.2
 0. 10       1.70   2.9            1.22   3.1             .48   2.2
 0. 10       1.70   2.9            1.22   3.1             .48   2.2
 0. 11       1.70   2.9            1.22   3.1             .48   2.2
 0. 12       1.70   2.9            1.22   3.1             .48   2.2
 0. 12       1.70   2.9            1.22   3.1             .48   2.2
 0. 13       1.70   2.9            1.22   3.1             .48   2.2
 0. 13       1.70   2.9            1.22   3.1             .48   2.2
 0. 14       1.70   2.9            1.22   3.1             .48   2.2
 0. 14       1.70   2.9            1.22   3.1             .48   2.2
 0. 15       1.70   2.9            1.22   3.1             .48   2.2
```

```
TEST NO.16 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
* * * * * * * * * * * * * * * *  T I M E   H I S T O R Y   O F   F L O W   A N D   V E L O C I T Y * * * * * * * * * * * * * * * *
                                          Q(CFS), VEL(FPS), HLOS(FT)

 TIME      CONDUIT 4000        CONDUIT 3000        CONDUIT 2000        CONDUIT
 0.  0       .04   0.0          0.00   0.0          0.00   0.0
 0.  1      1.89   4.9          1.01   3.7           .01    .4
 0.  1      1.83   4.7          1.51   4.5           .27   2.9
 0.  2      1.78   4.7          1.48   4.5           .30   3.2
 0.  2      1.77   4.7          1.49   4.5           .30   3.2
 0.  3      1.77   4.7          1.47   4.5           .30   3.2
 0.  3      1.77   4.7          1.47   4.5           .30   3.2
 0.  4      1.77   4.7          1.47   4.5           .30   3.2
 0.  4      1.77   4.7          1.47   4.5           .30   3.2
 0.  5      1.77   4.7          1.47   4.5           .30   3.2
 0.  5      1.77   4.7          1.47   4.5           .30   3.2
 0.  6      1.77   4.7          1.47   4.5           .30   3.2
 0.  6      1.77   4.7          1.47   4.5           .30   3.2
 0.  7      1.77   4.7          1.47   4.5           .30   3.2
 0.  7      1.77   4.7          1.47   4.5           .30   3.2
 0.  8      1.77   4.7          1.47   4.5           .30   3.2
 0.  8      1.77   4.7          1.47   4.5           .30   3.2
 0.  9      1.77   4.7          1.47   4.5           .30   3.2
 0.  9      1.77   4.7          1.47   4.5           .30   3.2
 0. 10      1.77   4.7          1.47   4.5           .30   3.2
 0. 10      1.77   4.7          1.47   4.5           .30   3.2
 0. 11      1.77   4.7          1.47   4.5           .30   3.2
 0. 11      1.77   4.7          1.47   4.5           .30   3.2
 0. 12      1.77   4.7          1.47   4.5           .30   3.2
 0. 12      1.77   4.7          1.47   4.5           .30   3.2
 0. 13      1.77   4.7          1.47   4.5           .30   3.2
 0. 13      1.77   4.7          1.47   4.5           .30   3.2
 0. 14      1.77   4.7          1.47   4.5           .30   3.2
 0. 14      1.77   4.7          1.47   4.5           .33   3.2
 0. 15      1.77   4.7          1.47   4.5           .30   3.2
```

```
TEST NO.16 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
 * * * * * * * * * * * * * * * * *  T I M E   H I S T O R Y   O F   F L O W   A N D   V E L O C I T Y  * * * * * * * * * * * * * * * *
                                       Q(CFS), VEL(FPS), FLOS(FT).

 TIME      CONDUIT 4000        CONDUIT 3000         CONDUIT 2010      CONDUIT
 0.  0        .51   0.0        0.00   0.0           0.00   0.0
 0.  1        .93   3.3         .19   1.3           0.00   0.0
 0.  1       1.08   3.2         .67   2.7            .01    .4
 0.  2       1.00   2.7         .76   2.8            .10   1.4
 0.  2       1.00   2.5         .79   2.8            .15   1.7
 0.  3       1.02   2.5         .81   2.8            .16   1.8
 0.  3       1.02   2.5         .81   2.8            .19   1.8
 0.  4       1.02   2.5         .81   2.8            .20   1.8
 0.  4       1.02   2.6         .82   2.8            .20   1.8
 0.  5       1.02   2.5         .82   2.8            .20   1.8
 0.  5       1.02   2.6         .82   2.8            .20   1.8
 0.  6       1.02   2.6         .82   2.8            .20   1.8
 0.  6       1.02   2.6         .82   2.8            .20   1.8
 0.  7       1.02   2.5         .82   2.8            .20   1.8
 0.  7       1.02   2.5         .82   2.8            .20   1.8
 0.  8       1.02   2.6         .82   2.8            .20   1.8
 0.  8       1.02   2.5         .82   2.8            .20   1.8
 0.  9       1.02   2.6         .82   2.8            .20   1.8
 0.  9       1.02   2.6         .82   2.8            .20   1.8
 0. 10       1.02   2.6         .82   2.8            .20   1.8
 0. 10       1.02   2.5         .82   2.8            .20   1.8
 0. 11       1.02   2.6         .82   2.8            .20   1.8
 0. 11       1.02   2.5         .82   2.8            .20   1.8
 0. 12       1.02   2.5         .82   2.8            .20   1.8
 0. 12       1.02   2.6         .82   2.8            .20   1.8
 0. 13       1.02   2.6         .82   2.8            .20   1.8
 0. 13       1.02   2.6         .82   2.8            .20   1.8
 0. 14       1.02   2.5         .82   2.8            .20   1.8
 0. 14       1.02   2.6         .82   2.8            .20   1.8
 0. 15       1.02   2.6         .82   2.8            .20   1.8
```

```
TEST NO.17 - SIDE WEIR
COMPARISON OF RESULTS WITH OBSERVATIONS
* * * * * * * * * * * * * *  T I M E   H I S T O R Y   O F   F L O W   A N D   V E L O C I T Y * * * * * * * * * * * * * *
                                                  Q(CFS), VEL(FPS), HLOS(FT)

  TIME       CONDUIT 4000           CONDUIT 3000           CONDUIT 2000       CONDUIT
 0.  0        .21   1.2             0.10   0.3             0.00   0.0
 0.  1        .57   2.5              .05    .7             0.00   0.0
 0.  1        .76   2.9              .36   2.2              .01    .3
 0.  2        .71   2.4              .45   2.2              .08   1.2
 0.  2        .70   2.2              .48   2.2              .15   1.5
 0.  3        .71   2.2              .50   2.3              .18   1.6
 0.  3        .72   2.2              .51   2.3              .19   1.6
 0.  4        .72   2.2              .51   2.3              .20   1.5
 0.  4        .72   2.2              .52   2.3              .20   1.6
 0.  5        .72   2.2              .52   2.3              .20   1.6
 0.  5        .72   2.2              .52   2.3              .21   1.6
 0.  6        .72   2.2              .52   2.3              .21   1.6
 0.  6        .72   2.2              .52   2.3              .20   1.6
 0.  7        .72   2.2              .52   2.3              .20   1.5
 0.  7        .72   2.2              .52   2.3              .20   1.6
 0.  8        .72   2.2              .52   2.3              .20   1.6
 0.  8        .72   2.2              .52   2.3              .20   1.6
 0.  9        .72   2.2              .52   2.3              .20   1.6
 0.  9        .72   2.2              .52   2.3              .20   1.6
 0. 10        .72   2.2              .52   2.3              .20   1.6
 0. 10        .72   2.2              .52   2.3              .20   1.6
 0. 11        .72   2.2              .52   2.3              .20   1.6
 0. 11        .72   2.2              .52   2.3              .20   1.6
 0. 12        .72   2.2              .52   2.3              .20   1.6
 0. 12        .72   2.2              .52   2.3              .20   1.6
 0. 13        .72   2.2              .52   2.3              .20   1.6
 0. 13        .72   2.2              .52   2.3              .20   1.6
 0. 14        .72   2.2              .52   2.3              .20   1.6
 0. 14        .72   2.2              .52   2.3              .20   1.6
 0. 15        .72   2.2              .52   2.3              .20   1.6
```

APPENDIX D

```
      PROGRAM MAIN (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C ***************************************************************
C
C THIS MODEL ( FOSW3 ) WAS DEVELOPED BY HANI MITRI IN 1980 AS A PART
C OF HIS THESIS SUBMITTED FOR PARTIAL FULFILLMENT OF THE DEGREE OF
C M.ENG. , DEPT. OF CIVIL ENG. , MCMASTER UNIVERSITY IN CANADA. THE
C MODEL IS DESIGNED TO DETERMINE THE WATER SURFACE PROFILE ALONG THE
C SIDE WEIR AND COMPUTE THE FLOW OVER IT. THE STRUCTURE OF THE MODEL
C CONSISTS OF A MAIN DRIVING PROGRAM THAT CONTROLS SIX SUBROUTINES.
C
C ***************************************************************
C
C NOTATION
C
C B     = BREADTH OF MAIN CHANNEL SECTION AT UPSTREAM END OF WEIR
C Z     = SIDE SLOPE OF MAIN CHANNEL SECTION (HZ TO VL)
C RN    = MANNING'S N
C RNC   = 1.0 IN METRIC UNITS AND =1.486 IN FPS UNITS
C S0    = BED SLOPE OF MAIN CHANNEL
C G     = GRAVITATIONAL ACCELERATION
C DELX  = INCREMENTAL DISTANCE IN X-DIRECTION
C C     = HEIGHT OF WEIR CREST ABOVE CHANNEL BED
C CWEIR= DEMARCHI COEFFICIENT OF DISCHARGE
C L     = WEIR LENGTH
C Q0    = DISCHARGE IN APPROACH CHANNEL
C W     = NO. OF SIDE WEIRS (0 OR 2)
C DBDX  = RATE OF CHANGE OF BREADTH WITH DISTANCE X
C QB(I)= DISCHAGES AT DOWNSTREAM CHANNEL
CDSTART= DEPTH CORRESPONDING TO FIRST DISCHARGE QB(1)
C DELDD= INCREMENTAL DEPTH TO GET DEPTH CORRESPONDING TO QB(2) ...ETC.
C VS    = VELOCITY OF FLOW IN MAIN CHANNEL AT UPSTREAM END
C H1    = HEAD ON WEIR AT ITS UPSTREAM END
C BETA  = MOMENTUM CORRECTION FACTOR
C U     = LOGITUDINAL COMPONENT OF THE SPILL VELOCITY OVER SIDE WEIR
C
C ***************************************************************
      REAL L
      COMMON/ONE/B,Z,RN,RNC,S0,SD,G,DELX,C,CWEIR,L,Q,D,QS,I,J,
     1SIGN,W,WW,DBDX,QB(9),DSTART,DELDD,DSS,VS,H1,D2,SEC,ISEC
     3,RATING
      COMMON/TWO/KK,KL,JJ,KG,IZ,CON1,ZZ,PR,KSUB,DELD,I2,I3
      COMMON/THREE/DW,QW,FR
      COMMON/FOUR/D5,Q5,D6,D6MAX,MM
C
C ***************************************************************
C
C INPUT DATA
C
      WRITE(6,210)
  210 FORMAT(1H ,2X,4HTEST,2X,8HNUMBER +)
      READ(5,230)TEST
  230 FORMAT(A3)
  180 WRITE(6,160)
  160 FORMAT(1H0,2X,6HDO YOU,5H WISH,7H METRIC,7H OR FPS,9H SYSTEM +,/)
      READ(5,165)UNITS
  165 FORMAT(A6)
```

```
      IF(UNITS.EQ.6HMETRIC)GO TO 170
      IF(UNITS.EQ.6HFPS   )GO TO 185
      GO TO 180
  185 G=32.2
      RNC=1.486
      GO TO 175
  170 G=9.81
      RNC=1.0
  175 WRITE(6,5)
    5 FORMAT(1H0,2X,32HENTER B0,Z,RN,S0,DELX,C,L,W,DBDX)
      READ(5,*)B0,Z,RN,S0,DELX,C,L,W,DBDX
      WRITE(6,10)
   10 FORMAT(1H0,2X,38HENTER DISCHARGE IN APPROACH CHANNEL Q0)
      READ(5,*)Q0
  225 WRITE(6,190)
  190 FORMAT(1H0,2X,49HDO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL +
     S,/)
      READ(5,195)RATING
  195 FORMAT(A3)
      IF(RATING.EQ.3HNO )GO TO 245
      IF(RATING.EQ.3HYES)GO TO 220
      GO TO 225
  220 WRITE(6,15)
   15 FORMAT(1H0,2X,54HENTER 9 DATA POINTS OF DISCHARGE IN DOWNSTREAM CH
     1ANNEL,/)
      READ(5,*) (QB(I),I=1,9)
      WRITE(6,30)
   30 FORMAT(1H0,2X,47HENTER THE DEPTH CORRESPONDING TO FIRST POINT OF
     123HDISCHARGE THEN GIVE THE,/,2X,18HINCREMENT IN DEPTH,/)
      READ(5,*)DSTART,DELDD
      GO TO 205
  245 WRITE(6,250)
  250 FORMAT(1H0,2X,4HDOWN,6HSTREAM,8H CHANNEL,4H BED,6H SLOPE,/)
      READ(5,*)SD
C
C ***************************************************************
C
C PRINTING DATA
C
  205 IF(B0.EQ.0.0)SEC=8HTRIANGLE
      IF(Z.EQ.0.0)SEC=9HRECTANGLE
      IF(B0.NE.0.0.AND.Z.NE.0.0)SEC=9HTRAPEZOID
      WRITE(6,215)TEST
  215 FORMAT(1H0,2X,4HTEST,2X,3HNO.,1X,A3,/)
      WRITE(6,110)SEC
  110 FORMAT(1H ,2X,24HMAIN CHANNEL SECTION IS ,A9,/)
      WRITE(6,200)
  200 FORMAT(1H0,4X,2HB0,7X,1HZ,8X,2HRN,7X,3HRNC,7X,2HS0,6X,1HG,8X,2HDE
     S,2HLX,/)
      WRITE(6,201)B0,Z,RN,RNC,S0,G,DELX
      WRITE(6,65)
   65 FORMAT(1H0,2X,9H    C    ,2X,9H    L    ,
     12X,9H    W    ,2X,7H   DBDX)
      WRITE(6,70)C,L,W,DBDX
   70 FORMAT(4(2X,F9.4))
  201 FORMAT(8F9.4)
      WRITE(6,202)
```

```
  202 FORMAT(1H0,4X,2HQ0)
      WRITE(6,203)Q0
      ZZ=0.0
  203 FORMAT(F9.4)
C
C ***************************************************************
C
C NORMAL AND CRITICAL DEPTHS AT UPSTREAM END
C
      JJ=0
      JET=0
      KG=0
      PR=0.0
      IZ=0
      KK=0
      LC=0
      WI=0.0
      KL=0
      Q=C0
      WW=0.0
      MM=0
      ISEC=0
      C=P0
      WRITE(6,35)
   35 FORMAT(1H0,2X,42HCRITICAL AND NORMAL DEPTHS AT UPSTREAM END./)
      CALL DCRIT(DC)
      CALL DNORM(DN)
      IF(DN.GT.(1.1*C))GO TO 621
      WRITE(6,240)
  240 FORMAT(1H0,2X,6HNORMAL,6H DEPTH,7H IS NOT,13H SUFFICIENTLY,
     $8H GREATER,5H THAN,7H HEIGHT,8H OF WEIR,6H CREST,/)
      Q3=Q0
      Q0=0.0
      GO TO 90
  621 CONTINUE
      IF(DC.GE.DN)GO TO 620
      IF(C.LE.(0.93*DC))GO TO 720
C
C ***************************************************************
C
C SUBCRITICAL FLOW UPSTREAM AND ALONG SIDE WEIR
C
C ***************************************************************
C
C
C
  520 WRITE(6,820)
  820 FORMAT(1H0,11HSUBCRITICAL,2X,7HPROFILE)
      SIGN=-1
      I1=0
      I=24
      IF(JET.EQ.1)GO TO 125
      DW=DN
      QW=Q0
      CALL CCEFF
  125 WRITE(6,75)CWEIR
   75 FORMAT(1H0,2X,22HCOEFF OF DISCHARGE IS ,F9.5)
```

```
      WRITE(6,105)FR
      DL=.01
      IF(C.GT.DC)GO TO 115
      DSS=DC+DL
      GO TO 120
  115 DSS=C+DL
  120 DELD=0.005
  522 DSS=DSS+DELD
 1628 CALL ENDCONT
         CONTINUE
      KSUB=1
      I1=I1+1
      IF(I1.GT.90)GO TO 95
      B=B0+CBDX*L
      CALL WSP(Q3,Q3)
      IF(I2.GT.30)GO TO 550
      IF(I3.GT.30)GO TO 550
        IF(Q3.GE.Q))GOTO1621
          IF(KK-1)722,21,21
  722   IF(KL-1)522,21,21
   21    CONTINUE
          CONTINUE
           LC=10
      B=B0
      AS=D2*(B+Z*D2)-W*0.50*Z*(D2-C)**2
      VS=Q3/AS
      DL=0.10
      H1=D2-C
       DC=(Q3-QS)/Q3
      GO TO 522
 1621    CONTINUE
          IF(HI-1.0)521,521,1626
 1626     IF(LC-1)1622,1622,1623
 1622 DSS=DSS-DELD
      GOTO 1628
 5523 .. IF(HI-1.0) 644,644,550
  644    CONTINUE
      CONTINUE
       DC=(Q3-QS)/Q3
        IF(DC-0.5) 24,25,25
   24      XL=1
         KG=0
        LC=0
      I1=0
      WI=10.
      DL=0.01
      IF(C.GT.DC)GO TO 135
      DSS=DC+DL
      GO TO 140
  135 DSS=C+DL
  140 DELD=0.005
      GOTO 522
   25 CONTINUE
        KK=KK+1
       LC=0
        KG=0
      I1=0
```

```
      WI=10.
      DL=0.01
      IF(C.GT.DC)GO TO 145
      DSS=DC+DL
      GO TO 150
  145 DSS=C+DL
  150 DELD=0.005
      B=B0
      AS=D2*(B+Z*D2)-W*0.50*Z*(D2-C)**2
      VS=Q3/AS
      HI=D2-C
      GOTO522
 1623 CONTINUE
  521 IF(ABS((Q3-Q0)/Q0).LT.0.01)GOTO7000
       DSS=DSS-DELD
       DELD=DELD/5.
      DQ=(Q3-QS)/Q3
      GO TO 522
 7000 IF(KK-1)7001,7002,7002
 7001 IF(KL-1)5523,7002,7002
 7002 KG=1
      DQ=(Q3-QS)/Q3
      WRITE(6,195)DQ
  195 FORMAT(1H0,2X,6HQS/Q0=,F8.4,/)
      B=B0+DBDX*L
      CALLWSP(D3,Q3)
      QOVER=Q0-QS
      WRITE(6,45)
      WRITE(6,50)Q0,QOVER,QS,DQ
      GO TO 550
C
C SUBCRITICAL FLOW IN THE APPROACH CHANNEL
C CHECK IF FLOW WILL TURN TO SUPERCRITICAL ALONG THE SIDE WEIR
C
C IF F1 NEGATIVE,SUBCRITICAL PROFILE
C
C IF F1 POSITIVE,CONTROL AT UPSTREAM END OF WEIR
C
C ASSUME FIRST THAT FLOW WILL REMAIN SUBCRITICAL
  720 CONTINUE
      Q=Q0
      B=B0
      A=DC*(B+Z*DC)-W*0.5*Z*(DC-C)**2
      P=B+(2*DC-W*(DC-C))*SQRT(1.+Z**2)
      R=A/P
      SF=(Q*RN/(A*RNC))**2/R**1.33
      JET=1
      DW=DN
      QW=Q0
      CALL CCEFF
      BETA=1.10
      DQDX=-W*2./3.*CWEIR*SQRT(2.*G)*(DC-C)**1.5
      F1=S0-SF-BETA*Q*DQDX/(G*A**2)+BETA*Q**2*DC*DBDX/(G*A**3)
      IF(F1.LT.0.)GO TO 520
C
C ***************************************************************
C
```

```
C SUBCRITICAL FLOW TURNING TO SUPERCRITICAL ALONG SIDE WEIR
C
C ***************************************************************
C
      WRITE(6,725)
  725 FORMAT(1H0,2X,11HSUBCRITICAL,1X,4HFLOW,1X,2HIN,1X,8HAPPROACH,
     11X,7HCHANNEL,5X,13HSUPERCRITICAL,1X,4HFLOW,1X,5HALONG,1X,
     14HSIDE,1X,4HWEIR)
      SIGN=+1
      I=0
      QS=Q0
      B=B0
      DSS=0.93*DC
      DW=DSS
      QW=Q0
      CALL CCEFF
      WRITE(6,80)CWEIR
   80 FORMAT(1H0,2X,22HCOEFF OF DISCHARGE IS ,F9.5)
      CON1=FR
      WRITE(6,105)CON1
  105 FORMAT(1H0,2X,33HFROUDE NUMBER AT UPSTREAM END IS ,F8.4,/)
      IZ=1
      KG=1
      D6MAX=0.0
      CALL WSP(D3,Q3)
      IF(J.GT.90)GO TO 550
C CHECK THE OCCURRENCE OF HYDRAULIC JUMP ALONG THE SIDE WEIR
C ***************************************************************
      WRITE(6,55)
      D=D3
      Q=Q3
      B=B0+DBDX*L
      CALL DCRIT(DC)
      ISEC=4
      CALL DNORM(DN)
      IF(DN.GE.D6MAX)GO TO 90
      DS=D3
      QS=Q3
      MM=1
      CALL DCONJ
      IF(DN.LE.CF)GO TO 90
      WRITE(6,60)
      GO TO 99
C
C ***************************************************************
C
C SUPERCRITICAL FLOW ON A STEEP SLOPE IN THE APPROACH CHANNEL AND
C ALONG THE SIDE WEIR.
C
C ***************************************************************
C
C
  522 WRITE(6,822)
  822 FORMAT(1H0,9HSUPERCRIT,2X,4HFLOW,2X,2HON,2X,5HSTEEP,2X,5HSLOPE)
      SIGN=+1
      I=0
      DW=DN
```

```
              QW=Q0
              CALL CCEFF
              IF(CHEIR.LE.0.0)CHEIR=0.0
              WRITE(6,85)CHEIR
        85    FORMAT(1H0,2X,22HCOEFF OF DISCHARGE IS ,F9.5)
              WRITE(6,105)FR
              PR=1.
              Q3=Q0
              B=B0
              DSS=DN
              CALL WSP(Q3,Q3)
              IF(J.GT.60)GO TO 550
      C CHECK THE OCCURRENCE OF HYDRAULIC JUMP ALONG THE SIDE WEIR
      C ************************************************************
              WRITE(6,55)
        55    FORMAT(1H0,2X,2HAT,4H THE,5H DOWN,6HSTREAM,4H END,/)
              D=D3
              Q=Q3
              B=B0+CBDX*L
              CALL DCRIT(DC)
              ISEC=4
              CALL DNORM(DN)
              DS=D3
              QS=Q3
              MM=0
              CALL DCONJ
              IF(DN.LE.D6)GO TO 90
              WRITE(6,60)
        60    FORMAT(1H0,2X,9HHYDRAULIC,5H JUMP,4H HAS,5H OCCURRED,6H ALONG,
             $4H THE,5H SIDE,5H WEIR,/,3X,6HACTUAL,9H OVERFLOW,3H IS,8H GREATER,
             $5H THAN,9H COMPUTED,4H ONE,/)
        90    QOVER=Q0-Q3
              DQ=QOVER/Q0
              WRITE(6,45)
        45    FORMAT(1H0,2X,2HQ0,10X,8HOVERFLOW,10X,13HRESIDUAL FLOW,10X,5HQS/Q0
             $,/)
              WRITE(6,50)Q0,QOVER,Q3,DQ
        50    FORMAT(1H0,2X,F8.4,4X,F8.4,12X,F8.4,10X,F8.4,/)
              GO TO 550
        95    WRITE(6,100)I1
       100    FORMAT(1H0,2X,*AFTER *,I2,* ITERATIONS Q3 DOES NOT CONVERGE*,1X
             $,*IN SUBCRITICAL CASE*,/)
              GO TO 550
      C
       550    STOP
              END
```

```
   SUBROUTINE DCRIT      73/173  OPT=2                         FTN 4.8+508        81/04/

              SUBROUTINE DCRIT(DC)
              REAL L
              COMMON/ONE/B,Z,RN,RNC,S0,SD,G,DELX,C,CWEIR,L,Q,D,QS,I,J,
             1SIGN,W,WW,CBDX,QB(9),QSTART,DELQQ,QSS,VS,H1,D2,SEC,ISEC
              IF(SEC.EQ.8HTRIANGLE)GO TO 20
              CONST=Q**2/G
              DC=((Q/B)**2/G)**0.33
              IF(SEC.EQ.9HRECTANGLE)GO TO 30
        10    A=DC*(B+Z*DC)
              ZED2=A**3/(B+2*Z*DC)
              IF(ABS(CONST-ZED2)/CONST.LE.0.01)GO TO 30
              DC=DC-(ZED2-CONST)/(3*A**2-2*Z*ZED2/(B+2*Z*DC))
              GO TO 10
        20    DC=(2.0*Q**2/(G*Z**2))**0.20
        30    WRITE(6,40)
        40    FORMAT(1H0,4X,2HDC)
              WRITE(6,50)DC
        50    FORMAT(F10.5)
              RETURN
              END
```

```
   SUBROUTINE DNORM      73/173  OPT=2                         FTN 4.8+508        81/04/

              SUBROUTINE DNORM(DN)
              REAL L
              COMMON/ONE/B,Z,RN,RNC,S0,SD,G,DELX,C,CWEIR,L,Q,D,QS,I,J,
             1SIGN,W,WW,CBDX,QB(9),QSTART,DELQQ,QSS,VS,H1,D2,SEC,ISEC
              S=S0
              IF(ISEC.EQ.4)S=SD
              IF(SEC.EQ.8HTRIANGLE)GO TO 20
              CONST=Q/S**0.5
              DN=(Q*RN/(B*RNC*S**0.5))**0.6
        10    A=DN*(B+Z*DN)
              R=A/(B+2*DN*SQRT(1.+Z**2))
              CONV=RNC*A*R**0.67/RN
              IF(ABS((CONST-CONV)/CONST).LE.0.01)GO TO 30
              DN=DN*(CONST/CONV)**0.5
              GO TO 10
        20    TOP=Q*RN*2.0**0.667*(1.0+Z**2)**0.333
              BOT=RNC*Z**1.667*S**0.50
              DN=(TOP/BOT)**0.375
        30    WRITE(6,40)
        40    FORMAT(1H0,4X,2HDN)
              WRITE(6,50)DN
        50    FORMAT(F10.5)
              RETURN
              END
```

```
   SUBROUTINE ENDCONT    73/173  OPT=2                         FTN 4.8+508        81/04/

              SUBROUTINE ENDCONT
              REAL L
              COMMON/ONE/B,Z,RN,RNC,S0,SD,G,DELX,C,CWEIR,L,Q,D,QS,I,J,
             1SIGN,W,WW,CBDX,QB(9),QSTART,DELQQ,QSS,VS,H1,D2,SEC,ISEC
             $,RATING
              IF(RATING.EQ.3HNO )GO TO 60
              N=9
              DQB2=0.0
              DQB3=0.0
              M=1+INT((QSS-QSTART)/DELQQ)
              IF(M-(N-2))30,40,10
        10    IF(M-(N-1))70,50,20
        20    IF(M.EQ.N)QS=QB(N)
              GOTO 70
        30    DQB3=QB(M+3)+3.0*(QB(M+1)-QB(M+2))-QB(M)
        40    DQB2=QB(M)-2.0*QB(M+1)+QB(M+2)
        50    DQB1=QB(M+1)-QB(M)
              Q0=QSTART+DELQQ*(M-1)
              T=(QSS-Q0)/DELQQ
              QS=QB(M)+T*DQB1+0.50*T*(T-1)*DQB2+T*(T-1)*(T-2)*DQB3/6.0
              GO TO 70
        60    B1=B+CBDX*L
              A1=QSS*(B1+Z*QSS)
              P1=B1+2.*QSS*SQRT(1+Z**2)
              R1=A1/P1
              QS=A1*R1**0.667*SD**0.50*RNC/RN
        70    RETURN
```

```
      SUBROUTINE WSP(D3,C3)
C THIS ROUTINE COMPUTES A W.S.PROFILE ALONG A SIDEWEIR
C OF CONSTANT TRAPEZOIDAL X=SECTION AND CONSTANT INVERT SLOPE
C SIGN=-1 FOR COMPUTING UPSTREAM AND +1 FOR COMPUTING DOWNSTREAM
      REAL L
      COMMON/ONE/B,Z,RN,RNC,S0,S0,G,DELX,C,CWEIR,L,Q,D,QS,I,J,
     1SIGN,W,WW,DBDX,QB(9),CSTART,DELQQ,DSS,VS,H1,Q2,SEC,ISEC
      COMMON/TWO/KK,KL,JJ,KG,IZ,CON1,ZZ,PR,KSUB,DELD,I2,I3
      COMMON/FOUR/Q5,Q5,Q6,DEMAX,MM
      IF(KQ-1)50,137,137
   50 IF(PR-1.)136,137,137
  137 CONTINUE
      IF(IZ.NE.1)GO TO 40
      WRITE(6,30)
   30 FORMAT(1H0,6X,2HD2,9X,2HQ2,9X,1HX,9X,4HDQDX,5X,5HDENOM,
     $6X,1HB,9X,2HQ6,/)
      GO TO 136
   40 WRITE(6,204)
  204 FORMAT(1H0,6X,2HD2,9X,2HQ2,9X,1HX,9X,4HDQDX,5X,
     15HDENOM,6X,1HB,/)
  136 CONTINUE
      I2=0
      I3=0
      GO TO 70
   65 I3=0
      DSS=DSS+DELD
      CALL ENDCONT
      I2=I2+1
      IF(I2.GT.30)GO TO 75
   70 X=0
      J=1
      Q1=QS
        D1=DSS
      A=D1*(B+Z*D1)-W*0.5*Z*(D1-C)**2
        V=Q1/A
      IF(IZ-1)190,191,191
  191   U=V*CON1
      BETA=1.1
        GOTO3
  190   CONTINUE
       IF(KL-1)26,27,27
   27  U=0.91*V*D1/C
      BETA=1.10
        GOTO3
   26     CONTINUE
       IF(KK-1)1,2,2
    1     U=V
      BETA=1.0
      GOTO151
    2     CONTINUE
       U=1.08*VS*(H1/(D1-C))
      BETA=1.10
        IF(KG-1)142,143,143
  143   CONTINUE
          WRITE(6,9)
    9   FORMAT(5X,14HFINAL SOLUTION)
  142   CONTINUE
```

```
    3     CONTINUE
        IF(KG-1)151,152,152
  152     WRITE(6,9)
  151   CONTINUE
      P=B+(2*D1-W*(D1-C))*SQRT(1.+Z**2)
      R=A/P
      T=B+Z*(2*D1-W*(D1-C))
      SF=(Q1*RN/(A*RNC))**2/R**1.33
      DQDX1=-W*2./3.*CWEIR*SQRT(2.*G)*(D1-C)**1.5
      DENOM=1-BETA*Q1**2*T/(G*A**3)
      DDDX1=(S0-SF-(2.0*V*BETA-U)*DQDX1/(G*A))/DENOM+(BETA*Q1**2*
     $D1*DBDX/(G*A**3))/DENOM
      IF(KG-1)55,148,148
   55 IF(PR-1.)233,148,148
  148 CONTINUE
      WRITE(6,850)D1,Q1,X,DQDX1,DENOM,B
  233        CONTINUE
  303 IF(I.LT.10)GO TO 300
      DELTX=DELX
      GO TO 301
  300 DELTX=DELX/5
  301 CONTINUE
C
      X=X+SIGN*DELTX
      IF((SIGN*X).GT.L)GO TO 304
      B=B+SIGN*DBDX*DELTX
      D2=D1+SIGN*DDDX1*DELTX
  302 IF((D2-C).LT.0.005)GO TO 305
      I3=I3+1
      IF(I3.GT.20)GO TO 85
      DQDX=-W*2./3.*CWEIR*SQRT(2.*G)*0.5*((D1-C)**1.5+(D2-C)**1.5)
      Q2=Q1+SIGN*DQDX*DELTX
      A=D2*(B+Z*D2)-W*0.5*Z*(D2-C)**2
       V2=Q2/A
        IF(IZ-1)192,193,193
  193    U2=V2*CON1
      BETA=1.1
         GOTO7
  192    CONTINUE
         IF(KL-1)28,29,29
   29   U2=0.91*V2*D2/C
      BETA=1.10
         GOTO7
   28    CONTINUE
       IF(KK-1)5,6,6
    5 U2=V2
      BETA=1.0
      GOTO7
    6 CONTINUE
      U2=1.16*VS*(H1/(D2-C))
      BETA=1.10
    7      CONTINUE
      P=B+(2*D2-W*(D2-C))*SQRT(1.+Z**2)
      R=A/P
      T=B+Z*(2*D2-W*(D2-C))
      DENOM=(1-(BETA*Q2**2*T)/(G*A**3))
      SF=(U2*RN/(A*RNC))**2/R**1.33
```

```
SUBROUTINE HSP          73/173  OPT=2                  FTN 4.8+508      81/04/

             DQCX2=-W*2./3.*CHEIR*SQRT(2.*G)*(D2-C)**1.5
             DDCX2=(SO-SF-(2.*V2*BETA-U2)*DQCX2/(G*A))/DENOM+
            $(BETA*Q2**2*B2*DQDX/(G*A**3))/DENOM
             DDCX=0.5*(DDCX1+DDCX2)
             TEMP=D2
             D2=D1+SIGN*DDCX*DELX
             IF(ABS(TEMP-D2).GT.0.00005)GO TO 302
             IF(KG-1.)60,134,134
        60   IF(PR-1.)133,134,134
       134      CONTINUE
             IF(IZ.NE.1)GO TO 135
             D5=D2
             Q5=Q2
             MM=1
             CALL DCONJ
             IF(D6.GT.D6MAX)D6MAX=D6
             WRITE(6,95)D2,Q2,X,DDCX2,DENOM,B,D6
        95   FORMAT(4(2X,F9.5),2X,3(2X,F9.4))
             GO TO 133
       135   CONTINUE
             WRITE(6,850)D2,Q2,X,DDCX2,DENOM,B
       850   FORMAT(3(2X,F9.5),2X,F9.5,2X,2(2X,F9.4))
       133      CONTINUE
             D1=D2
             Q1=Q2
             DDCX1=DDCX2
             I=I+1
             I3=0
             GO TO 303
       305   CONTINUE
             IF(KSUB.EQ.1)GO TO 65
             J=100
             WRITE (6,207)
       207   FORMAT(1H0,9HCRITDEPTH)
             GO TO 304
        75   WRITE(6,80)I2
        80   FORMAT(1H0,*AFTER *,I2,* ITERATIONS IN HSP THERE IS NO *,
            $*CONVERGENCE*,/)
             GO TO 304
        85   WRITE(6,90)I3
        90   FORMAT(1H0,* AFTER *,I2,* ITERATIONS D2 DOES NOT CONVERGE TO D1*
            $,/)
       304   D3=D2
             Q3=Q2
             RETURN
             END
```

```
SUBROUTINE COEFF        73/173  OPT=2                  FTN 4.8+508      81/04/

             SUBROUTINE COEFF
             REAL L
             COMMON/ONE/B,Z,RN,RNC,SO,SD,G,DELX,C,CHEIR,L,Q,D,DS,I,J,
            1SIGN,W,WW,DQDX,QB(9),DSTART,DELDD,DSS,VS,H1,D2,SEC,ISEC
             COMMON/THREE/DW,QW,FR
             D=DW
             Q=QW
             A=(B+Z*D)*D-0.50*W*Z*(D-C)**2
             T=B+Z*(2.0*D-W*(D-C))
             V=Q/A
             FR=V/SQRT(G*A/T)
             IF(FR.LT.0.60)GO TO 20
             IF(FR.LT.1.0 )GO TO 30
             IF(FR.LT.1.80)GO TO 40
             CHEIR=0.362-0.018*(FR-1.80)
             GO TO 50
        20   CHEIR=0.611*SQRT(1.0-3.0*FR**2/(FR**2+2.0))
             GO TO 50
        30   CHEIR=0.45-0.06*(FR-0.60)
             GO TO 50
        40   CHEIR=0.95*SQRT(2.0-3.0*FR**2/(FR**2+2.0))
        50   CONTINUE
             RETURN
             END
```

```
SUBROUTINE DCONJ        73/173  OPT=2                  FTN 4.8+508      81/04/

             SUBROUTINE DCONJ
             COMMON/ONE/B,Z,RN,RNC,SO,SD,G,DELX,C,CHEIR,L,Q,D,DS,I,J,
            1SIGN,W,WW,DQDX,QB(9),DSTART,DELDD,DSS,VS,H1,D2,SEC,ISEC
             COMMON/TWO/KK,KL,JJ,KG,IZ,CON1,ZZ,PR,KSUB,DELD,I2,I3
             COMMON/FOUR/D5,Q5,D6,D6MAX,MM
      C      CALCULATE CROSS SECTIONAL AREA
             IF(SEC.EQ.8HTRIANGLE )GO TO 10
             A5=D5*(B+Z*D5)
             A5Y=D5*D5/6.0*(2.0*Z*D5+3.0*B)
             GO TO 20
        10   A5=Z*D5**2
             A5Y=Z*D5**3/3.0
        20   CONTINUE
             V5=Q5/A5
             U=V5
             IF(IZ.EQ.2)U=CON1*V5
             CONST=Q5*V5+G*A5Y
             DY=0.01
             D6=D5+DY
        30   D6=D6+DY
             QSJ=-2.2627*W*CHEIR*G**0.50*((D6-C)**2.5-(D5-C)**2.5)
             Q6=Q5+QSJ
             IF(SEC.EQ.8HTRIANGLE )GO TO 40
             A6=D6*(B+Z*D6)
             A6Y=D6*D6/6.0*(2.0*Z*D6+3.0*B)
             GO TO 50
        40   A6=Z*D6**2
             A6Y=Z*D6**3/3.0
        50   CONTINUE
             V6=Q6/A6
             FUNCT=Q6*V6-QSJ*U+G*A6Y
             IF(FUNCT.GT.CONST)GO TO 60
             IF(ABS(CONST-FUNCT)/CONST.LT.0.01)GO TO 70
             GO TO 30
        60   D6=D6-DY
             DY=DY/5.0
             GO TO 30
        70   IF(MM.EQ.1)GO TO 90
             WRITE(6,80)D6
        80   FORMAT(1H0,2X,9HCONJUGATE,6H DEPTH,3H IS,F9.4)
        90   RETURN
             END
```

APPENDIX E

```
 MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM
 WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW

   TEST NUMBER +
 *INPUT*  1V

   DO YOU WISH METRIC OR FPS SYSTEM +

 *INPUT*  METRIC

   ENTER B0,Z,PN,S0,DELX,C,L,W,DDDX
 *INPUT*  .455  0  .012  .001  .1  .25  2.3  1  0

   ENTER DISCHARGE IN APPROACH CHANNEL Q0
 *INPUT*  .083

   DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL +

 *INPUT*  NO

   DOWNSTREAM CHANNEL BED SLOPE

 *INPUT*  .00017

   TEST  NO. 1V

   MAIN CHANNEL SECTION IS RECTANGLE

     B0        Z         PN        RNC        S0        G         DELX

   .4550    0.0000    .0120    1.0000     .0010    9.8100    .1000
      C         L          W         DDDX
    .2500    2.3000    1.0000    0.0000

    Q0
   .0830

   CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

    DC
   .15313

    DN
   .27723

 SUBCRITICAL  PROFILE

   COEFF OF DISCHARGE IS    .53921

   FROUDE NUMBER AT UPSTREAM END IS     .3990

   QS/Q0= .5259

      D2         Q2          X          DDDX       DENOM        B

     FINAL SOLUTION
     FINAL SOLUTION
    .31020     .03958     0.00000     .00372      .9716      .4550
    .30980     .04192     -.10000     .00429      .9580      .4550
    .30934     .04424     -.20000     .00483      .9642      .4550


    .30883     .04652     -.30000     .00535      .9602      .4550
    .30827     .04878     -.40000     .00584      .9560      .4550
    .30757     .05100     -.50000     .00631      .9516      .4550
    .30701     .05319     -.60000     .00674      .9471      .4550
    .30632     .05534     -.70000     .00715      .9423      .4550
    .30559     .05745     -.80000     .00752      .9374      .4550
    .30482     .05951     -.90000     .00786      .9323      .4550
    .30402     .06153    -1.00000     .00817      .9270      .4550
    .30319     .06351    -1.10000     .00844      .9216      .4550
    .30233     .06544    -1.20000     .00868      .9161      .4550
    .30145     .06732    -1.30000     .00889      .9104      .4550
    .30055     .06916    -1.40000     .00906      .9046      .4550
    .29964     .07094    -1.50000     .00921      .8987      .4550
    .29871     .07268    -1.60000     .00932      .8927      .4550
    .29778     .07437    -1.70000     .00940      .8866      .4550
    .29683     .07600    -1.80000     .00945      .8804      .4550
    .29589     .07759    -1.90000     .00948      .8741      .4550
    .29494     .07914    -2.00000     .00947      .8678      .4550
    .29400     .08063    -2.10000     .00945      .8614      .4550
    .29305     .08207    -2.20000     .00939      .8550      .4550
    .29212     .08347    -2.30000     .00932      .8486      .4550

     Q0          OVERFLOW          RESIDUAL FLOW          QS/Q0

    .0830        .0434             .0396                  .5259
```

```
HWMHFHFHFHMHFHMHWHMHMHFHMHMHMHWHMHMHMHMHFHMHMHMHFHMHWHMHMHMHMHFHMHMHMHMHMHMHFHMHMHMHMHMHMHFHMHMHMHFHMI
HMHMHMHMHFHMHMHMHMHMHMHFHMHMHFHMHMHMHMHMHMHMHMHMHFHMHMHMHMHFHMHMHFHMHMHMHMHMHMHMHMHFHMHMHMHMHMHMHMHMHI

   TEST   NUMBER +
*INPUT*   2V

  DO YOU WISH METRIC OR FPS SYSTEM +

*INPUT*   METRIC

  ENTER BO,Z,RN,SO,DELX,C,L,W,DDDX
*INPUT*   .455   0   .012   .001   .1   .25   2.3   1   0

  ENTER DISCHARGE IN APPROACH CHANNEL QO
*INPUT*   .087

  DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL +

*INPUT*   NO

  DOWNSTREAM CHANNEL BED SLOPE

*INPUT*   .00034

  TEST  NO. 2V

  MAIN CHANNEL SECTION IS RECTANGLE

    BO         Z           RN        RNC          SO        G          DELX

   .4550   0.0000      .0120    1.0000       .0010    9.8100      .1000

     C            L            W            DDDX
   .2500       2.3000       1.0000       0.0000

  QO
  .0870

 CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

  DC
  .15796

  DN
  .28739

 SUBCRITICAL  PROFILE

  COEFF OF DISCHARGE IS    .54018

  FROUDE NUMBER AT UPSTREAM END IS     .3962

  QS/QO=  .3787

         D2            Q2           X            CDDX          DENOM           B

    FINAL SOLUTION
   .30200       .05408      0.00000       .00718           .9425         .4550
   .30128       .05595      -.10000       .00732           .9380         .4550
   .30054       .05774      -.20000       .00745           .9334         .4550
   .29979       .05959      -.30000       .00756           .9287         .4550


   .29903       .06133      -.40000       .00767           .9238         .4550
   .29826       .06304      -.50000       .00776           .9189         .4550
   .29747       .06471      -.60000       .00784           .9138         .4550
   .29669       .06634      -.70000       .00791           .9087         .4550
   .29589       .06793      -.80000       .00797           .9035         .4550
   .29509       .06948      -.90000       .00801           .8983         .4550
   .29429       .07098     -1.00000       .00805           .8929         .4550
   .29348       .07245     -1.10000       .00807           .8875         .4550
   .29268       .07388     -1.20000       .00808           .8821         .4550
   .29187       .07526     -1.30000       .00809           .8766         .4550
   .29105       .07661     -1.40000       .00808           .8711         .4550
   .29025       .07792     -1.50000       .00806           .8655         .4550
   .28945       .07919     -1.60000       .00803           .8599         .4550
   .28865       .08042     -1.70000       .00799           .8544         .4550
   .28785       .08161     -1.80000       .00794           .8488         .4550
   .28706       .08277     -1.90000       .00788           .8431         .4550
   .28628       .08389     -2.00000       .00781           .8375         .4550
   .28550       .08497     -2.10000       .00774           .8319         .4550
   .28473       .08612     -2.20000       .00766           .8264         .4550
   .28397       .08734     -2.30000       .00757           .8208         .4550
  QO              OVERFLOW              RESIDUAL FLOW              QS/QO

   .0870           .0329                 .0541                    .3787
```

INFERIEURE

```
   TEST  NUMBER +
 *INPUT*   3V
   DO YOU WISH METRIC OR FPS SYSTEM +
 *INPUT*  METRIC
   ENTER B0,Z,RN,S0,DELX,C,L,W,DBDX
 *INPUT*  .455  0.  .012  .0012  .1  .2  2.3  1  0
   ENTER DISCHARGE IN APPROACH CHANNEL Q0
 *INPUT*  .096
   DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL +
 *INPUT*  NO
   DOWNSTREAM CHANNEL BED SLOPE
 *INPUT*  .00312
   TEST  NO. 3V

   MAIN CHANNEL SECTION IS RECTANGLE

     B0         Z          RN         RNC         S0        G          DELX
    .4550    0.0000      .0120     1.0000      .0012     9.8100      .1000
      C          L           W          DBDX
    .2500      2.3000      1.0000      0.0000
   Q0
   .0960
   CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

   DC
   .16856
   DN
   .28996
  SUBCRITICAL  PROFILE
   COEFF OF DISCHARGE IS    .52639
   FROUDE NUMBER AT UPSTREAM END IS     .4336

   QS/Q0= .6913

     D2          Q2          X           CODX         DENOM        B

    FINAL  SOLUTION
    FINAL  SOLUTION
    .28520     .02984     0.00000      .00144        .9792      .4550
    .28496     .03370     -.10000      .00342        .9734      .4550
    .28452     .03753     -.20000      .00537        .9669      .4550

    .28389     .04133     -.30000      .00727        .9596      .4550
    .28307     .04508     -.40000      .00910        .9515      .4550
    .28207     .04877     -.50000      .01086        .9426      .4550
    .28090     .05239     -.60000      .01253        .9329      .4550
    .27957     .05591     -.70000      .01410        .9225      .4550
    .27809     .05935     -.80000      .01555        .9113      .4550
    .27646     .06269     -.90000      .01688        .8993      .4550
    .27472     .06592    -1.00000      .01808        .8865      .4550
    .27285     .06904    -1.10000      .01915        .8729      .4550
    .27089     .07204    -1.20000      .02009        .8587      .4550
    .26885     .07491    -1.30000      .02085        .8437      .4550
    .26673     .07765    -1.40000      .02147        .8279      .4550
    .26456     .08027    -1.50000      .02194        .8116      .4550
    .26235     .08275    -1.60000      .02226        .7946      .4550
    .26011     .08511    -1.70000      .02243        .7771      .4550
    .25787     .08734    -1.80000      .02246        .7591      .4550
    .25553     .08944    -1.90000      .02235        .7406      .4550
    .25341     .09142    -2.00000      .02211        .7219      .4550
    .25121     .09328    -2.10000      .02175        .7027      .4550
    .24906     .09502    -2.20000      .02127        .6834      .4550
    .24696     .09665    -2.30000      .02069        .6639      .4550
   Q0          OVERFLOW        RESIDUAL FLOW        QS/Q0

    .0960       .0662             .0298             .6913
```

ITEE INFERIEURE

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HWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHW
WHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWH

  TEST  NUMBER ?
*INPUT*   4V
--DO-YOU-WISH-METRIC-OR-FPS SYSTEM-?------------------------------------------
 *INPUT*   METRIC

  ENTER B0,Z,RN,S0,DELX,C,L,W,DBDX
*INPUT*   .455   0   .012   .0015   .1   .2   2.3   1   0
  ENTER DISCHARGE IN APPROACH CHANNEL Q0
--*INPUT*---.12---------------------------------------------------------------

  DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL ?
 *INPUT*  NO

  DOWNSTREAM CHANNEL BED SLOPE
--*INPUT*---.00072------------------------------------------------------------

  TEST  NO. 4V

  MAIN CHANNEL SECTION IS RECTANGLE

-----B0--------Z--------RN--------RNC--------S0--------G--------DELX----------
   .4550   0.0000    .0120   1.0000     .0015   9.8100    .1000

     C          L          W          DBDX
   .2000     2.3000     1.0000     0.0000

   Q0
---.1200----------------------------------------------------------------------
  CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

   DC
  .19531
-----DN-----------------------------------------------------------------------
  .31494
 SUBCRITICAL PROFILE
  COEFF OF DISCHARGE IS     .50909
  FROUDE NUMBER AT UPSTREAM END IS     .4764
------------------------------------------------------------------------------

  QS/Q0 = .4015

     D2          Q2          X          DQDX        DENOM        B

    FINAL SOLUTION
----.28300------.07236----0.00000------.01766---------.8749--------.4550------
    .28113      .07590    -.10000      .01852         .8597        .4550
    .27933      .07932    -.20000      .01933         .8437        .4550
    .27732      .08261    -.30000      .02015         .8268        .4550


    .27527      .08578    -.40000      .02093         .8090        .4550
    .27314      .08882    -.50000      .02167         .7904        .4550
    .27094      .09173    -.60000      .02237         .7709        .4550
    .26867      .09450    -.70000      .02303         .7507        .4550
    .26633      .09714    -.80000      .02364         .7296        .4550
----.26394------.09964----.90000-------.02420---------.7076--------.4550------
    .26150      .10200   -1.00000      .02470         .6849        .4550
    .25901      .10423   -1.10000      .02514         .6614        .4550
    .25647      .10631   -1.20000      .02550         .6372        .4550
    .25391      .10826   -1.30000      .02580         .6122        .4550
    .25132      .11008   -1.40000      .02600         .5866        .4550
    .24871      .11176   -1.50000      .02612         .5603        .4550
    .24610      .11331   -1.60000      .02615         .5334        .4550
----.24349------.11474---1.70000-------.02606---------.5060--------.4550------
    .24089      .11604   -1.80000      .02587         .4782        .4550
    .23832      .11723   -1.90000      .02555         .4500        .4550
    .23579      .11830   -2.00000      .02511         .4216        .4550
    .23330      .11926   -2.10000      .02454         .3931        .4550
    .23083      .12013   -2.20000      .02381         .3647        .4550
    .22853      .12090   -2.30000      .02294         .3365        .4550
----Q0------------OVERFLOW--------RESIDUAL-FLOW-----------QS/Q0
     .1200        .0476              .0724                .4015
```

```
 TEST  NUMBER ?
*INPUT*   5V

 DO YOU WISH METRIC OR FPS SYSTEM ?

*INPUT*   METRIC

 ENTER BO,Z,RN,SO,DELX,C,B,H,DBDX
*INPUT*   .455    0    .012    .0015    .1    .2    1.2    1    0

 ENTER DISCHARGE IN APPROACH CHANNEL Q0
*INPUT*   .0848

 DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL ?

*INPUT*   NO

 DOWNSTREAM CHANNEL BED SLOPE
*INPUT*   .00017

 TEST  NO. 5V

 MAIN CHANNEL SECTION IS RECTANGLE

     BO        Z         RN        RNC        SO        G         DELX
   .4550    0.0000     .0120    1.0000     .0015    9.8100     .1000

      C          L          H         DBDX
    .2000     1.2000     1.0000     0.0000

    Q0
   .0848

 CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

    DC
   .15531

    DN
   .24170

 SUBCRITICAL  PROFILE

  COEFF OF DISCHARGE IS     .40853

  FROUDE NUMBER AT UPSTREAM END IS    .5008

  QS/Q0 = .5610

      D2          Q2           X           DQDX         DENOM        D

   FINAL SOLUTION
   FINAL SOLUTION
   .23700      .03743     0.00000      .00255        .9710       .4550
   .23662      .04186     -.10000      .00498        .9636       .4550
   .23601      .04626     -.20000      .00737        .9551       .4550

   .23515      .05061     -.30000      .00969        .9450       .4550
   .23407      .05490     -.40000      .01193        .9358       .4550
   .23277      .05910     -.50000      .01408        .9246       .4550
   .23126      .06321     -.60000      .01612        .9124       .4550
   .22955      .06731     -.70000      .01803        .8992       .4550
   .22766      .07109     -.80000      .01977        .8850       .4550
   .22560      .07485     -.90000      .02140        .8698       .4550
   .22339      .07846    -1.00000      .02285        .8535       .4550
   .22104      .08193    -1.10000      .02412        .8362       .4550
   .21857      .08525    -1.20000      .02522        .8179       .4550
  Q0             OVERFLOW            RESIDUAL FLOW           QS/Q0

   .0848           .0474                 .0374                .5610
```

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```
 TEST  NUMBER +
*INPUT*  6V.
 DO YOU WISH METRIC OR FPS SYSTEM +
*INPUT*  METRIC
 ENTER D0,Z,RN,SO,DELX,C,L,W,DBDX
*INPUT*  .455  0  .012  .0015  .1  .17  2.3  1  0
 ENTER DISCHARGE IN APPROACH CHANNEL QO
*INPUT*  .25
 DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL +
*INPUT*  NO
 DOWNSTREAM CHANNEL BED SLOPE
*INPUT*  .0015
 TEST  NO. 6V.

 MAIN CHANNEL SECTION IS RECTANGLE

   D0        Z          RN        RNC        SO        G         DELX
  .4550    0.0000     .0120     1.0000     .0015    9.8100     .1900
     C          L          W         DBDX
   .1700     2.3000     1.0000     0.0000
  QO
 .2500
 CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

  DC
 .31703
  DN
 .57119
 SUBCRITICAL FLOW IN APPROACH CHANNEL      SUPERCRITICAL FLOW ALONG SIDE WEIR
 COEFF OF DISCHARGE IS   .88844
 FROUDE NUMBER AT UPSTREAM END IS   1.0958

     D2          Q2          X          CDDX      DENCM        D          D6
   FINAL SOLUTION
   .29484      .25000     0.00000     -.54861     -.3208     .4550
   .28552      .24781      .02000     -.38379     -.4797     .4550     .3755
   .27865      .24584      .04000     -.30369     -.5132     .4550     .3727
   .27304      .24404      .06000     -.25382     -.5841     .4550     .3711
   .26834      .24236      .08000     -.21924     -.6459     .4550     .3683
   .26427      .24079      .10000     -.19307     -.7021     .4550     .3662
   .26056      .23932      .12000     -.17265     -.7532     .4550     .3646

   .25728      .23792      .14000     -.15618     -.8002     .4550     .3633
   .25429      .23661      .16000     -.14255     -.8439     .4550     .3623
   .25155      .23535      .18000     -.13106     -.8846     .4550     .3616
   .24903      .23416      .20000     -.12121     -.9225     .4550     .3590
   .23863      .22889      .30000     -.08686    -1.0886     .4550     .3546
   .23095      .22455      .40000     -.06662    -1.2178     .4550     .3510
   .22495      .22089      .50000     -.05333    -1.3219     .4550     .3490
   .22010      .21773      .60000     -.04385    -1.4085     .4550     .3461
   .21606      .21496      .70000     -.03685    -1.4801     .4550     .3461
   .21265      .21251      .80000     -.03137    -1.5426     .4550     .3427
   .20974      .21031      .90000     -.02697    -1.5959     .4550     .3417
   .20722      .20833     1.00000     -.02344    -1.6415     .4550     .3392
   .20502      .20653     1.10000     -.02054    -1.6806     .4550     .3391
   .20309      .20488     1.20000     -.01813    -1.7141     .4550     .3371
   .20137      .20336     1.30000     -.01609    -1.7428     .4550     .3364
   .19985      .20196     1.40000     -.01435    -1.7674     .4550     .3358
   .19849      .20065     1.50000     -.01286    -1.7883     .4550     .3345
   .19727      .19943     1.60000     -.01157    -1.8060     .4550     .3333
   .19617      .19828     1.70000     -.01044    -1.8208     .4550     .3322
   .19517      .19720     1.80000     -.00946    -1.8331     .4550     .3312
   .19427      .19613     1.90000     -.00854    -1.8453     .4550     .3303
   .19346      .19522     2.00000     -.00778    -1.8527     .4550     .3295
   .19271      .19433     2.10000     -.00711    -1.8586     .4550     .3287
   .19203      .19342     2.20000     -.00650    -1.8629     .4550     .3280
   .19141      .19258     2.30000     -.00596    -1.8658     .4550     .3274
 AT THE DOWNSTREAM END

  DC
 .26668
  DN
 .46045
  QC          OVERFLOW          RESIDUAL FLOW          QS/QC

  .2500        .0574               .1926                .2297
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TEST NUMBER +
*INPUT* 7V
 DO YOU WISH METRIC OR FPS SYSTEM +
*INPUT*  METRIC
 ENTER DO,Z,FN,SO,DELX,C,L,W,DBDX
*INPUT* .455  0  .012  .0015  .1   .17  2.3   1   0
 ENTER DISCHARGE IN APPROACH CHANNEL QO
*INPUT*  .2
 DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL +
*INPUT*  NO
 DOWNSTREAM CHANNEL BED SLOPE
*INPUT*  .0015
 TEST  NO: 7V

 MAIN CHANNEL SECTION IS RECTANGLE

    DO        Z         FN       FNC        SO        G        DELX
   .4550    0.0000     .0120    1.0000     .0015    9.8100     .1000
      C         L          W          DBDX
    .1700    2.3000     1.0000      0.0000
    QO
   .2000
 CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

    DC
   .27362

    DN
   .47507
 SUPCRITICAL FLOW IN APPROACH CHANNEL      SUPERCRITICAL FLOW ALONG SIDE WEIR
 COEFF OF DISCHARGE IS    .89003
 FROUDE NUMBER AT UPSTREAM END IS   1,0933

       D2           C2          X           DDQX       DENOM        E          D6
    FINAL SOLUTION
    .25446       .20000      0.00000      -.32937       -.3149      .4550
    .24871       .19877       .02000      -.24622       -.3914      .4550      .3237
    .24425       .19766       .04000      -.19995       -.4525      .4550      .3262
    .24055       .19664       .06000      -.16956       -.5040      .4550      .3248
    .23738       .19569       .08000      -.14727       -.5502      .4550      .3234
    .23461       .19479       .10000      -.13032       -.5914      .4550      .3246
    .23213       .19395       .12000      -.11689       -.6287      .4550      .3221


    .22991       .19316       .14000      -.10593       -.6629      .4550      .3199
    .22788       .19241       .16000      -.09680       -.6944      .4550      .3199
    .22602       .19170       .18000      -.08905       -.7237      .4550      .3200
    .22431       .19102       .20000      -.08237       -.7511      .4550      .3183
    .21725       .18831       .30000      -.05878       -.8682      .4550      .3172
    .21206       .18552       .40000      -.04503       -.9554      .4550      .3141
    .20801       .18342       .50000      -.03584      -1.0246      .4550      .3120
    .20475       .18159       .60000      -.02939      -1.0794      .4550      .3109
    .20206       .17998       .70000      -.02446      -1.1259      .4550      .3121
    .19980       .17855       .80000      -.02066      -1.1641      .4550      .3098
    .19789       .17726       .90000      -.01767      -1.1957      .4550      .3079
    .19624       .17609      1.00000      -.01526      -1.2219      .4550      .3062
    .19482       .17502      1.10000      -.01328      -1.2436      .4550      .3068
    .19357       .17403      1.20000      -.01163      -1.2615      .4550      .3056
    .19248       .17311      1.30000      -.01025      -1.2761      .4550      .3045
    .19151       .17225      1.40000      -.00908      -1.2879      .4550      .3035
    .19065       .17145      1.50000      -.00807      -1.2973      .4550      .3027
    .18989       .17069      1.60000      -.00719      -1.3064      .4550      .3019
    .18921       .16997      1.70000      -.00642      -1.3114      .4550      .3012
    .18860       .16929      1.80000      -.00577      -1.3155      .4550      .3006
    .18805       .16864      1.90000      -.00520      -1.3172      .4550      .3001
    .18755       .16802      2.00000      -.00470      -1.3184      .4550      .2995
    .18711       .16742      2.10000      -.00425      -1.3182      .4550      .2991
    .18670       .16684      2.20000      -.00387      -1.3172      .4550      .2987
    .18634       .16628      2.30000      -.00352      -1.3164      .4550      .2983
 AT THE DOWNSTREAM END

    DC
   .24223

    DN
   .40907

    QO          OVERFLOW          RESIDUAL FLOW          QS/QO

   .2000         .0337               .1663                .1686
```

```
WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW

 TEST  NUMBER ?
*INPUT*   8V
  DO YOU WISH METRIC OR FPS SYSTEM ?
*INPUT*   METRIC
  ENTER B0,Z,RN,S0,DELX,C,L,W,DDOX
*INPUT*  .455  0  .012  .001  .1  .1  2.3  1  0
  ENTER DISCHARGE IN APPROACH CHANNEL Q0
*INPUT*   .1196
  DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL ?
*INPUT*   NO
  DOWNSTREAM CHANNEL BED SLOPE
*INPUT*   .001
  TEST  NO. 8V.

  MAIN CHANNEL SECTION IS RECTANGLE

     B0          Z           RN        RNC          S0        G          DELX
   .4550     0.0000       .0120     1.0000       .0010     9.8100      .1000
       C            L            W         DDOX
   .1000       2.3000       1.0000       0.0000

    Q0
   .1196
  CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

    DC
   .19488

    DN
   .36406
  SUBCRITICAL FLOW IN APPROACH CHANNEL    SUPERCRITICAL FLOW ALONG SIDE WEIR
  COEFF OF DISCHARGE IS    .89368
  FROUDE NUMBER AT UPSTREAM END IS    1.0877

        D2           Q2           X          DDOX        DENOM        B          QS
     FINAL SOLUTION
     .18124       .11960      0.00000      -.38908       -.3014      .4550
     .17477       .11845       .02000      -.25772       -.4247      .4550       .2328
     .17018       .11742       .04000      -.20075       -.5153      .4550       .2302
     .16651       .11648       .06000      -.16659       -.5905      .4550       .2285
     .16342       .11560       .08000      -.14264       -.6579      .4550       .2274
     .16074       .11479       .10000      -.12907       -.7178      .4550       .2267
     .15838       .11402       .12000      -.11147       -.7721      .4550       .2234

     .15626       .11329       .14000      -.10058       -.8220      .4550       .2263
     .15433       .11261       .16000      -.09160       -.8681      .4550       .2243
     .15258       .11195       .18000      -.08406       -.9111      .4550       .2246
     .15096       .11133       .20000      -.07762       -.9513      .4550       .2230
     .14432       .10859       .30000      -.05512      -1.1263      .4550       .2223
     .13945       .10632       .40000      -.04224      -1.2583      .4550       .2195
     .13566       .10440       .50000      -.03368      -1.3649      .4550       .2177
     .13259       .10273       .60000      -.02768      -1.4501      .4550       .2166
     .13005       .10127       .70000      -.02309      -1.5236      .4550       .2141
     .12792       .09996       .80000      -.01956      -1.5845      .4550       .2139
     .12610       .09879       .90000      -.01677      -1.6352      .4550       .2121
     .12454       .09773      1.00000      -.01453      -1.6774      .4550       .2125
     .12318       .09675      1.10000      -.01268      -1.7124      .4550       .2112
     .12199       .09586      1.20000      -.01115      -1.7413      .4550       .2100
     .12094       .09503      1.30000      -.00985      -1.7648      .4550       .2099
     .12001       .09425      1.40000      -.00875      -1.7838      .4550       .2090
     .11918       .09353      1.50000      -.00781      -1.7988      .4550       .2072
     .11844       .09285      1.60000      -.00694      -1.8135      .4550       .2064
     .11778       .09221      1.70000      -.00625      -1.8209      .4550       .2058
     .11713       .09160      1.80000      -.00564      -1.8261      .4550       .2052
     .11665       .09102      1.90000      -.00511      -1.8289      .4550       .2046
     .11616       .09047      2.00000      -.00463      -1.8296      .4550       .2043
     .11622       .08993      2.10000      -.00421      -1.8285      .4550       .2037
     .11532       .08942      2.20000      -.00384      -1.8257      .4550       .2013
     .11499       .08893      2.30000      -.00350      -1.8215      .4550       .2010
  AT THE DOWNSTREAM END

    DC
   .16127

    DN
   .29228
  Q0            OVERFLOW          RESIDUAL FLOW          QS/Q0

   .1196         .0307              .0889                .2564
```

```
TEST NUMBER ?
*INPUT*  9V
 DO YOU WISH METRIC OR FPS SYSTEM ?
*INPUT*  METRIC
 ENTER B0,Z,RN,S0,DELX,C,L,W,DBDX
*INPUT*  .455  0  .012  .001  .1  .1  2.3  1  0
 ENTER DISCHARGE IN APPROACH CHANNEL Q0
*INPUT*  .154
 DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL ?
*INPUT*  NO
 DOWNSTREAM CHANNEL BED SLOPE
*INPUT*  .001
 TEST  NO. 9V

 MAIN CHANNEL-SECTION IS RECTANGLE

   B0         Z          RN         RNC        S0       G         DELX
  .4550    0.0000     .0120     1.0000     .0010    9.8100     .1000
       C          L           W          DBDX
    .1000     2.3000      1.0000     0.0000
  Q0
  .1540
 CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

  DC
 .23026
  DN
 .45291
 SUPCRITICAL FLOW IN APPROACH CHANNEL     SUPERCRITICAL FLOW ALONG SIDE WEIR
 COEFF OF DISCHARGE IS  .89189
 FROUDE NUMBER AT UPSTREAM END IS   1.0905

    D2         Q2           X          DDDX       DENOM       B          QE
   FINAL SOLUTION
  .21415     .15400     0.00000     -.58996     -.3030      .4550
  .20455     .15209      .02000     -.36999     -.4637      .4550      .2725
  .19802     .15040      .04000     -.28288     -.5783      .4550      .2700
  .19286     .14884      .06000     -.23295     -.6729      .4550      .2669
  .18853     .14740      .08000     -.19956     -.7552      .4550      .2645
  .18479     .14605      .10000     -.17476     -.8305      .4550      .2629
  .18149     .14480      .12000     -.15571     -.8993      .4550      .2615


  .17852     .14360      .14000     -.14050     -.9628      .4550      .2605
  .17584     .14247      .16000     -.12801    -1.0222      .4550      .2595
  .17329     .14140      .18000     -.11754    -1.0775      .4550      .2574
  .17112     .14038      .20000     -.10851    -1.1298      .4550      .2571
  .16181     .13586      .30000     -.07770    -1.3593      .4550      .2518
  .15494     .13214      .40000     -.05962    -1.5437      .4550      .2489
  .14957     .12899      .50000     -.04779    -1.6939      .4550      .2456
  .14521     .12627      .60000     -.03936    -1.8207      .4550      .2432
  .14159     .12389      .70000     -.03314    -1.9265      .4550      .2416
  .13862     .12177      .80000     -.02823    -2.0202      .4550      .2405
  .13589     .11988      .90000     -.02434    -2.1008      .4550      .2379
  .13361     .11817     1.00000     -.02119    -2.1700      .4550      .2376
  .13162     .11662     1.10000     -.01861    -2.2297      .4550      .2358
  .12987     .11523     1.20000     -.01645    -2.2810      .4550      .2339
  .12832     .11389     1.30000     -.01462    -2.3249      .4550      .2323
  .12693     .11268     1.40000     -.01307    -2.3624      .4550      .2309
  .12569     .11155     1.50000     -.01173    -2.3942      .4550      .2317
  .12458     .11051     1.60000     -.01057    -2.4209      .4550      .2306
  .12357     .10953     1.70000     -.00956    -2.4431      .4550      .2290
  .12266     .10860     1.80000     -.00862    -2.4653      .4550      .2287
  .12184     .10773     1.90000     -.00786    -2.4786      .4550      .2278
  .12109     .10690     2.00000     -.00716    -2.4892      .4550      .2271
  .12043     .10611     2.10000     -.00656    -2.4969      .4550      .2264
  .11977     .10537     2.20000     -.00601    -2.5019      .4550      .2242
  .11923     .10465     2.30000     -.00552    -2.5046      .4550      .2232
 AT THE DOWNSTREAM END

  DC
 .17844
  DN
 .33148
 QC             OVERFLOW            RESIDUAL FLOW           QS/QO

 .1540           .0494                  .1046               .3205
```

```
  TEST  NUMBER ?
*INPUT*  10V

  DO YOU WISH METRIC OR FPS SYSTEM ?
*INPUT*  METRIC

  ENTER B0,Z,RN,S0,DELX,C,L,W,DBDX
*INPUT*  .455  0  .012  .0012  .1  .2  2.3  1  0

  ENTER DISCHARGE IN APPROACH CHANNEL Q0
*INPUT*  .116

  DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL ?
*INPUT*  NO

  DOWNSTREAM CHANNEL BED SLOPE
*INPUT*  .00036

  TEST  NO. 10V

  MAIN CHANNEL SECTION IS RECTANGLE

     B0        Z         RN        RNC       S0       G       DELX
   .4550    0.0000     .0120    1.0000    .0012   9.8100    .1000
     C          L          W        DBDX
   .2000     2.3000     1.0000    0.0000

    Q0
   .1160

  CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

    DC
   .19099

    DN
   .33454

SUBCRITICAL  PROFILE

  COEFF OF DISCHARGE IS     .53130

  FROUDE NUMBBR AT UPSTREAM END IS     .4207

  QS/Q0= .5224

     D2         Q2          X          DQDX      DENOM      B

   FINAL SOLUTION
   FINAL SOLUTION
   .30200     .05565     0.00000     .02331     .9391     .4550
   .29953     .06067     -.10000     .02612     .9258     .4550
   .29679     .06549     -.20000     .02868     .9111     .4550

   .29381     .07011     -.30000     .03098     .8950     .4550
   .29061     .07450     -.40000     .03299     .8775     .4550
   .28722     .07866     -.50000     .03471     .8586     .4550
   .28365     .08259     -.60000     .03611     .8382     .4550
   .28002     .08625     -.70000     .03720     .8166     .4550
   .27625     .08968     -.80000     .03795     .7936     .4550
   .27243     .09285     -.90000     .03843     .7691     .4550
   .26859     .09580    -1.00000     .03855     .7434     .4550
   .26474     .09851    -1.10000     .03836     .7167     .4550
   .26093     .10094    -1.20000     .03786     .6891     .4550
   .25718     .10323    -1.30000     .03708     .6606     .4550
   .25353     .10527    -1.40000     .03606     .6317     .4550
   .24998     .10712    -1.50000     .03477     .6022     .4550
   .24658     .10878    -1.60000     .03325     .5725     .4550
   .24334     .11028    -1.70000     .03153     .5429     .4550
   .24029     .11162    -1.80000     .02963     .5136     .4550
   .23742     .11283    -1.90000     .02760     .4845     .4550
   .23477     .11390    -2.00000     .02546     .4570     .4550
   .23234     .11487    -2.10000     .02325     .4302     .4550
   .23012     .11573    -2.20000     .02101     .4047     .4550
   .22813     .11651    -2.30000     .01877     .3808     .4550
  Q0          OVERFLOW          RESIDUAL FLOW          QS/Q0

   .1160       .0604              .0556                 .5224
```

```
HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH

TEST NUMBER ?
*INPUT*  11V
 DO YOU WISH METRIC OR FPS SYSTEM ?
*INPUT*  METRIC
 ENTER B0,Z,RN,S0,DELX,C,L,W,DDDX
*INPUT*  .455  0  .012  .0015  .1  .1  2.3  1  0
 ENTER DISCHARGE IN APPROACH CHANNEL Q0
*INPUT*  .128
 DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL ?
*INPUT*  NO
 DOWNSTREAM CHANNEL BED SLOPE
*INPUT*  .0015
 TEST  NO. 11V

 MAIN CHANNEL SECTION IS RECTANGLE

   B0        Z          RN        RNC       S0       G        DELX
  .4550   0.0000     .0120    1.0000    .0015   9.8100    .1000
     C          L          W         DDDX
   .1000     2.3000    1.0000     0.0000
   Q0
  .1280
 CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

   DC
  .20581
   DN
  .33414
 SUBCRITICAL FLOW IN APPROACH CHANNEL     SUPERCRITICAL FLOW ALONG SIDE WEIR
 COEFF OF DISCHARGE IS  .89320
 FROUDE NUMBER AT UPSTREAM END IS   1.0885

    D2          Q2          X          DDDX        DENOM        B          D6
   FINAL SOLUTION
  .18954      .12800    0.00000     -.44107      -.3032     .4550
  .18225      .12667     .02000     -.28767      -.4353     .4550       .2423
  .17716      .12548     .04000     -.22204      -.5342     .4550       .2412
  .17310      .12440     .06000     -.18392      -.6148     .4550       .2391
  .16968      .12339     .08000     -.15733      -.6871     .4550       .2397
  .16673      .12245     .10000     -.13788      -.7516     .4550       .2367
  .16412      .12157     .12000     -.12287      -.8102     .4550       .2361


  .16173      .12073     .14000     -.11085      -.8640     .4550       .2358
  .15967      .11994     .16000     -.10097      -.9140     .4550       .2337
  .15773      .11919     .18000     -.09268      -.9607     .4550       .2337
  .15593      .11848     .20000     -.08559     -1.0044     .4550       .2320
  .14863      .11532     .30000     -.06087     -1.1960     .4550       .2306
  .14325      .11272     .40000     -.04672     -1.3421     .4550       .2272
  .13909      .11052     .50000     -.03731     -1.4613     .4550       .2250
  .13564      .10861     .60000     -.03072     -1.5576     .4550       .2236
  .13283      .10694     .70000     -.02567     -1.6415     .4550       .2228
  .13049      .10545     .80000     -.02179     -1.7118     .4550       .2205
  .12843      .10412     .90000     -.01873     -1.7711     .4550       .2204
  .12668      .10291    1.00000     -.01625     -1.8212     .4550       .2187
  .12515      .10181    1.10000     -.01421     -1.8633     .4550       .2172
  .12382      .10081    1.20000     -.01252     -1.8987     .4550       .2158
  .12264      .09987    1.30000     -.01109     -1.9283     .4550       .2166
  .12159      .09900    1.40000     -.00988     -1.9528     .4550       .2156
  .12065      .09819    1.50000     -.00383     -1.9729     .4550       .2147
  .11982      .09743    1.60000     -.00797     -1.9926     .4550       .2139
  .11907      .09672    1.70000     -.00710     -2.0042     .4550       .2131
  .11839      .09604    1.80000     -.00643     -2.0131     .4550       .2124
  .11778      .09540    1.90000     -.00583     -2.0194     .4550       .2118
  .11722      .09479    2.00000     -.00530     -2.0233     .4550       .2112
  .11672      .09421    2.10000     -.00483     -2.0251     .4550       .2087
  .11625      .09365    2.20000     -.00441     -2.0251     .4550       .2093
  .11581      .09311    2.30000     -.00404     -2.0233     .4550       .2078
 AT THE DOWNSTREAM END

   DC
  .16420
   DN
  .25135
 Q0          OVERFLOW           RESIDUAL FLOW          QS/Q0

  .1280       .0349              .0931                 .2725
```

```
WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW

 TEST  NUMBER ?
*INPUT*  12V
 DO YOU WISH METRIC OR FPS SYSTEM ?
*INPUT*  METRIC
 ENTER B0,Z,RN,S0,DELX,C,L,W,DBDX
*INPUT*  .455  0  .012  .0015  .1  .1  2.3  1  0
 ENTER DISCHARGE IN APPROACH CHANNEL Q0
*INPUT*  .116
 DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL ?
*INPUT*  NO
 DOWNSTREAM CHANNEL BED SLOPE
*INPUT*  .0015
 TEST  NO. 12V

 MAIN CHANNEL SECTION IS RECTANGLE

   B0        Z          RN.        RNC        S0        G          DELX
 .4550    0.0000     .0120     1.0000     .0015    9.8100     .1000
    C         L          W          DBDX
  .1000    2.3000     1.0000     0.0000
  Q0
 .1160
 CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

  DC
 .19199
  DN
 .30079
 SUBCRITICAL FLOW IN APPROACH CHANNEL     SUPERCRITICAL FLOW ALONG SIDE WEIR
 COEF. OF DISCHARGE IS  .89389
 FROUDE NUMBER AT UPSTREAM END IS   1.0874

   Y2          Q2          X          DDDX       DENOM       B          QS
 FINAL SOLUTION
 .17762      .11600     0.00000    -.36893     -.3006     .4550
 .17147      .11493      .02000    -.24611     -.4200     .4550     .2275
 .16709      .11396      .04000    -.19203     -.5083     .4550     .2271
 .16357      .11308      .06000    -.15946     -.5815     .4550     .2256
 .16061      .11226      .08000    -.13660     -.6469     .4550     .2246
 .15805      .11150      .10000    -.11978     -.7052     .4550     .2240
 .15578      .11078      .12000    -.10677     -.7580     .4550     .2218

 .15375      .11011      .14000    -.09633     -.8064     .4550     .2214
 .15191      .10947      .16000    -.08773     -.8512     .4550     .2219
 .15023      .10886      .18000    -.08051     -.8929     .4550     .2212
 .14868      .10827      .20000    -.07433     -.9319     .4550     .2207
 .14232      .10571      .30000    -.05275    -1.1012     .4550     .2183
 .13767      .10360      .40000    -.04040    -1.2287     .4550     .2157
 .13404      .10180      .50000    -.03219    -1.3314     .4550     .2140
 .13111      .10025      .60000    -.02644    -1.4133     .4550     .2131
 .12863      .09888      .70000    -.02204    -1.4838     .4550     .2127
 .12665      .09767      .80000    -.01866    -1.5423     .4550     .2106
 .12492      .09657      .90000    -.01599    -1.5908     .4550     .2099
 .12342      .09558     1.00000    -.01384    -1.6312     .4550     .2094
 .12213      .09467     1.10000    -.01208    -1.6646     .4550     .2081
 .12099      .09384     1.20000    -.01061    -1.6922     .4550     .2070
 .11999      .09306     1.30000    -.00937    -1.7147     .4550     .2060
 .11911      .09234     1.40000    -.00832    -1.7328     .4550     .2051
 .11833      .09167     1.50000    -.00736    -1.7505     .4550     .2043
 .11763      .09103     1.60000    -.00660    -1.7604     .4550     .2035
 .11700      .09043     1.70000    -.00594    -1.7678     .4550     .2030
 .11643      .08986     1.80000    -.00536    -1.7728     .4550     .2024
 .11592      .08932     1.90000    -.00485    -1.7755     .4550     .2019
 .11546      .08880     2.00000    -.00440    -1.7762     .4550     .2015
 .11504      .08830     2.10000    -.00400    -1.7753     .4550     .2010
 .11466      .08782     2.20000    -.00364    -1.7727     .4550     .2007
 .11431      .08737     2.30000    -.00332    -1.7688     .4550     .1983
 AT THE DOWNSTREAM END

  DC
 .15140
  DN
 .24717
 Q0            OVERFLOW          RESIDUAL FLOW          QS/Q0

 .1160          .0286               .0874               .2469
```

```
 TEST  NUMBER ?
*INPUT*  13V
 DO YOU WISH METRIC OR FPS SYSTEM ?
*INPUT*  METRIC
 ENTER B0,Z,RN,S0,DELX,C,L,W,DBOX
*INPUT*  .455  0  .012  .0015  .1  .1  1.2  1  0
 ENTER DISCHARGE IN APPROACH CHANNEL Q0
*INPUT*  .13
 DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL ?
*INPUT*  NO
 DOWNSTREAM CHANNEL BED SLOPE
*INPUT*  .0015
 TEST  NO. 13V

 MAIN CHANNEL SECTION IS RECTANGLE

  B0        Z        RN       RNC       S0       G        DELX
 .4550   0.0000    .0120    1.0000    .0015    9.8100    .1000
   C        L          W         DBOX
 .1000    1.2000    1.0000    0.0000

  Q0
 .1300
 CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

  DC
 .20390

  DN
 .33516
 SUBCRITICAL FLOW IN APPROACH CHANNEL     SUPERCRITICAL FLOW ALONG SIDE WEIR
 COEFF OF DISCHARGE IS  .89309
 FROUDE NUMBER AT UPSTREAM END IS    1.0886

    D2          Q2          X          DDDX      DENOM        B          D6
   FINAL SOLUTION
  .19149      .13000     0.00000     -.45293     -.3036      .4550
  .18402      .12863      .02000     -.29431     -.4378      .4550      .2460
  .17881      .12740      .04000     -.22694     -.5382      .4550      .2428
  .17466      .12628      .06000     -.18791     -.6199      .4550      .2407
  .17117      .12524      .08000     -.16071     -.6932      .4550      .2412
  .16816      .12427      .10000     -.14083     -.7587      .4550      .2382
  .16549      .12336      .12000     -.12549     -.8181      .4550      .2375


  .16311      .12250      .14000     -.11322     -.8729      .4550      .2371
  .16094      .12168      .16000     -.10313     -.9236      .4550      .2369
  .15895      .12091      .18000     -.09466     -.9710      .4550      .2350
  .15714      .12017      .20000     -.08743    -1.0156      .4550      .2351
  .14966      .11691      .30000     -.06219    -1.2107      .4550      .2317
  .14416      .11423      .40000     -.04775    -1.3597      .4550      .2282
  .13987      .11196      .50000     -.03815    -1.4816      .4550      .2279
  .13639      .10999      .60000     -.03142    -1.5802      .4550      .2264
  .13351      .10827      .70000     -.02627    -1.6662      .4550      .2235
  .13108      .10673      .80000     -.02231    -1.7385      .4550      .2231
  .12900      .10536      .90000     -.01917    -1.7996      .4550      .2210
  .12721      .10412     1.00000     -.01664    -1.8512      .4550      .2192
  .12565      .10298     1.10000     -.01456    -1.8948      .4550      .2197
  .12428      .10194     1.20000     -.01283    -1.9315      .4550      .2183
 AT THE DOWNSTREAM END

  DC
 .17238

  DN
 .27783
 Q0          OVERFLOW          RESIDUAL FLOW          QS/Q0

 .1300        .0281              .1019                .2158
```

```
TEST  NUMBER +
*INPUT*  1
 DO YOU WISH METRIC OR FPS SYSTEM +
*INPUT*  METRIC
 ENTER BO,Z,RN,SO,DELX,C,L,W,CBOX
*INPUT*  .15  0  .01  .0177  .04  .1  .56  1  0
 ENTER DISCHARGE IN APPROACH CHANNEL QO
*INPUT*  .036
 DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL +
*INPUT*  NO
 DOWNSTREAM CHANNEL BED SLOPE
*INPUT*  .0177
. TEST  NO. 1

 MAIN CHANNEL SECTION IS RECTANGLE

   BO        Z          RN        RNC        SO       G          DELX
 .1500   0.0000     .0100   1.0000     .0177   9.8100     .0400
    C          L          W          DBOX
  .1000      .5600     1.0000     0.0000
   QO
  .0360
 CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

   DC
  .18352

   DN
  .13663
SUPERCRIT  FLOW  ON  STEEP  SLOPE
 COEFF OF DISCHARGE IS   .59682
 FROUDE NUMBER AT UPSTREAM END IS   1.5173

     D2          Q2          X           CDDX        CENCM        B
   .13663      .03600    0.00000      -.08471     -1.3021      .1500
   .13598      .03590     .00800      -.08153     -1.3240      .1500
   .13532      .03581     .01600      -.07861     -1.3447      .1500
   .13471      .03572     .02400      -.07587     -1.3648      .1500
   .13411      .03563     .03200      -.07328     -1.3844      .1500
   .13353      .03554     .04000      -.07083     -1.4035      .1500
   .13298      .03545     .04800      -.06852     -1.4222      .1500
   .13244      .03537     .05600      -.06633     -1.4404      .1500


   .13191      .03529     .06400      -.06425     -1.4581      .1500
   .13141      .03521     .07200      -.06228     -1.4754      .1500
   .13092      .03513     .08000      -.06040     -1.4923      .1500
   .12866      .03477     .12000      -.05230     -1.5703      .1500
   .12670      .03444     .16000      -.04572     -1.6416      .1500
   .12498      .03415     .20000      -.04034     -1.7058      .1500
   .12346      .03388     .24000      -.03586     -1.7638      .1500
   .12210      .03364     .28000      -.03214     -1.8166      .1500
   .12088      .03342     .32000      -.02895     -1.8647      .1500
   .11977      .03321     .36000      -.02621     -1.9088      .1500
   .11877      .03303     .40000      -.02383     -1.9492      .1500
   .11786      .03285     .44000      -.02164     -1.9897      .1500
   .11703      .03269     .48000      -.01985     -2.0231      .1500
   .11627      .03254     .52000      -.01826     -2.0542      .1500
   .11557      .03240     .56000      -.01684     -2.0829      .1500
 AT THE DOWNSTREAM END

   DC
  .17118

   DN
  .12499
 CONJUGATE DEPTH IS     .2076
 QO            OVERFLOW            RESIDUAL FLOW          CS/QO

   .0360        .0036                .0324               .1001
```

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HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH

TEST NUMBER ?
*INPUT*  2
 DO YOU WISH METRIC OR FPS SYSTEM ?
*INPUT*  METRIC
 ENTER B0,Z,RN,S0,DELX,C,L,W,DBDX
*INPUT*  .15   0   .01   .02   .04   .1   .56   1   0
 ENTER DISCHARGE IN APPROACH CHANNEL Q0
*INPUT*  .045
 DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL ?
*INPUT*  NO
 DOWNSTREAM CHANNEL BED SLOPE
*INPUT*  .02
 TEST  NO. 2

 MAIN CHANNEL SECTION IS RECTANGLE

   B0        Z          RN         RNC        S0       G         DELX
  .1500    0.0000     .0100     1.0000     .0200    9.8100     .0400
     C          L          W           DBDX
   .1000      .5600     1.0000      0.0000
  Q0
 .0450
 CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

   DC
  .21264
   DN
  .15581
SUPERCRIT  FLOW  ON  STEEP  SLOPE
 COEFF OF DISCHARCE IS   .56666
 FROUDE NUMBER AT UPSTREAM END IS   1.5574

    D2          Q2          X           DDDX        DENOM        B
  .15581      .04500     0.00000     -.13242     -1.4255     .1500
  .15477      .04483      .00800     -.12708     -1.4565     .1500
  .15377      .04466      .01600     -.12223     -1.4857     .1500
  .15281      .04449      .02400     -.11770     -1.5141     .1500
  .15189      .04433      .03200     -.11345     -1.5418     .1500
  .15100      .04418      .04000     -.10946     -1.5689     .1500
  .15014      .04402      .04800     -.10570     -1.5953     .1500
  .14931      .04388      .05600     -.10216     -1.6211     .1500


  .14850      .04373      .06400     -.09881     -1.6463     .1500
  .14772      .04359      .07200     -.09565     -1.6709     .1500
  .14697      .04345      .08000     -.09265     -1.6950     .1500
  .14352      .04281      .12000     -.07985     -1.8067     .1500
  .14053      .04223      .16000     -.06956     -1.9099     .1500
  .13792      .04171      .20000     -.06126     -2.0035     .1500
  .13560      .04124      .24000     -.05442     -2.0890     .1500
  .13354      .04081      .28000     -.04870     -2.1673     .1500
  .13169      .04041      .32000     -.04385     -2.2393     .1500
  .13002      .04005      .36000     -.03970     -2.3057     .1500
  .12850      .03971      .40000     -.03611     -2.3671     .1500
  .12712      .03940      .44000     -.03299     -2.4240     .1500
  .12586      .03911      .48000     -.03024     -2.4768     .1500
  .12469      .03885      .52000     -.02782     -2.5259     .1500
  .12363      .03859      .56000     -.02556     -2.5756     .1500
 AT THE DOWNSTREAM END

  DC
 .19215
  DN
 .13757
 CONJUGATE DEPTH IS   .2256
 Q0            OVERFLOW          RESIDUAL FLOW          QS/Q0

  .0450           .0064             .0386              .1423
```

```
  TEST  NUMBER ?
*INPUT*   3
  DO YOU WISH METRIC OR FPS SYSTEM ?
*INPUT*   METRIC
  ENTER BO,Z,RN,SO,DELX,C,L,W,DBDX
*INPUT*  .15   0   .01   .065   .04   .0515   .56   1   0
  ENTER DISCHARGE IN APPROACH CHANNEL QO
*INPUT*   .041
  DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL ?
*INPUT*   NO
  DOWNSTREAM CHANNEL BED SLOPE
*INPUT*   .065
  TEST  NO. 3

 MAIN CHANNEL SECTION IS RECTANGLE

    BO        Z          RN        RNC        SO       G.        DELX
  .1500    0.0000     .0100     1.0000     .0650   9.8100     .0400

      C          L          W          DBDX
  .0515      .5600     1.0000      0.0000

  QO
 .0410
  CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

  DC
 .19997
  DN
 .09056
SUPERCRIT  FLOW  ON  STEEP  SLOPE
 COEFF OF DISCHARGE IS   .33676
  FROUDE NUMBER AT UPSTREAM END IS   3.2022

     D2          Q2          X          DDDX      DENOM      B
   .09056     .04100     0.00000    -.01999    -9.2540     .1500
   .09040     .04094      .00800    -.01985    -9.2777     .1500
   .09024     .04088      .01600    -.01971    -9.3012     .1500
   .09009     .04082      .02400    -.01957    -9.3246     .1500
   .08993     .04076      .03200    -.01944    -9.3478     .1500
   .08978     .04070      .04000    -.01930    -9.3710     .1500
   .08962     .04064      .04800    -.01917    -9.3941     .1500
   .08947     .04058      .05600    -.01904    -9.4172     .1500

   .08932     .04052      .06400    -.01891    -9.4401     .1500
   .08917     .04046      .07200    -.01878    -9.4629     .1500
   .08902     .04040      .08000    -.01865    -9.4857     .1500
   .08828     .04012      .12000    -.01801    -9.6025     .1500
   .08757     .03984      .16000    -.01742    -9.7125     .1500
   .08689     .03957      .20000    -.01685    -9.8204     .1500
   .08623     .03931      .24000    -.01631    -9.9263     .1500
   .08558     .03906      .28000    -.01579   -10.0301     .1500
   .08496     .03881      .32000    -.01530   -10.1318     .1500
   .08436     .03857      .36000    -.01482   -10.2316     .1500
   .08378     .03834      .40000    -.01437   -10.3294     .1500
   .08321     .03811      .44000    -.01394   -10.4252     .1500
   .08266     .03789      .48000    -.01352   -10.5191     .1500
   .08213     .03767      .52000    -.01312   -10.6112     .1500
   .08161     .03746      .56000    -.01274   -10.7013     .1500
  AT THE DOWNSTREAM END

  DC
 .18841
  DN
 .08457
  CONJUGATE DEPTH IS   .2176
  QO          OVERFLOW          RESIDUAL FLOW          QS/QO

  .0410        .0035              .0375              .0863
```

```
[illegible]

 TEST  NUMBER +
*INPUT*  4
 DO YOU WISH METRIC OR FPS SYSTEM +
*INPUT*  METRIC
 ENTER B0,Z,RN,S0,DELX,C,L,W,DBOX
*INPUT*  .15  0  .01  .0105  .04  .0515  .56  1  0
 ENTER DISCHARGE IN APPROACH CHANNEL Q0
*INPUT*  .016
 DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL +
*INPUT*  NO
 DOWNSTREAM CHANNEL BED SLOPE
*INPUT*  .0105
 TEST  NO. 4

 MAIN CHANNEL-SECTION IS RECTANGLE

   B0         Z          RN         RNC         S0        G           DELX
  .1500    0.0000      .0100     1.0000      .0105    9.8100       .0400
      C            L           W           DBOX
    .0515        .5600      1.0000        0.0000

   Q0
  .0160
 CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

   DC
  .10746

   DN
  .08855
SUPERCRIT  FLOW  ON  STEEP  SLOPE
 COEFF OF DISCHARGE IS   .75687
 FROUDE NUMBER AT UPSTREAM END IS    1.2924

      D2          Q2          X          DDDX       DENOM        E
    .08855      .01600    0.00000     -.22243      -.6703      .1500
    .08689      .01588     .00800     -.19339      -.7403      .1500
    .08543      .01576     .01600     -.17119      -.8046      .1500
    .08413      .01565     .02400     -.15370      -.8638      .1500
    .08296      .01555     .03200     -.13950      -.9186      .1500
    .08189      .01545     .04000     -.12703      -.9735      .1500
    .08091      .01535     .04800     -.11725     -1.0207      .1500
    .08001      .01527     .05600     -.10876     -1.0658      .1500

    .07917      .01519     .06400     -.10139     -1.1085      .1500
    .07839      .01511     .07200     -.09482     -1.1492      .1500
    .07765      .01503     .08000     -.08902     -1.1881      .1500
    .07452      .01469     .12000     -.06734     -1.3620      .1500
    .07210      .01440     .16000     -.05369     -1.5009      .1500
    .07015      .01415     .20000     -.04378     -1.6247      .1500
    .06855      .01394     .24000     -.03654     -1.7304      .1500
    .06720      .01375     .28000     -.03103     -1.8216      .1500
    .06604      .01358     .32000     -.02670     -1.9011      .1500
    .06504      .01343     .36000     -.02322     -1.9709      .1500
    .06417      .01330     .40000     -.02038     -2.0324      .1500
    .06340      .01318     .44000     -.01801     -2.0867      .1500
    .06272      .01307     .48000     -.01588     -2.1414      .1500
    .06212      .01297     .52000     -.01424     -2.1820      .1500
    .06158      .01287     .56000     -.01282     -2.2188      .1500
 AT THE DOWNSTREAM END

   DC
  .09309

   DN
  .07518
 CONJUGATE DEPTH IS    .1156
 QD           OVERFLOW         RESIDUAL FLOW          QS/Q0

     .0160        .0031            .0129              .1959
```

```
 TEST  NUMBER +
*INPUT*  5
 DO YOU WISH METRIC OR FPS SYSTEM +
*INPUT*  METRIC
 ENTER BO,Z,RN,SO,DELX,C,L,W,DBDX
*INPUT* .15  0  .01  .0209  .04   .0515  .56  1  0
 ENTER DISCHARGE IN APPROACH CHANNEL, QO
*INPUT*  .0215
 DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL +
*INPUT*  NO
 DOWNSTREAM CHANNEL BED SLOPE
*INPUT*  .0209
 TEST  NO. 5

 MAIN CHANNEL SECTION IS RECTANGLE

   BO        Z          RN        RNC       SO       G        DELX
  .1500    0.0000     .0100     1.0000    .0209   9.8100    .0400
     C          L            W          DBDX
   .0515      .5600       1.0000      0.0000

  QO
 .0215
 CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

  DC
 .13060

  DN
 .08534
SUPERCRIT  FLOW  ON  STEEP  SLOPE
 COEFF OF DISCHARGE IS    .36136
 FROUDE NUMBER AT UPSTREAM END IS   1.8356

      D2          Q2          X          DDDX      DENOM       B
    .08534      .02150     0.00000     -.03887    -2.3696     .1500
    .08503      .02145      .00800     -.03816    -2.3900     .1500
    .08473      .02140      .01600     -.03748    -2.4098     .1500
    .08443      .02134      .02400     -.03682    -2.4294     .1500
    .08414      .02129      .03200     -.03618    -2.4488     .1500
    .08385      .02124      .04000     -.03556    -2.4679     .1500
    .08357      .02119      .04800     -.03495    -2.4869     .1500
    .08329      .02115      .05600     -.03436    -2.5057     .1500


    .08302      .02110      .06400     -.03379    -2.5242     .1500
    .08275      .02105      .07200     -.03323    -2.5426     .1500
    .08249      .02100      .08000     -.03269    -2.5608     .1500
    .08123      .02078      .12000     -.03017    -2.6482     .1500
    .08007      .02056      .16000     -.02792    -2.7386     .1500
    .07900      .02036      .20000     -.02587    -2.8167     .1500
    .07800      .02018      .24000     -.02411    -2.8914     .1500
    .07707      .02000      .28000     -.02253    -2.9626     .1500
    .07619      .01983      .32000     -.02109    -3.0305     .1500
    .07536      .01966      .36000     -.01979    -3.0952     .1500
    .07461      .01951      .40000     -.01861    -3.1570     .1500
    .07389      .01936      .44000     -.01753    -3.2159     .1500
    .07320      .01923      .48000     -.01653    -3.2721     .1500
    .07256      .01909      .52000     -.01562    -3.3258     .1500
    .07195      .01896      .56000     -.01478    -3.3771     .1500
  AT THE DOWNSTREAM END

  DC
 .12022

  DN
 .07765
 CONJUGATE DEPTH IS    .1540
 QO          OVERFLOW          RESIDUAL FLOW          QS/QO

   .0215       .0025              .0190                .1179
```

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HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH

 TEST  NUMBER ?
*INPUT*  6
  DO YOU WISH METRIC OR FPS SYSTEM ?
*INPUT*  METRIC
  ENTER B0,Z,RN,S0,DELX,C,L,W,DBDX
*INPUT*  .15  0  .01  .0138  .04   .0515  .56  1  0
  ENTER DISCHARGE IN APPROACH CHANNEL Q0
*INPUT*  .018
  DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL ?
*INPUT*  NO
  DOWNSTREAM CHANNEL BED SLOPE
*INPUT*  .0138
  TEST  NO. 6
 MAIN CHANNEL SECTION IS RECTANGLE
   B0        Z          RN        RNC        S0        G         DELX
  .1500    0.0000     .0100    1.0000     .0138    9.8100     .0400
     C          L          W          DBDX
   .0515      .5600     1.0000     0.0000
   Q0
  .0180
 CRITICAL AND NORMAL DEPTHS AT UPSTREAM END
   DC
  .11615
   DN
  .08729
SUPERCRIT  FLOW  ON  STEEP  SLOPE.
  COEFF OF DISCHARGE IS    .62024
  FROUDE NUMBER AT UPSTREAM END IS    1.4855
     D2          Q2          X          DDDX        DENOM        B
   .08729      .01800    0.00000     -.11184     -1.2066      .1500
   .08642      .01790     .00800     -.10527     -1.2515      .1500
   .08560      .01781     .01600     -.09963     -1.2923      .1500
   .08483      .01772     .02400     -.09451     -1.3317      .1500
   .08409      .01763     .03200     -.08985     -1.3698      .1500
   .08339      .01755     .04000     -.08559     -1.4067      .1500
   .08272      .01746     .04800     -.08168     -1.4425      .1500
   .08208      .01738     .05600     -.07807     -1.4771      .1500

   .08147      .01731     .06400     -.07474     -1.5108      .1500
   .08088      .01723     .07200     -.07164     -1.5435      .1500
   .08032      .01716     .08000     -.06877     -1.5752      .1500
   .07781      .01682     .12000     -.05707     -1.7192      .1500
   .07570      .01653     .16000     -.04816     -1.8510      .1500
   .07391      .01627     .20000     -.04132     -1.9679      .1500
   .07237      .01603     .24000     -.03592     -2.0724      .1500
   .07102      .01582     .28000     -.03156     -2.1665      .1500
   .06983      .01563     .32000     -.02795     -2.2516      .1500
   .06877      .01546     .36000     -.02494     -2.3287      .1500
   .06782      .01530     .40000     -.02239     -2.3990      .1500
   .06697      .01515     .44000     -.02007     -2.4704      .1500
   .06621      .01502     .48000     -.01823     -2.5267      .1500
   .06551      .01489     .52000     -.01661     -2.5790      .1500
   .06487      .01477     .56000     -.01520     -2.6270      .1500
  AT THE DOWNSTREAM END
   DC
  .10196
   DN
  .07525
  CONJUGATE DEPTH IS   .1269
  Q0        OVERFLOW        RESIDUAL FLOW        QS/Q0
    .0180       .0032              .0148            .1792
```

```
 TEST NUMBER +
*INPUT*  7
 DO YOU WISH METRIC OR FPS SYSTEM +
*INPUT*  METRIC
 ENTER B0,Z,RN,S0,DELX,C,L,W,DBDX
*INPUT*  .15  0  .01  .0392  .04  .0515  .56  1  0
 ENTER DISCHARGE IN APPROACH CHANNEL Q0
*INPUT*  .029
 DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL +
*INPUT*  NO
 DOWNSTREAM CHANNEL BED SLOPE
*INPUT*  .0392
 TEST  NO. 7

 MAIN CHANNEL SECTION IS RECTANGLE

   B0        Z         RN        RNC        S0       G         DELX
  .1500    0.0000    .0100    1.0000     .0392    9.8100    .0400
    C          L          W         DBDX
  .0515      .5600     1.0000     0.0000

  Q0
  .0290
 CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

  DC
  .15912
  DN
  .08436
SUPERCRIT  FLOW  ON  STEEP  SLOPE
 COEFF OF DISCHARGE IS    .34906
 FROUDE NUMBER AT UPSTREAM END IS   2.5191

    D2          Q2          X          DQDX       DENOM        E
  .08436      .02900    0.00000    -.02233     -5.3458     .1500
  .08419      .02895     .00800    -.02211     -5.3648     .1500
  .08401      .02890     .01600    -.02190     -5.3834     .1500
  .08383      .02885     .02400    -.02170     -5.4019     .1500
  .08366      .02881     .03200    -.02149     -5.4204     .1500
  .08349      .02876     .04000    -.02129     -5.4387     .1500
  .08332      .02871     .04800    -.02109     -5.4569     .1500
  .08315      .02867     .05600    -.02089     -5.4750     .1500


  .08299      .02862     .06400    -.02070     -5.4931     .1500
  .08282      .02857     .07200    -.02051     -5.5110     .1500
  .08265      .02853     .08000    -.02032     -5.5288     .1500
  .08186      .02831     .12000    -.01938     -5.6206     .1500
  .08111      .02809     .16000    -.01854     -5.7051     .1500
  .08038      .02789     .20000    -.01774     -5.7874     .1500
  .07969      .02769     .24000    -.01699     -5.8673     .1500
  .07902      .02750     .28000    -.01629     -5.9450     .1500
  .07838      .02731     .32000    -.01563     -6.0205     .1500
  .07777      .02713     .36000    -.01500     -6.0938     .1500
  .07718      .02696     .40000    -.01441     -6.1651     .1500
  .07662      .02679     .44000    -.01385     -6.2343     .1500
  .07607      .02663     .48000    -.01332     -6.3015     .1500
  .07555      .02647     .52000    -.01282     -6.3668     .1500
  .07505      .02632     .56000    -.01235     -6.4302     .1500
 AT THE DOWNSTREAM END

  DC
  .14926

  DN
  .07843
 CONJUGATE DEPTH IS    .1834
 Q0          OVERFLOW          RESIDUAL FLOW          QS/Q0

 .0290        .0027               .0263              .0922
```

```
 TEST  NUMBER ?
*INPUT*  8
 DO YOU WISH METRIC OR FPS SYSTEM ?
*INPUT*  METRIC
 ENTER B0,Z,RN,S0,DELX,C,L,H,DDOX
*INPUT*  .15   0   .01   .0017   .04   .1   .56   1   0
 ENTER DISCHARGE IN APPROACH CHANNEL Q0
*INPUT*  .0113
 DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL ?
*INPUT*  NO
 DOWNSTREAM CHANNEL BED SLOPE
*INPUT*  .0002
 TEST  NO. 8
 MAIN CHANNEL SECTION IS RECTANGLE
    B0        Z         RN        RNC       S0        G         DELX
  .1500    0.0000     .0100    1.0000     .0017    9.8100     .0400
     C          L          H          DDOX
   .1000      .5600     1.0000     0.0000
   Q0
  .0113
 CRITICAL AND NORMAL DEPTHS AT UPSTREAM END
   DC
  .08542
   DN
  .13304
SUBCRITICAL  PROFILE
 COEFF OF DISCHARGE IS    .51221
 FROUDE NUMBER AT UPSTREAM END IS    .4690
 QS/Q0= .6277
    D2          Q2          X          DDOX       DENOM       B
   FINAL SOLUTION
   FINAL SOLUTION
  .14700      .00421     0.00000     .00333       .9722     .1500
  .14678      .00482     -.04000     .00772       .9633     .1500
  .14638      .00543     -.08000     .01201       .9531     .1500

  .14582      .00603     -.12000     .01614       .9416     .1500
  .14510      .00662     -.16000     .02009       .9285     .1500
  .14422      .00719     -.20000     .02377       .9142     .1500
  .14320      .00774     -.24000     .02718       .8983     .1500
  .14205      .00827     -.28000     .03036       .8813     .1500
  .14079      .00878     -.32000     .03319       .8622     .1500
  .13942      .00927     -.36000     .03542       .8421     .1500
  .13796      .00973     -.40000     .03736       .8205     .1500
  .13644      .01016     -.44000     .03889       .7976     .1500
  .13486      .01057     -.48000     .04010       .7730     .1500
  .13325      .01095     -.52000     .04057       .7474     .1500
  .13162      .01131     -.56000     .04093       .7206     .1500
 Q0            OVERFLOW          RESIDUAL FLOW        QS/Q0

  .0113        .0071              .0042               .6277
```

```
TEST NUMBER +
*INPUT*  9
DO YOU WIS METRIC OR FPS SYSTEM +
*INPUT*  METRIC
 ENTER B0,Z,RN,S0,DELX,C,L,W,QBDX
*INPUT*  .15  0  .01  .0013  .04  .1  .56  1  0
 ENTER DISCHARGE IN APPROACH CHANNEL QQ
*INPUT*  .0105
 DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL +
*INPUT*  NO
 DOWNSTREAM CHANNEL BED SLOPE
*INPUT*  .0001
 TEST  NO. 9

 MAIN CHANNEL SECTION IS RECTANGLE

   B0       Z         RN       RNC        S0       G         DELX
 .1500   0.0000    .0100    1.0000     .0013   9.8100    .0400
    C          L          W         QBDX
  .1000      .5600     1.0000     0.0000
   QQ
 .0105
 CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

   DC
 .08138
   DN
 .14498
SUBCRITICAL  PROFILE
 COEFF OF DISCHARGE IS   .53710
 FROUDE NUMBER AT UPSTREAM END IS    .4049

 QS/QQ= .7203

    D2         Q2          X          DQDX        DENOM      B
   FINAL SOLUTION
   FINAL SOLUTION
  .14600     .00295    0.00000    -.00460        .9861     .1500
  .14609     .00358    -.04000     .00034        .9795     .1500
  .14600     .00421    -.08000     .00468        .9717     .1500

  .14572     .00483    -.12000     .00924        .9625     .1500
  .14526     .00544    -.16000     .01367        .9518     .1500
  .14463     .00605    -.20000     .01791        .9397     .1500
  .14383     .00664    -.24000     .02192        .9262     .1500
  .14288     .00721    -.28000     .02564        .9112     .1500
  .14179     .00776    -.32000     .02902        .8946     .1500
  .14057     .00829    -.36000     .03204        .8766     .1500
  .13923     .00880    -.40000     .03466        .8570     .1500
  .13780     .00928    -.44000     .03692        .8362     .1500
  .13629     .00973    -.48000     .03866        .8137     .1500
  .13472     .01016    -.52000     .03994        .7898     .1500
  .13310     .01055    -.56000     .04076        .7647     .1500
   QQ          OVERFLOW        RESIDUAL FLOW        QS/QQ

  .0105         .0075              .0030             .7203
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HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH
HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH

 TEST NUMBER +
*INPUT*  10
 DO YOU WISH METRIC OR FPS SYSTEM +

*INPUT*  METRIC
 ENTER BO,Z,RN,SO,DELX,C,L,W,DBDX
*INPUT*  .15  0  .01  .002  .04  .1  .56  1  0
 ENTER DISCHARGE IN APPROACH CHANNEL QO
*INPUT*  .0125

 DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL +
*INPUT*  NO

 DOWNSTREAM CHANNEL BED SLOPE
*INPUT*  .0001

 TEST  NO. 10

 MAIN CHANNEL SECTION IS RECTANGLE

   BO        Z          RN       RNC        SO      G        DELX
  .1500    0.0000     .0100    1.0000     .0020   9.8100    .0400
     C            L           W          DBDX
   .1000        .5600       1.0000      0.0000
   QO
  .0125

 CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

   DC
  .09130
   DN
  .14024

 SUBCRITICAL  PROFILE
 COEFF OF DISCHARGE IS      .49594
 FROUDE NUMBER AT UPSTREAM END IS     .5066

 QS/QO= .7458

      D2           Q2          X            DQDX      DENOM       B

   FINAL SOLUTION
   FINAL SOLUTION
  .15630       .00320     0.00000      -.00836         .9866      .1500
  .15621       .00398     -.04000      -.00207         .9793      .1500
  .15617       .00476     -.08000       .00424         .9704      .1500


  .15587       .00554     -.12000       .01051         .9597      .1500
  .15533       .00630     -.16000       .01664         .9472      .1500
  .15464       .00706     -.20000       .02258         .9327      .1500
  .15353       .00779     -.24000       .02825         .9163      .1500
  .15229       .00851     -.28000       .03358         .8979      .1500
  .15085       .00919     -.32000       .03850         .8773      .1500
  .14922       .00985     -.36000       .04296         .8545      .1500
  .14742       .01047     -.40000       .04691         .8295      .1500
  .14548       .01106     -.44000       .05030         .8021      .1500
  .14341       .01161     -.48000       .05310         .7724      .1500
  .14124       .01212     -.52000       .05536         .7406      .1500
  .13900       .01259     -.56000       .05687         .7061      .1500
  QO             OVERFLOW            RESIDUAL FLOW            QS/QO

  .0125          .0093               .0032                    .7458
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MWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMW
WMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWM

  TEST NUMBER ?
*INPUT*  11
  DO YOU WISH METRIC OR FPS SYSTEM ?
*INPUT*  METRIC
  ENTER QO,Z,RN,SO,DELX,C,L,W,DQDX
*INPUT*  .15   0   .01   .002   .04   .1   .56   1   0
  ENTER DISCHARGE IN APPROACH CHANNEL QO
*INPUT*  .0115
  DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL ?
*INPUT*  NO
  DOWNSTREAM CHANNEL BED SLOPE
*INPUT*  .0003
  TEST  NO. 11

  MAIN CHANNEL SECTION IS RECTANGLE

    B0        Z        RN       RNC        SO        G        DELX
  .1500    0.0000    .0100    1.0000    .0020    9.8100    .040

    C          L          W          DQDX
  .1000      .5600     1.0000      0.0000

   QO
  .0115

  CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

   DC
  .09542

   DN
  .13051
 SUBCRITICAL  PROFILE
  COEFF OF DISCHARGE IS     .49023
  FROUDE NUMBER AT UPSTREAM END IS     .5191

  QS/QO= .5548

   D2          Q2          X          DQDX       DENOM        B

   FINAL SOLUTION
   FINAL SOLUTION
   .14620     .00512    0.00000     .00977       .9582      .1500
   .14573     .00559    -.04000     .01355       .9478      .1500
   .14512     .00625    -.08000     .01717       .9363      .1500


   .14436     .00680    -.12000     .02060       .9234      .1500
   .14348     .00733    -.16000     .02380       .9093      .1500
   .14246     .00785    -.20000     .02674       .8934      .1500
   .14134     .00835    -.24000     .02940       .8761      .1500
   .14018     .00882    -.28000     .03181       .8592      .1500
   .13881     .00924    -.32000     .03382       .8394      .1500
   .13742     .00971    -.36000     .03548       .8192      .1500
   .13597     .01011    -.40000     .03678       .7973      .1500
   .13448     .01050    -.44000     .03773       .7743      .1500
   .13296     .01086    -.48000     .03830       .7502      .1500
   .13143     .01119    -.52000     .03852       .7251      .1500
   .12989     .01150    -.56000     .03839       .6991      .1500
    QO          OVERFLOW          RESIDUAL FLOW          QS/QO

   .0115       .0064              .0051                 .5548
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MHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMHMH
WHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWHWH

TEST NUMBER +
*INPUT*  12
  DO YOU WISH METRIC OR FPS SYSTEM +
*INPUT*  METRIC
  ENTER BO,Z,RN,SO,DELX,C,L,W,DBDX
*INPUT*  .15  0  .01  .003  .04  .1  .56  1  0
  ENTER DISCHARGE IN APPROACH CHANNEL QO
*INPUT*  .0155
  DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL +
*INPUT*  NO
  DOWNSTREAM CHANNEL BED SLOPE
*INPUT*  .0003
  TEST  NO. 12

MAIN CHANNEL SECTION IS RECTANGLE

   BO        Z         RN       RNC        SO       G         DELX
  .1500    0.0000    .0100    1.0000    .0030    9.8100    .0400
     C         L         W       DBDX
   .1000     .5600    1.0000    0.0000

   QO
  .0155
  CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

   DC
  .10523
   DN
  .14165
 SUBCRITICAL  PROFILE
  COEFF OF DISCHARGE IS   .44887
  FROUDE NUMBER AT UPSTREAM END IS    .6188

  QS/QO= .6164

    DZ         Q2          X         CDDX        DENOM         B
    FINAL SOLUTION
    FINAL SOLUTION
   .16643     .00600    0.00000     .01079      .9611      .1500
   .16585     .00693    -.04000     .01829      .9480      .1500
   .16497     .00778    -.08000     .02563      .9327      .1500

   .16340     .00865    -.12000     .03272      .9152      .1500
   .16236     .00949    -.16000     .03949      .8951      .1500
   .16065     .01030    -.20000     .04588      .8725      .1500
   .15870     .01107    -.24000     .05181      .8471      .1500
   .15652     .01181    -.28000     .05723      .8189      .1500
   .15413     .01250    -.32000     .06210      .7875      .1500
   .15156     .01314    -.36000     .06636      .7524      .1500
   .14884     .01374    -.40000     .06997      .7148      .1500
   .14598     .01428    -.44000     .07292      .6731      .1500
   .14301     .01478    -.48000     .07526      .6281      .1500
   .13997     .01523    -.52000     .07678      .5788      .1500
   .13689     .01563    -.56000     .07758      .5255      .1500
  QO          OVERFLOW         RESIDUAL FLOW       QS/QO

  .0155        .0095              .0060           .6164
```

```
   TEST  NUMBER +
 *INPUT*  13
   DO YOU WISH METRIC OR FPS SYSTEM +
 *INPUT*  METRIC
   ENTER BO,Z,RN,SO,DELX,C,L,H,DDDX
 *INPUT*  .15  0  .01  .0016  .04  .1  .56  1  0
   ENTER DISCHARGE IN APPPOACH CHANNEL QO
 *INPUT*  .0115
   DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL +
 *INPUT*  NO
   DOWNSTREAM CHANNEL BED SLOPE
 *INPUT*  .0002
   TEST  NO. 13

   MAIN CHANNEL SECTION IS RECTANGLE

     BO        Z          RN        RNC        SO      G          DELX
    .1500    0.0000     .0100    1.0000     .0016   9.8100     .0400
      C          L          H          DDDX
    .1000      .5600     1.0000      0.0000
    QO
   .0115
   CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

    DC
   .08642
    DN
   .14340
  SUBCRITICAL  PROFILE
   COEFF OF DISCHARGE IS    .51979
   FROUDE NUMBER AT UPSTREAM END IS     .4504

   QS/QO= .6335

        D2          Q2          X            CDDX       DENOM      B
     FINAL SOLUTION
     FINAL SOLUTION
    .14720      .00422      0.00000      .00192         .9732      .1500
    .14703      .00484     -.04000       .00651         .9632      .1500
    .14668      .00547     -.08000       .01101         .9528      .1500


    .14615      .00608     -.12000       .01536         .9410      .1500
    .14546      .00668     -.16000       .01952         .9277      .1500
    .14460      .00727     -.20000       .02343         .9129      .1500
    .14359      .00784     -.24000       .02705         .8966      .1500
    .14244      .00839     -.28000       .03034         .8787      .1500
    .14117      .00891     -.32000       .03326         .8594      .1500
    .13979      .00941     -.36000       .03578         .8384      .1500
    .13831      .00988     -.40000       .03795         .8162      .1500
    .13676      .01033     -.44000       .03960         .7922      .1500
    .13515      .01075     -.48000       .04080         .7668      .1500
    .13351      .01114     -.52000       .04155         .7401      .1500
    .13184      .01150     -.56000       .04185         .7122      .1500
   QO            OVERFLOW           RESIDUAL FLOW          QS/QO

     .0115        .0073              .0042                 .6335
```

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HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH

TEST NUMBER +
*INPUT*  14
 DO YOU WISH METRIC OR FPS SYSTEM +
*INPUT*  METRIC
 ENTER B0,Z,RN,S0,DELX,C,L,W,DPDX*
*INPUT* .15  0  .01  .001  .04  .1  .56  1  0
 ENTER DISCHARGE IN APPROACH CHANNEL Q0
*INPUT* .048
 DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL +
*INPUT*  NO
 DOWNSTREAM CHANNEL BED SLOPE
*INPUT*  .001
 TEST  NO. 14

--MAIN CHANNEL-SECTION-IS-RECTANGLE

   B0        Z         RN        RNC       S0        G         DELX
  .1500    0.0000    .0100    1.0000    .0010    9.8100    .0400
     C          L          W          DPDX
   .1000      .5600     1.0000     0.0000
   Q0
  .0480
 CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

   DC
  .22190
   DN
  .61445
 SUBCRITICAL FLOW IN APPROACH CHANNEL     SUPERCRITICAL FLOW ALONG SIDE WEIR
 COEFF OF DISCHARGE IS     .89228
 FROUDE NUMBER AT UPSTREAM END IS   1.0899

    D2          Q2          X          DDDX       DENOM       B          D6
  FINAL SOLUTION
  .20636      .04800     0.00000    -1.66534    -.3066     .1500
  .19578      .04732      .00800     -.97934    -.4864     .1500      .2418
  .18893      .04673      .01600     -.73364    -.6143     .1500      .2373
  .18361      .04620      .02400     -.59717    -.7184     .1500      .2340
  .17919      .04571      .03200     -.50723    -.8083     .1500      .2312
  .17540      .04525      .04000     -.44095    -.8905     .1500      .2294
  .17207      .04483      .04800     -.39043    -.9653     .1500      .2269

  .16911      .04444      .05600     -.35035   -1.0342     .1500      .2251
  .16644      .04406      .06400     -.31763   -1.0983     .1500      .2244
  .16401      .04371      .07200     -.29032   -1.1583     .1500      .2224
  .16178      .04338      .08000     -.26712   -1.2147     .1500      .2218
  .15268      .04193      .12000     -.18758   -1.4613     .1500      .2167
  .14609      .04077      .16000     -.14178   -1.6585     .1500      .2125
  .14101      .03982      .20000     -.11230   -1.8182     .1500      .2102
  .13694      .03900      .24000     -.09153   -1.9529     .1500      .2077
  .13358      .03839      .28000     -.07636   -2.0654     .1500      .2064
  .13076      .03770      .32000     -.06451   -2.1655     .1500      .2048
  .12837      .03716      .36000     -.05521   -2.2519     .1500      .2044
  .12631      .03668      .40000     -.04776   -2.3269     .1500      .2023
  .12452      .03626      .44000     -.04168   -2.3922     .1500      .2017
  .12295      .03587      .48000     -.03665   -2.4491     .1500      .2010
  .12157      .03553      .52000     -.03243   -2.4988     .1500      .2000
  .12034      .03520      .56000     -.02885   -2.5423     .1500      .1991
 AT THE DOWNSTREAM-END

   DC
  .18082
   DN
  .46222
   Q0          OVERFLOW          RESIDUAL FLOW          QS/Q0

  .0480          .0128               .0352              .2667
```

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MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM

 TEST  NUMBER +
*INPUT*  15
 DO YOU WISH METRIC OR FPS SYSTEM +
*INPUT*  METRIC
 ENTER B0,Z,RN,S0,DELX,C,L,H,DBOX
*INPUT*  .15  0  .01  .009  .04  .0515  .56  1  0
 ENTER DISCHARGE IN APPROACH CHANNEL Q0
*INPUT*  .05
 DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL +
*INPUT*  NO
 DOWNSTREAM CHANNEL BED SLOPE
*INPUT*  .009
 TEST  NO. 15

 MAIN CHANNEL SECTION IS RECTANGLE

    B0        Z         RN        RNC        S0        G         DELX
  .1500    0.0000     .0100     1.0000     .0090    9.8100     .0400

     C          L          H         DBOX
   .0515      .5600     1.0000     0.0000

    Q0
  .0500
 CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

    DC
  .22796
    DN
  .23256
 SUBCRITICAL FLOW IN APPROACH CHANNEL    SUPERCRITICAL FLOW ALONG SIDE WEIR
 COEFF OF DISCHARGE IS     .89200
 FROUDE NUMBER AT UPSTREAM END IS   1.0903

     D2          Q2          X          DQDX       DENOM        B          D6
    FINAL SOLUTION
   .21200      .05000     0.00000    -3.08423     -.3076      .1500
   .19379      .04876      .00800    -1.46815     -.6285      .1500      .2290
   .18360      .04769      .01600    -1.07925     -.8324      .1500      .2212
   .17579      .04672      .02400     -.87299    -1.0028      .1500      .2150
   .16934      .04583      .03200     -.73861    -1.1557      .1500      .2101
   .16382      .04501      .04000     -.64324    -1.2949      .1500      .2062
   .15896      .04424      .04800     -.56975    -1.4270      .1500      .2030


   .15464      .04352      .05600     -.51173    -1.5516      .1500      .1994
   .15073      .04284      .06400     -.46449    -1.6701      .1500      .1967
   .14718      .04220      .07200     -.42513    -1.7834      .1500      .1940
   .14391      .04159      .08000     -.39174    -1.8923      .1500      .1919
   .13053      .03894      .12000     -.27727    -2.3963      .1500      .1825
   .12076      .03681      .16000     -.21105    -2.8389      .1500      .1756
   .11317      .03505      .20000     -.16842    -3.2249      .1500      .1704
   .10704      .03355      .24000     -.13823    -3.5753      .1500      .1662
   .10196      .03226      .28000     -.11582    -3.8951      .1500      .1625
   .09767      .03114      .32000     -.09879    -4.1819      .1500      .1601
   .09399      .03016      .36000     -.0850     -4.4541      .1500      .1580
   .09081      .02929      .40000     -.0740     -4.7043      .1500      .1556
   .08802      .02851      .44000     -.0650     -4.9348      .1500      .1543
   .08557      .02781      .48000     -.05753    -5.1472      .1500      .1520
   .08340      .02718      .52000     -.05123    -5.3431      .1500      .1506
   .08146      .02660      .56000     -.04587    -5.5239      .1500      .1495
 AT THE DOWNSTREAM END

    DC
  .15031
    DN
  .14061
  QC          OVERFLOW          RESIDUAL FLOW       QS/QO

   .0500       .0234              .0266              .4679
```

```
 TEST NUMBER +
*INPUT*  16
 DO YOU WISH METRIC OR FPS SYSTEM +
*INPUT*  METRIC
 ENTER BO,Z,RN,SO,DELX,C,L,W,DDDX
*INPUT*  .15   0.   .01   .002   .04   .1   .56   1   0
 ENTER DISCHARGE IN APPROACH CHANNEL QO
*INPUT*  .029
 DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL +
*INPUT*  NO
 DOWNSTREAM CHANNEL BED SLOPE
*INPUT*  .002
 TEST  NO. 16

 MAIN CHANNEL SECTION IS RECTANGLE

   BO        Z          RN        RNC        SO        G          DELX
  .1500    0.0000     .0100     1.0000     .0020    9.8100      .0400
     C           L           W          DDDX
   .1000       .5600      1.0000      0.0000

   QO
  .0290
 CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

   DC
  .15912
   DN
  .28404
 SUBCRITICAL FLOW IN APPROACH CHANNEL      SUPERCRITICAL FLOW ALONG SIDE WEIR .
 COEFF OF DISCHARGE IS   .89585
 FROUDE NUMBER AT UPSTREAM END IS   1.0844

      D2          Q2          X          DDDX       DENOM        B          D6
   FINAL SOLUTION
    .14798      .02900     0.00000     -.61390      -.2935      .1500
    .14383      .02879      .00800     -.42210      -.3890      .1500       .1878
    .14082      .02861      .01600     -.33192      -.4590      .1500       .1868
    .13840      .02844      .02400     -.27360      -.5199      .1500       .1848
    .13637      .02829      .03200     -.23353      -.5720      .1500       .1844
    .13462      .02815      .04000     -.20389      -.6180      .1500       .1846
    .13308      .02801      .04800     -.18089      -.6592      .1500       .1831

    .13170      .02789      .05600     -.16241      -.6967      .1500       .1821
    .13047      .02777      .06400     -.14720      -.7310      .1500       .1825
    .12934      .02766      .07200     -.13443      -.7627      .1500       .1813
    .12831      .02756      .08000     -.12299      -.7940      .1500       .1807
    .12413      .02711      .12000     -.08579      -.9164      .1500       .1789
    .12113      .02675      .16000     -.06439     -1.0071      .1500       .1775
    .11883      .02645      .20000     -.05067     -1.0759      .1500       .1768
    .11700      .02620      .24000     -.04069     -1.1338      .1500       .1758
    .11552      .02598      .28000     -.03341     -1.1805      .1500       .1755
    .11429      .02578      .32000     -.02789     -1.2184      .1500       .1743
    .11327      .02561      .36000     -.02359     -1.2494      .1500       .1737
    .11239      .02546      .40000     -.02016     -1.2749      .1500       .1744
    .11164      .02532      .44000     -.01738     -1.2958      .1500       .1736
    .11099      .02519      .48000     -.01490     -1.3162      .1500       .1730
    .11043      .02508      .52000     -.01308     -1.3289      .1500       .1724
    .10994      .02497      .56000     -.01151     -1.3396      .1500       .1719
  AT THE DOWNSTREAM END

   DC
  .14414
   DN
  .24957
  QO         OVERFLOW           RESIDUAL FLOW          QS/QO

    .0290      .0040               .0250                 .1391
```

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WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW

TEST NUMBER +
*INPUT*  17
 DO YOU WISH METRIC OR FPS SYSTEM +
*INPUT*  METRIC
 ENTER B0,Z,RN,S0,DELX,C,L,W,DBDX
*INPUT*  .15  0  .01  .001  .04  .0515  .56  1  0
 ENTER DISCHARGE IN APPROACH CHANNEL Q0
*INPUT*  .0205
 DO YOU HAVE RATING CURVE FOR DOWNSTREAM CHANNEL +
*INPUT*  NO
 DOWNSTREAM CHANNEL BED SLOPE
*INPUT*  .001
 TEST  NO. 17

 MAIN CHANNEL SECTION IS RECTANGLE

    B0        Z         RN        RNC        S0        G        DELX
   .1500   0.0000     .0100    1.0000     .0010    9.8100    .0400
     C            L         W         DBDX
   .0515        .5600    1.0000     0.0000

   Q0
  .0205
 CRITICAL AND NORMAL DEPTHS AT UPSTREAM END

   DC
  .12656

   DN
  .28396
 SUBCRITICAL FLOW IN APPROACH CHANNEL     SUPERCRITICAL FLOW ALONG SIDE WEIR
 COEFF OF DISCHARGE IS  .89829
 FROUDE NUMBER AT UPSTREAM END IS   1.0806

     D2           Q2          X          DDDX       DENOM        B          D6
   FINAL SOLUTION
   .11770      .02050    0.00000    -1.17295      -.2845      .1500
   .11051      .02017     .00800     -.62356      -.5006      .1500      .1429
   .10618      .01988     .01600     -.45871      -.6458      .1500      .1402
   .10286      .01962     .02400     -.37209      -.7605      .1500      .1389
   .10012      .01938     .03200     -.31347      -.8643      .1500      .1369
   .09778      .01916     .04000     -.27177      -.9569      .1500      .1358
   .09573      .01896     .04800     -.24018     -1.0413      .1500      .1345

   .09391      .01877     .05600     -.21523     -1.1192      .1900      .1339
   .09227      .01859     .06400     -.19492     -1.1917      .1500      .1327
   .09077      .01842     .07200     -.17801     -1.2597      .1500      .1316
   .08941      .01826     .08000     -.16367     -1.3239      .1500      .1314
   .08385      .01756     .12000     -.11421     -1.6099      .1500      .1279
   .07983      .01700     .16000     -.08662     -1.8309      .1500      .1258
   .07673      .01653     .20000     -.06851     -2.0151      .1500      .1239
   .07424      .01614     .24000     -.05598     -2.1662      .1500      .1226
   .07219      .01579     .28000     -.04645     -2.3012      .1500      .1214
   .07048      .01550     .32000     -.03919     -2.4167      .1500      .1205
   .06903      .01524     .36000     -.03350     -2.5158      .1500      .1194
   .06778      .01500     .40000     -.02894     -2.6013      .1500      .1190
   .06669      .01479     .44000     -.02523     -2.6751      .1500      .1183
   .06575      .01460     .48000     -.02215     -2.7388      .1500      .1177
   .06491      .01443     .52000     -.01957     -2.7937      .1500      .1169
   .06418      .01427     .56000     -.01723     -2.8496      .1500      .1166
 AT THE DOWNSTREAM END

   DC
  .09966

   DN
  .20826
  Q0          OVERFLOW          RESIDUAL FLOW          QS/Q0

    .0205      .0062              .0143               .3037
```