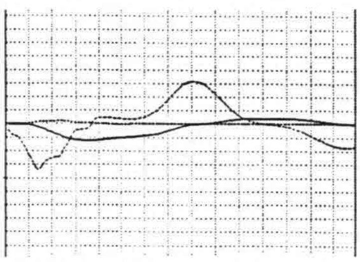
Ir. C. Verspuy

ECDUFLOW

Evaluation Check DUFLOW

Research concerning PC-program ECDUFLOW



IHE
DELFT

International Institute for
Hydraulic and Environmental
Engineering

Delft, The Netherlands

Ir. C. Verspuy

Delft, July 1991

ECDUFLOW

Evaluation Check DUFLOW

Research concerning PC-program ECDUFLOW

International Institute for
Hydraulic and Environmental
Engineering

Public Works and
Waterways Department -
Tidal Waters Division

Delft University of
Technology - Faculty of
Civil Engineering

E C D U F L O W

Evaluation Check DUFLOW

CONTENTS

1. INTRODUCTION

Using the micro-computer package DUFLOW for the simulation of one-dimensional unsteady flow in channel systems (Ref. [1]) it is very important to check the results of the very first calculation for a new canal system. The first MODEL of a new network system will contain one or more mistakes concerning the cross-sections, the storage area or the boundary conditions.
The very first DUFLOW results of a new model have to be analyzed in detail, to be sure that mistakes are detected immediately.
As is described in the DUFLOW usersguide (Ref. [1]) much attention has been paid already to get good output facilities.
In 1991 a PC-program ECDUFLOW became available for systematic evaluation calculations which are based on DUFLOW output files.
In Chapter 2 the relation between DUFLOW and ECDUFLOW is discussed. After a brief decription of the additional facilities ECDUFLOW is used in Chapter 3 to analyze the results of a specific calculation (Ref. [2]) to illustrate the facilities and to make it clear that they are very comfortable. The new skills are important for a good insight concerning the physical performance of unsteady flow problems (not only tidal waves, but also flood waves and e.g. "bandjirs" in rivers (Ref. [3]), unsteady flow in polders (Ref. [4]) etc.).
To illustrate the operational use of ECDUFLOW the DUFLOW results concerning the propagation of a tidal wave in a system are considered in Chapter 3.
A second illustration is given in Chapter 4 by means of the DUFLOW results concerning the propagation of a translatory wave in a canal.

The PC-package DUFLOW is ment to analyze unsteady flow problems in practice and to get a good physical insight.
ECDUFLOW is an important additional tool because it supports the evaluation of DUFLOW results in behalf of problem analysis.
ECDUFLOW forms an improvement of the output facilities for the benefit of reporting DUFLOW results (Ref. [2], [3], [4]).
The new tool ECDUFLOW will be at users disposal (Ref. [6]) for analysis and research.

2. PC - PROGRAM ECDUFLOW

In 1991 the wishes for automatic evaluation calculations has been satisfied. An additional PC-program became available which is based on the DUFLOW organisation of files etc.
The purpose of the program is to analyze the results of a DUFLOW simulation immediately after the execution of the calculations.

Evaluation check by PC-calculations

An arbitrary section as an element of a network system is considered (see Figure 2.1.). The section length (about 0.01 times the wave length) can be less than 100 m or e.g. 10 km.
The differential equations describing one-dimensional unsteady flow in open channel systems (simulated by DUFLOW, see Ref. [1]), neglecting the wind term and with $\alpha = 1$, are written in the form :

$$B \frac{\delta h}{\delta t} + \frac{\delta Q}{\delta x} = 0 \tag{1}$$

$$\frac{1}{g\,A} \left[\frac{\delta Q}{\delta t} + \frac{\delta}{\delta x}\left(\frac{Q^2}{A}\right) \right] + \frac{\delta h}{\delta x} + \frac{Q\,|Q|}{C^2\,A^2\,R} = 0 \tag{2}$$

Integration of (1) and (2) in x-direction over the section length (see Figure 1) gives the following expressions :

$$\int_1^2 -B \frac{\delta h}{\delta t}\,dx + \int_1^2 \frac{\delta Q}{\delta x}\,dx = 0 \tag{3}$$

$$\int_1^2 \frac{1}{g\,A} \left[\frac{\delta Q}{\delta t} + \frac{\delta}{\delta x}\left(\frac{Q^2}{A}\right) \right] dx + \int_1^2 \frac{\delta h}{\delta x}\,dx + \int_1^2 \frac{Q\,|Q|}{C^2\,A^2\,R}\,dx = 0 \tag{4}$$

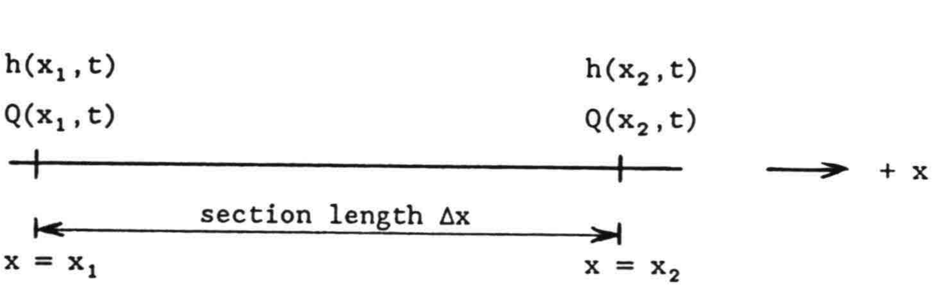


Figure 2.1. A section of a network with section length Δx.

The parameters in (3) and (4) are functions of x and t. On each time level t the average values in the section (see Figure 2.1.) is substituted and written as h_{av} , Q_{av} , etc.
The results of the integration using average values over the section length Δx are written in the form :

$$Q(x_2) - Q(x_1) = - B_{av} \Delta x \frac{dh_{av}}{dt} = \Delta F \frac{dh_{av}}{dt} \tag{5}$$

$$h(x_2) - h(x_1) = - \frac{1}{g A_{av}} [\frac{dQ_{av}}{dt} \Delta x + Q_2^2/A_2 - Q_1^2/A_1] - \frac{\Delta x}{(C^2 A^2 R)_{av}} Q_{av}|Q_{av}| \tag{6}$$

When the functions $h(x_1,t)$, $h(x_2,t)$, $Q(x_1,t)$ and $Q(x_2,t)$ and the dimensions of the section are well known, ΔF, A_{av}, .. etc. can be determined for h_{av} at the time level which is choosen to calculate the terms at the right hand side of the equations (5) and (6).
Equation (5) gives the possibility to check the difference between the discharge at point 2 and the discharge at point 1 at any time level t. For any element that difference equals the internal storage (mass-balance without additional inflow or outflow).
Equation (6) gives the balance between the water level difference over the section length Δx and the sum of (three contributions of):

- the local acceleration term;
- the advective or convective acceleration term;
- the friction term.

The two equations (5) and (6) together give the possibility to check the results of calculations and also the results of measurements.
These evaluation calculations have to be performed by hand to get insight and overview. The integration in x-direction makes that the dimension [1] ("slope") of the terms in equation (2) is changed in equation (6) into the dimension [L] (of a difference in head over the section length Δx).

To simplify the operational execution of evaluation calculations based on the balance equations (5) and (6) the DUFLOW user can apply ECDUFLOW.

An arbitrary time level t is considered and denoted by a superscript "n". At that time level the following functions has been defined :

$$H1^n = h(x_1, t^n)$$
$$H2^n = h(x_2, t^n)$$
$$Q1^n = Q(x_1, t^n)$$
$$Q2^n = Q(x_2, t^n)$$

In ECDUFLOW the parameters **SW**, **A**, **R** and **C** has been defined :

$\Delta F = B * \Delta x =$ **SW** $* L$ ⟶ the average storage width from cross-section profile times L (= Δx)

A_{av} = **A** ⟶ the average cross-section area

R_{av} = **R** ⟶ the average value for R = A/O in which A is the area and O is the wetted perimeter from the cross-section profile

C_{av} = **C** ⟶ the average value of C is interpolated linearly (via K if Manning formula is used (see MENU NETWORK).

The average values for A, R, SW and C are determined as the average between the values at begin and end of the section (which is not always equal to the value in the middle of the section).
The average values of these parameters and the values of the functions $H1^n$, $H2^n$, $Q1^n$ and $Q2^n$ are presented in tables on the screen (and printed , see applications).

The average velocities at nodes 1 and 2 are defined as **v1** and **v2** and calculated as the discharge devided by the cross-sectional area. To determine the time derivatives at the time level t two functions are defined for the section :

Hav = the average of H1 and H2 over a section
Qav = the average of Q1 and Q2 over a section

The time derivatives are determined as follows :

$$\frac{dh_{av}}{dt} = \frac{H_{av}^{n+1} - H_{av}^{n-1}}{2\,\Delta t}$$

$$\frac{dQ_{av}}{dt} = \frac{Q_{av}^{n+1} - Q_{av}^{n-1}}{2\,\Delta t}$$

The time interval Δt in these expressions is equal to the output interval which is rounded to the nearest multiple of the timestep of the calculation (see Calculation Definition) !

With these definitions the equations (5) an (6), concerning a time level t and a section from node 1 to node 2, are transformed into:

$$Q2^n - Q1^n = SW^n * L * \frac{H_{av}^{n+1} - H_{av}^{n-1}}{2\ \Delta t} \qquad (7)$$

$$H2^n - H1^n = \frac{-L}{gA} * \frac{Q_{av}^{n+1} - Q_{av}^{n-1}}{2\ \Delta t} - \frac{Q2^n\ v2^n - Q1^n\ v1^n}{gA} - \frac{Q_{av}\ |Q_{av}|}{C^2\ A^2\ R} \qquad (8)$$

The values of the mean parameters, the functions and the values of the terms of the equations (7) and (8) are presented on the screen for each of the time levels which are defined during the execution of ECDUFLOW.

Use of the program.

Before starting ECDUFLOW the user have to be sure that the files, defined in the "Filenames" option of the DUFLOW MASTER MENU are consistent with each other. ECDUFLOW reads data from the most recently defined files (see MASTER MENU). Besides the result file it also needs the network file for the cross-section definition and the boundary file to see whether the Chezy or Manning formula has been used. ECDUFLOW does NOT check whether these files really belong together or whether the input files have been changed after the calculation (that belongs to the result file) is made. One has to prevent an analysis with wrong combinations !!
The user has to remember that the time interval of the result file can be larger than the timestep of the DUFLOW calculations (see Calculation Definition).
For the time derivatives ECDUFLOW uses one value forward and one value backward. The time distance depends on the output interval which is used during the calculation. This output interval can be any multiple of the calculation timestep. To discover numerical instabilities it is advised to take the output interval equal to the calculation interval.

After starting the program (by typing ECDUFLOW) the menu ANALYSIS appears (see Figure 2.2.).

```
program DUFLOW                              Analysis
-----------------------------------------------------------------------------
data directory: C:\DUFLOW\                  Network file : TRANSLV.BND  ←
                                            Boundary file: TRANSLV.NET  ←
                                            Result file  : TRANSLV.RES  ←
selected section : None  ←

                          MENU ANALYSIS

                        → S  Select section
                          D  Details of calculation
                          T  Table
                          G  Graph

                          I  Info
                          Q  Quit
```

Figure 2.2. Menu ANALYSIS of ECDUFLOW

The options D, T and G are disabled until a section is selected. ←

Option "S" : **"Select section"**

From the sections of which results have been written to the result file one section must be chosen as subject of analysis.

Option "D" : **"DETAILS of Calculation"**

For a series of output steps all data concerning the equations (7) and (8) are given. The user can select one or more time levels (see applications) or can ask for presenting all the time levels which were defined in the output file.

Option "T" : **"TABLE"**

The terms of the momentum equation (8) are presented in a table (see applications).

Option "G" : "GRAPH"

The behaviour of the terms of the momentum equation (see equation (8)) is presented in a graph. On the screen the five lines (the three terms, the sum of those and the calculated difference in head, which should be equal to the sum of the three terms) can be switched on and off. This makes it possible to select one, two, three or four lines in one graph. In case one term is relatively small compared to the others it is possible to select a larger scale to study the behaviour of the term. The graph layout can be modified which is very important to create clear graphs before they are printed. When the user has managed a graph displayed on the screen it can be printed directly ("print screen"). A graph can also be sent to a plotter(file) in the same way as in DUFLOW.

ECDUFLOW needs data at one time level **before** and one time level **after** the time level which is considered (with superscript "n"). Therefore the check can not be made at the first or at the last time level of the output file.

The execution of evaluation calculations with the program ECDUFLOW is illustrated by means of two different applications which are described briefly in Chapter 3 and Chapter 4.

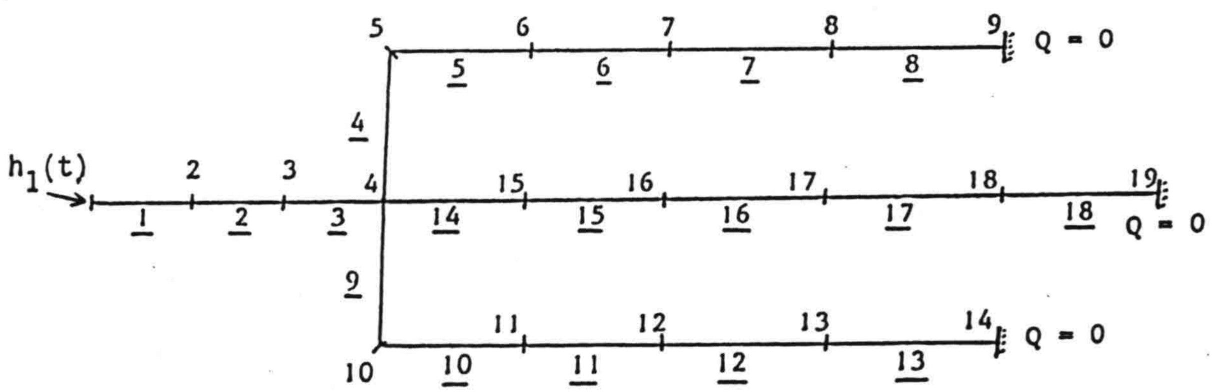
3. ECDUFLOW APPLICATION I

3.1. Introduction

The PC–program ECDUFLOW is based on the existence of a specific result file of DUFLOW which has to be defined via the MASTER MENU (immediately after a DUFLOW calculation or via "Change Filenames"). To analyse a DUFLOW result file three facilities can be used : "Analysis – DETAILS of calculation", "Analysis – TABLE" and "Analysis – GRAPH".

In this chapter these three facilities are illustrated by means of the results for IRRSYS (Ref. [2]). The main parameters of the network system IRRSYS are :

	length in km	flow width in m	storage width in m	mean depth in m	C $m^{1/2}/s$
sections 1, 2 and 3 :	1	10	10	3	40
,, 4 and 9 :	2	10	10	3	40
,, 5 ... 18 :	1	10	80	3	40



→ + x

positive discharge Q

flood flow

Figure 3.1. Network system IRRSYS

The network system IRRSYS consisting of 18 branches and all the DUFLOW results are decribed in Ref. [2]. Only the main information

of the problem IRRSYS is given here and some additional information is presented in Appendix I. The emphazis of this chapter concerns the ECDUFLOW-information and the operational adventages of this program.
The main information of the problem IRRSYS is presented briefly.
The **boundary conditions** are :

- node 1 : $h_1(t) = \hat{h}_1 \cos(\omega t - \kappa)$
  in which $\hat{h}_1 = 1.00$ m , $\kappa = 0$ and
  $\omega = 2\pi/(24*3600) = 0.73 * 10^{-4}$ rad./s.

- node 9, node 14 and node 19 : $Q_9(t) = Q_{14}(t) = Q_{19}(t) = 0.$

The time levels are given in minutes and are measured from the start of the calculations (t = 0).
In Figure 3.2. and Figure 3.3. on page 10 the water levels and the discharges in (one branch of) the system IRRSYS are drawn.
Figure 3.2. gives the water levels at nodes 1 ... 9 (see Fig. 3.1.)
Figure 3.3. gives the flow rate through each of the cross-sections at the nodes 1 ... 8 of network IRRSYS as a function of time .
These periodical functions h(t) and Q(t) are typical characteristic for the tidal propagation in this system :

- a large dampening and large phase shift of the functions h(t) over the primary canals (section 1, 2 and 3) ;
- almost no phase shift of the functions Q(t), caused by very small friction and inertia influences in the other sections 4 ... 18 , while the storage area if these sections is relatively large;
- the discharge in sections 1, 2 and 3 is almost constant in x-direction;

When the tidal range at node 1 (boundary) is compared with the internal tidal range at nodes 4 or 9, we find that the "amplification factor" is about : 0.42. This value can be interpretated by means of an analytic solution (see Appendix I). Because this factor is very small (related to the ratio of the canal length and the wave length $L/\lambda \approx 1/50$) the analysis of parameter variations is very interesting. Before an additional calculation concerning one parameter variation or another is executed a good prediction of the DUFLOW solution can be made (see Ref. [2]).

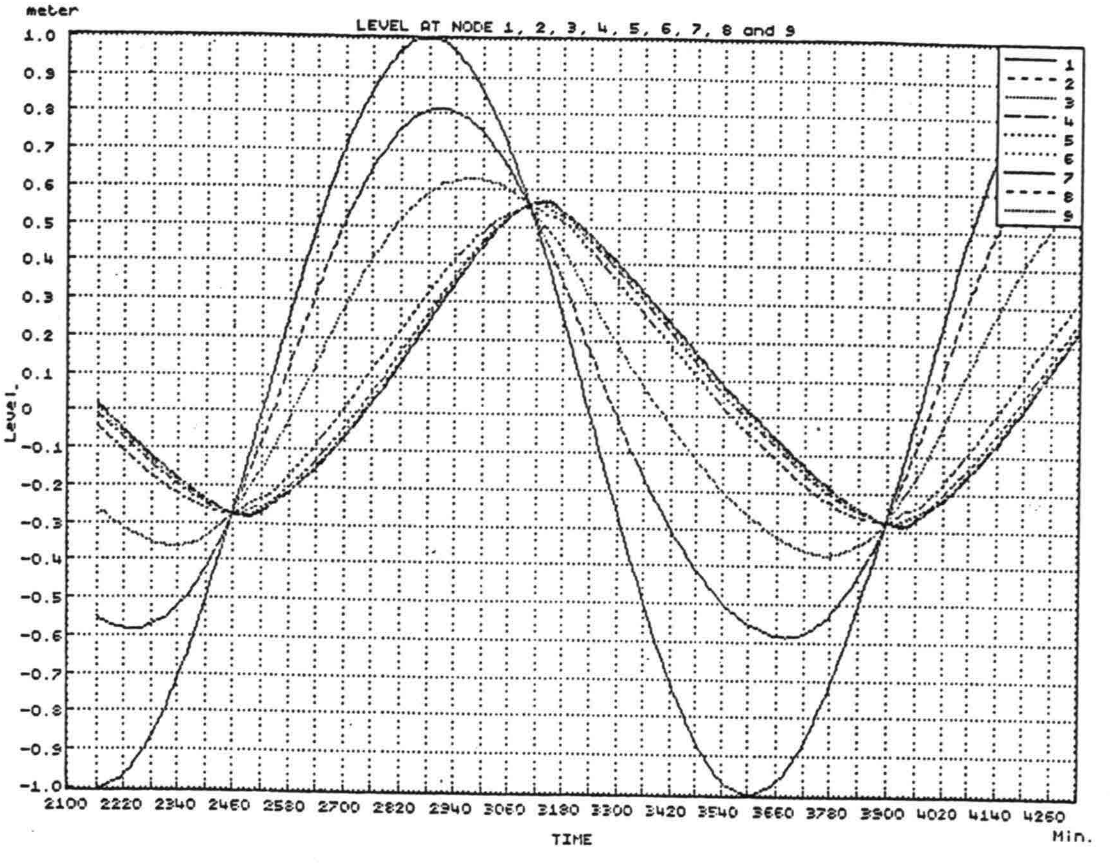


Figure 3.2. Water levels at nodes 1, 2, 3, 4, 5, 6, 7, 8, 9.

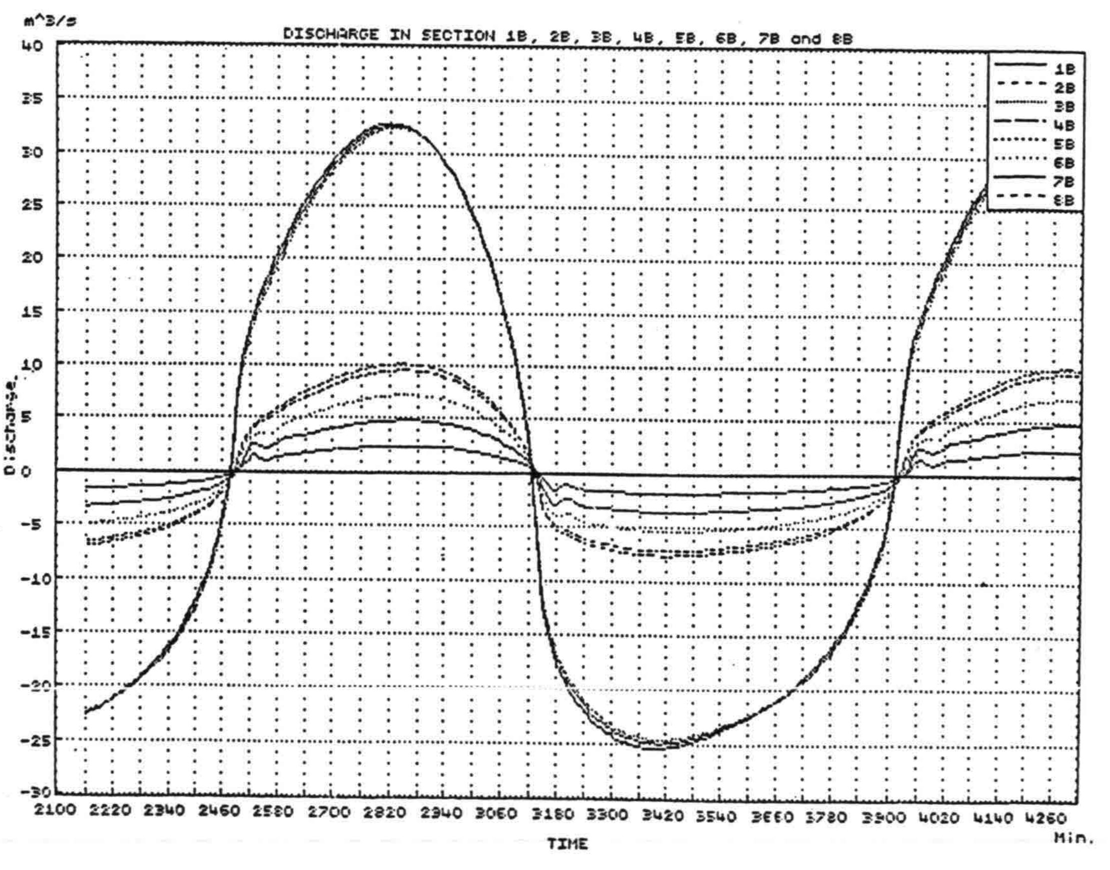


Figure 3.3. Discharge in section 1, 2, 3, 4, 5, 6, 7, 8.

The discharge in the primary canal can easily be estimated by multiplying the estimated value of $\frac{\delta h}{\delta t}$ at node 4 and the internal storage area $F = 1.08 * 10^6\ m^2$. Using ECDUFLOW the results of equation (7) are given for the selected section.
The evaluation calculations with ECDUFLOW emphasize the results of equation (8) in relation with the graphical presentation of water levels and the flow rate of a selected section.

3.2. Analysis – DETAILS of Calculation

To understand the impulse and momentum balance concerning a section of a network system, the package DUFLOW offers the facility to draw two waterlevels (at the boundaries) in combination with the (mean) discharge of a section. For section 1 of the primary canal this information is drawn in Figure 3.4.

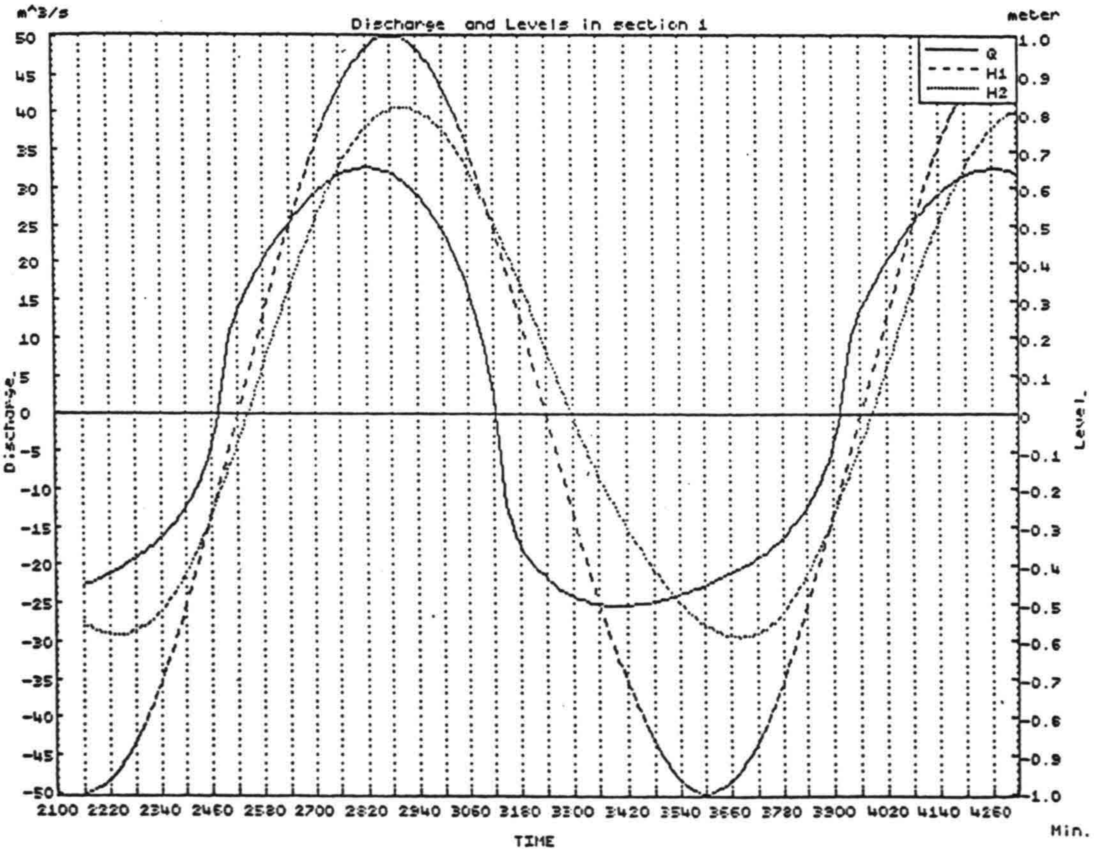


Figure 3.4. Water levels and discharge in section 1.

For time levels t = 2490 minutes and t = 2830 minutes the calculations details are given in the Table 1 on the next page.

```
program DUFLOW                                   analysis - Details
-------------------------------------------------------------------------------
CALCULATION TIME LEVEL  2490 minutes              SECTION     1

L    length             =      1000.00 m          Friction term:
H1   level begin        =    -0.173650 m                -Q*|Q|*L
H2   level end          =    -0.202250 m                ---------      = -0.001996 m
Hav. prev timestep      =    -0.225685 m                C^2*A^2*R
Hav. next timestep      =    -0.151360 m
Q1   discharge begin    =      2.45150 m3/s
Q2   discharge end      =      1.81240 m3/s       Acceleration term:
Q    average disch.     =      2.13195 m3/s             -L    dQ
Qav. prev timestep      =     -1.58570 m3/s             --- * ---      = -0.026285 m
Qav. next timestep      =      7.11560 m3/s             gA    dt
A1   area begin         =     28.26350 m^2
A2   area end           =     27.97750 m^2
A    average area       =     28.12050 m^2        Advective term:
R    hydr. radius       =     1.799805 m                Q1^2/A1-Q2^2/A2
SW   Storage width      =     10.00000 m                ---------------  =  0.000345 m
C    de Chezy coeff.    =       40.000 m^(1/2)/s              gA
dt   time interval      =          600 sec

SW*L*dH/dt              =       0.6194 m3/s       SUM of the 3 terms   = -0.027936 m
Q1 - Q2                 =       0.6391 m3/s       H2 - H1              = -0.028600 m
```

```
program DUFLOW                                   analysis - Details
-------------------------------------------------------------------------------
CALCULATION TIME LEVEL  2830 minutes              SECTION     1

L    length             =      1000.00 m          Friction term:
H1   level begin        =     0.965930 m                -Q*|Q|*L
H2   level end          =     0.756930 m                ---------      = -0.205802 m
Hav. prev timestep      =     0.848605 m                C^2*A^2*R
Hav. next timestep      =     0.872620 m
Q1   discharge begin    =     32.80500 m3/s
Q2   discharge end      =     32.60300 m3/s       Acceleration term:
Q    average disch.     =     32.70400 m3/s             -L    dQ
Qav. prev timestep      =     32.65250 m3/s             --- * ---      = -0.000118 m
Qav. next timestep      =     32.70600 m3/s             gA    dt
A1   area begin         =     39.65930 m^2
A2   area end           =     37.56930 m^2
A    average area       =     38.61430 m^2        Advective term:
R    hydr. radius       =     2.178393 m                Q1^2/A1-Q2^2/A2
SW   Storage width      =     10.00000 m                ---------------  = -0.003057 m
C    de Chezy coeff.    =       40.000 m^(1/2)/s              gA
dt   time interval      =          600 sec

SW*L*dH/dt              =       0.2001 m3/s       SUM of the 3 terms   = -0.208976 m
Q1 - Q2                 =       0.2020 m3/s       H2 - H1              = -0.209000 m
```

Table 1 ECDUFLOW Calculations - Details section 1

At the time level t = 2490 minutes (see Figure 3.4.) the average discharge is almost zero so friction is small and inertia is relatively large.
At the time level t = 2830 minutes the contribution of the friction term is maximum (about – 0.206 m) and contribution of the acceleration term is almost zero. The advective term is negative and gives about – 0.003 m.
For the time levels t = 3140 minutes and t = 3550 minutes the calculations details are presented in Table 2 on page 14.
At the time level t = 3140 minutes (see Figure 3.4.) the average discharge is almost zero so the contribution of the friction term (and that of the advective term) is almost zero while the contribution of the acceleration term is relatively large: about 0.026 m which is almost equal to the sum of the three terms.
At the time level t = 3550 minutes (see Figure 3.4.) the flow rate in the selected section 1 is maximum, so the contribution of the friction term is maximum : about 0.445 m.
The advective term gives about 0.025 m and the contribution of the acceleration term is almost zero : about – 0.001 m.
In Table 4 in Appendix I the calculation details of two other time levels are given for this selected section 1

- Calculation details t = 3600 minutes and t = 3930 minutes.

Selecting the section 2 and the section 3 the similar information is considered for these sections of the primary canal.
In Appendix I the following additional information is given :

- Figure I.1. : Water levels and mean discharge section 2.
- Table 5. : Calculation details t = 2830 and t = 3550 minutes.
- Figure I.2. : Water levels and mean discharge section 3.
- Table 6. : Calculation details t = 2830 and t = 3550 mimutes.

3.3. Analysis – TABLE

The results of ECDUFLOW concerning section 1 for 16 time levels t = 2410, 2420, 2430, ...2490,..... 2560 minutes in Table 3 on page 15 give the history of the three terms. For 32 other time levels the information is given in Table 7. and 8. in Appendix I.

```
program DUFLOW                                        analysis - Details
--------------------------------------------------------------------------------------
CALCULATION TIME LEVEL  3140 minutes                  SECTION    1

L    length              =    1000.00 m               Friction term:
H1   level begin         =   0.461750 m                    -Q*|Q|*L
H2   level end           =   0.489420 m                    ---------     =  0.000823 m
Hav. prev timestep       =   0.508500 m                    C²*A²*R
Hav. next timestep       =   0.442210 m
Q1   discharge begin     =   -2.08630 m3/s
Q2   discharge end       =   -1.52580 m3/s
Q    average disch.      =   -1.80605 m3/s            Acceleration term:
Qav. prev timestep       =    2.65155 m3/s                 -L     dQ
Qav. next timestep       =   -7.88125 m3/s                 -- *  ---     =  0.025743 m
A1   area begin          =   34.61750 m²                   gA     dt
A2   area end            =   34.89420 m²
A    average area        =   34.75585 m²              Advective term:
R    hydr. radius        =   2.050343 m                    Q1²/A1-Q2²/A2
SW   Storage width       =   10.00000 m                    -------------  =  0.000173 m
C    de Chezy coeff.     =     40.000 m½/s                      gA
dt   time interval       =        600 sec

SW*L*dH/dt               =    -0.5524 m3/s            SUM of the 3 terms  =  0.026740 m
Q1 - Q2                  =    -0.5605 m3/s            H2 - H1             =  0.027670 m
```

```
program DUFLOW                                        analysis - Details
--------------------------------------------------------------------------------------
CALCULATION TIME LEVEL  3550 minutes                  SECTION    1

L    length              =    1000.00 m               Friction term:
H1   level begin         =  -0.965930 m                    -Q*|Q|*L
H2   level end           =  -0.497980 m                    ---------     =  0.444723 m
Hav. prev timestep       =  -0.719710 m                    C²*A²*R
Hav. next timestep       =  -0.742925 m
Q1   discharge begin     =  -23.96800 m3/s
Q2   discharge end       =  -23.77300 m3/s            Acceleration term:
Q    average disch.      =  -23.87050 m3/s                 -L     dQ
Qav. prev timestep       =  -24.04000 m3/s                 -- *  ---     = -0.001303 m
Qav. next timestep       =  -23.69200 m3/s                 gA     dt
A1   area begin          =   20.34070 m²
A2   area end            =   25.02020 m²
A    average area        =   22.68045 m²              Advective term:
R    hydr. radius        =   1.556717 m                    Q1²/A1-Q2²/A2
SW   Storage width       =   10.00000 m                    -------------  =  0.025413 m
C    de Chezy coeff.     =     40.000 m½/s                      gA
dt   time interval       =        600 sec

SW*L*dH/dt               =    -0.1935 m3/s            SUM of the 3 terms  =  0.468833 m
Q1 - Q2                  =    -0.1950 m3/s            H2 - H1             =  0.467950 m
```

Table 2 ECDUFLOW Calculations Details section 1

program DUFLOW Analysis - Table

Analysis section 1 Page 4

Time min.	H1 (m) H2 (m)	Q1 (m) Q2 (m)	A1 (m²) A2 (m²)	R (m)	C (m½/s)	FRICTION (m)	ACCELERA-TION (m)	CONVEC-TION (m)
2410	-0.462	-11.13	25.38	1.70	40.0	0.0722	-0.0067	-0.0013
	-0.397	-11.64	26.03					
2420	-0.423	-10.06	25.77	1.71	40.0	0.0575	-0.0074	-0.0013
	-0.374	-10.59	26.26					
2430	-0.383	-8.85	26.17	1.73	40.0	0.0434	-0.0083	-0.0013
	-0.349	-9.40	26.51					
2440	-0.342	-7.46	26.58	1.74	40.0	0.0303	-0.0095	-0.0012
	-0.322	-8.03	26.78					
2450	-0.301	-5.83	26.99	1.75	40.0	0.0183	-0.0113	-0.0010
	-0.295	-6.42	27.05					
2460	-0.259	-3.85	27.41	1.77	40.0	0.0081	-0.0141	-0.0007
	-0.266	-4.45	27.34					
2470	-0.216	-1.28	27.84	1.78	40.0	0.0011	-0.0192	-0.0003
	-0.235	-1.89	27.65					
2480	-0.174	2.45	28.26	1.80	40.0	-0.0020	-0.0263	0.0003
	-0.202	1.81	27.98					

program DUFLOW Analysis - Table

Analysis section 1 Page 5

Time min.	H1 (m) H2 (m)	Q1 (m) Q2 (m)	A1 (m²) A2 (m²)	R (m)	C (m½/s)	FRICTION (m)	ACCELERA-TION (m)	CONVEC-TION (m)
2490	-0.131	7.41	28.69	1.81	40.0	-0.0215	-0.0244	0.0010
	-0.172	6.82	28.28					
2500	-0.087	10.63	29.13	1.83	40.0	-0.0435	-0.0149	0.0014
	-0.141	9.97	28.59					
2510	-0.044	12.49	29.56	1.84	40.0	-0.0589	-0.0100	0.0014
	-0.109	11.89	28.91					
2520	0.000	14.06	30.00	1.86	40.0	-0.0724	-0.0083	0.0014
	-0.079	13.43	29.21					
2530	0.044	15.40	30.44	1.87	40.0	-0.0843	-0.0071	0.0015
	-0.045	14.75	29.55					
2540	0.087	16.57	30.87	1.89	40.0	-0.0947	-0.0065	0.0013
	-0.012	15.94	29.88					
2550	0.131	17.71	31.31	1.90	40.0	-0.1048	-0.0060	0.0013
	0.022	17.06	30.22					
2560	0.174	18.74	31.74	1.92	40.0	-0.1139	-0.0055	0.0011
	0.056	18.10	30.56					

Table 3 ECDUFLOW Analysis - TABLE section 1

In Table 3 the water levels and the discharges at the boundaries of section 1 are presented together with the values of three terms of equation (8) for sixteen time levels. This Table 3 illustrates the second new facility which can be used in relation with the graphical time related output of DUFLOW (see Figure 3.4.).

3.4. Analysis – GRAPH

The behaviour of the terms of momentum equation can be presented by means of ECDUFLOW : Analysis – GRAPH.
Five, four, three, two or only one term can be drawn in a graph.
In Figure 3.5. the friction term together with the acceleration term and the convective term is presented as a function of time in one graph. Two terms are presented in Figure 3.6. and Figure 3.7. gives the four terms of equation (8).

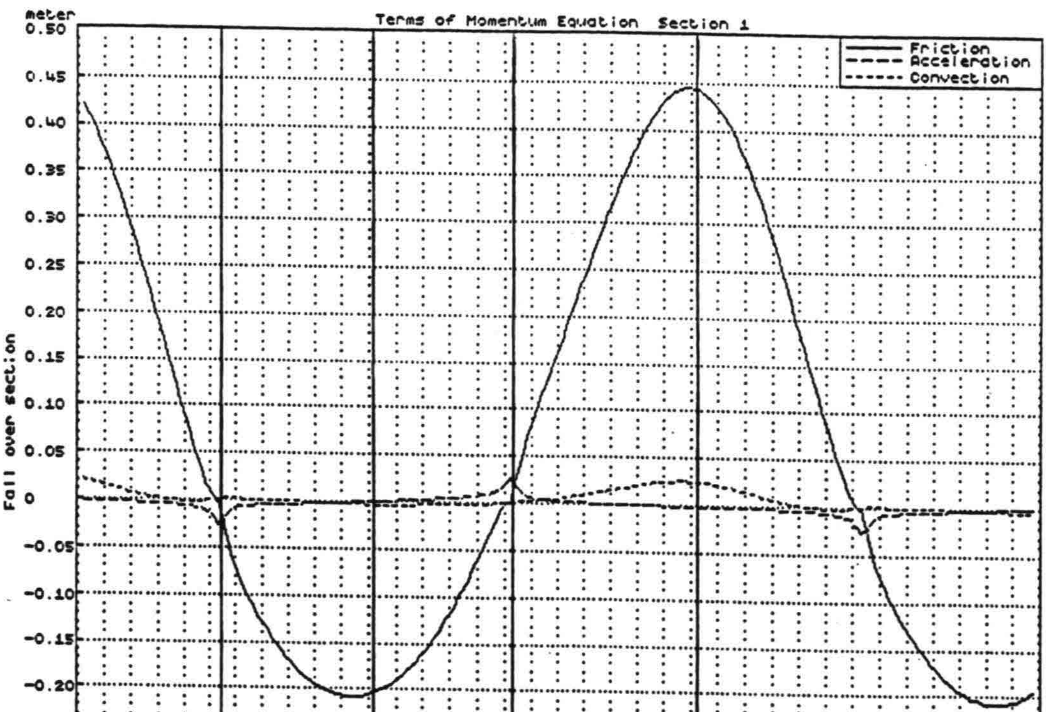


Figure 3.5. Three terms of the momentum equation – section 1

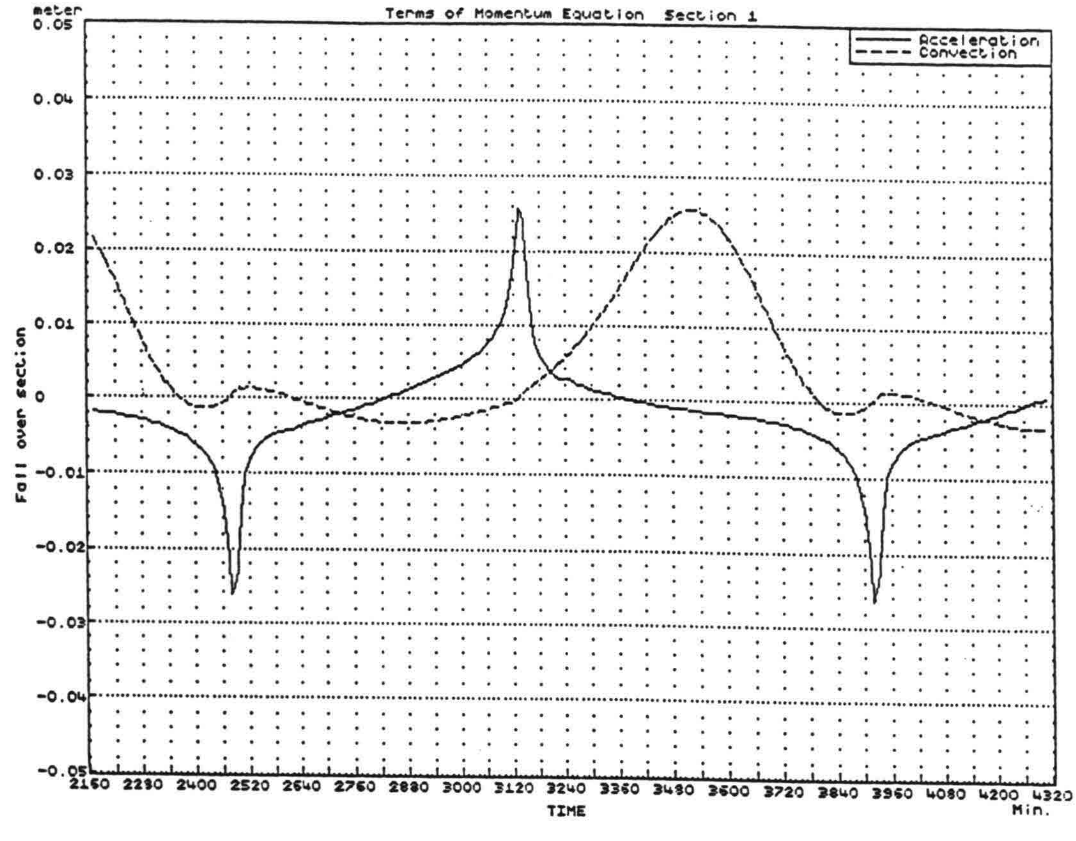


Figure 3.6. Acceleration term and convection term - section 1

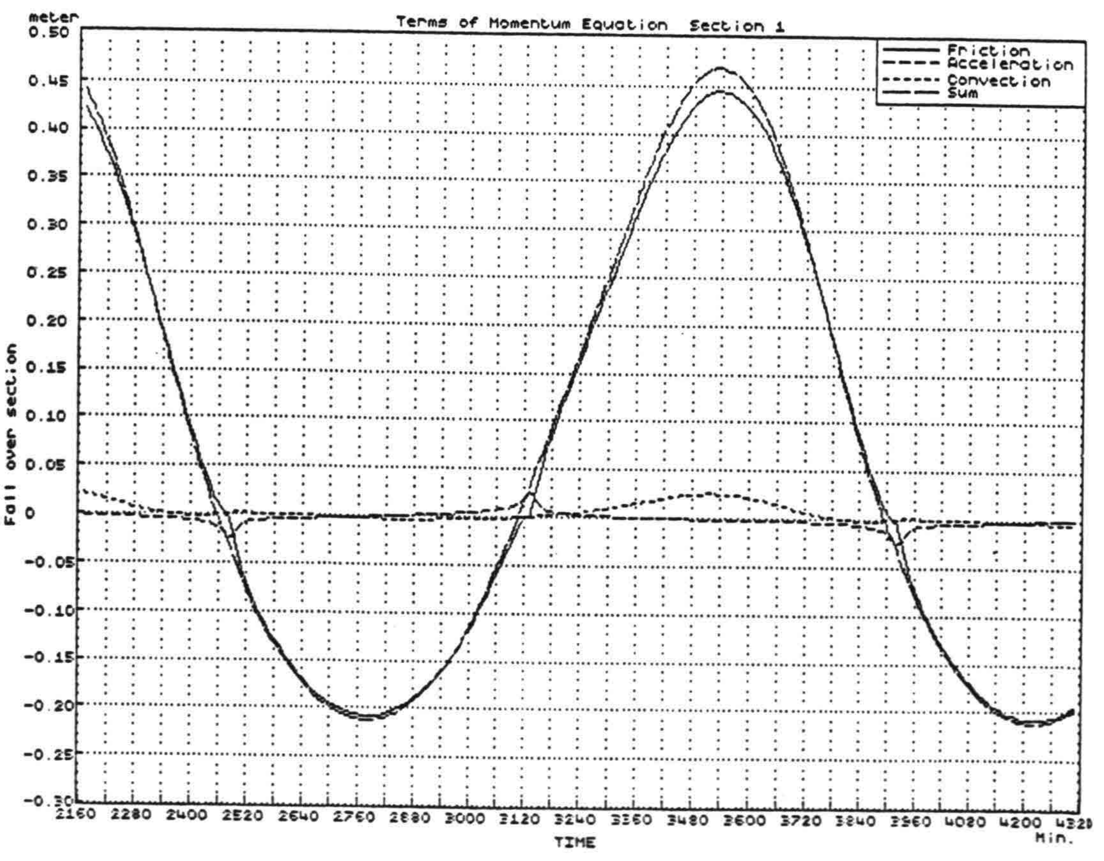


Figure 3.7. Four terms of the momentum equation (8) section 1

The performance of the water levels and discharges in a section (in this case section 1 of the network) can be related to the history of the terms of the differential equations. In Table 3 the results for sixteen successive time levels (including the time level of Table 1) are given. It is possible to present this information for all the time levels of a tidal period.

In Figure 3.5. the performance of the three terms of the momentum equation is drawn for t = 2160 minutes until t = 4320 minutes. The time levels of Table 1 and 2 are indicated in this Figure 3.5. The figures 3.4. and 3.5. in combination with the evaluation calculations as illustrated in Tables 1 and 2 make it possible to get a complete view of the balance equations over an entire period. The new DUFLOW facilities by means of ECDUFLOW make it easy to analyse the DUFLOW results in more detail by several graphs (different combinations of terms are possible) of the terms of the differential equations solved by DUFLOW.
The other information of the DUFLOW result file concerning IRRSYS can be presented in the same way. The functions h(t) and Q(t) for section 2 and section 3 are given in Appendix I Fig. I.3. and I.4. Some ECDUFLOW results are given in Table 5 ... 8. The user is invited to compare these results with the results of section 1.
An anlysis of e.g. section 4 will learn that in this system IRRSYS the friction term in the secondary canals is relatively small (see also Figure 3.2.).
Evaluation calculations are very important to analyse the results of calculations (and the results of measurements).
The new facitities will also be very useful to calibrate a model.

The application concerning IRRSYS shows that friction is dominating the other characteristic influence for unsteady flow : inertia.
Note : Depending on the boundary conditions and the initial conditions the results of any DUFLOW calculation will be dominated by acceleration influences over a time interval in which the results commonly will not be written to the result file (see Calculation Definition : "start of output").
In Chapter 4 this type of problems is emphasized by a second application concerning the propagation of a translatory wave (with dominating acceleration influences).

4. ECDUFLOW APPLICATION II

The second illustration of ECDUFLOW concerns a translatory wave in a canal. This second application, which is briefly described here, is interesting because inertia influences are dominating.
A prismatic canal with vertical walls (flow width and storage width are constant and equal to 167 m), with horizontal bottom (the waterdepth equals 3.6 m) and with a length of 12 km is considered. In Figure 4.1. twelve sections of 1000 m are distinguished.

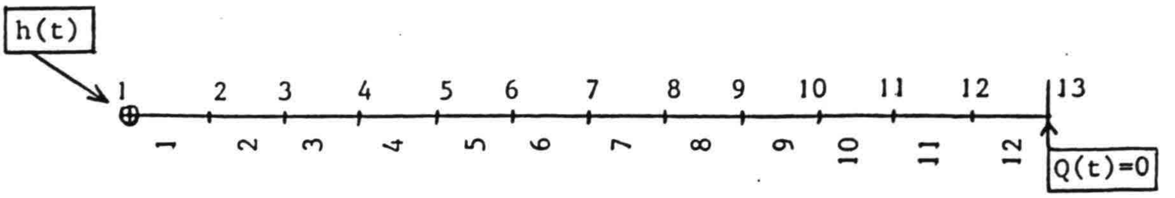


Figure 4.1. Canal , L = 12000 m.

The initial conditions are : all velocities are zero and the waterdepth is 3.60 m. The bottom level agrees with – 3.60 m so the reference level agrees with the water level (at rest). At one boundary (closed end) the boundary condition is $Q_{13}(t) = 0$.
The boundary condition at the other end is given in Figure 4.2. : the waterlevel is increasing in 2000 seconds (≈ 33 minutes) from level 0.00 m until level + 0.25 m.

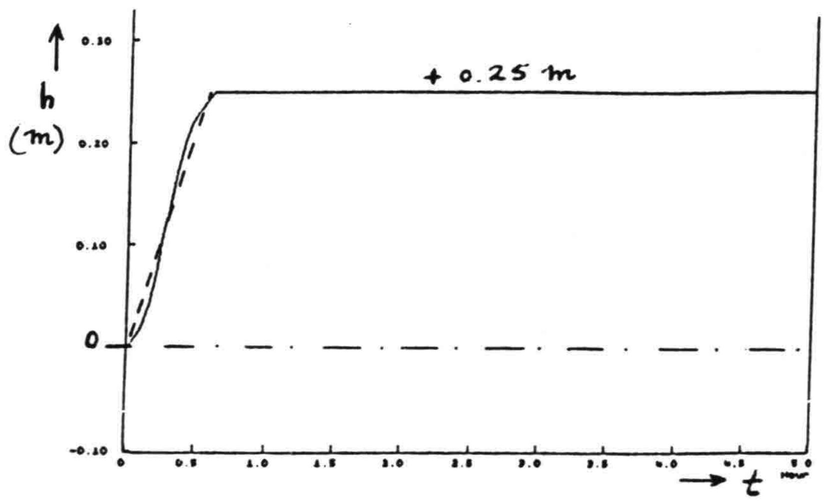
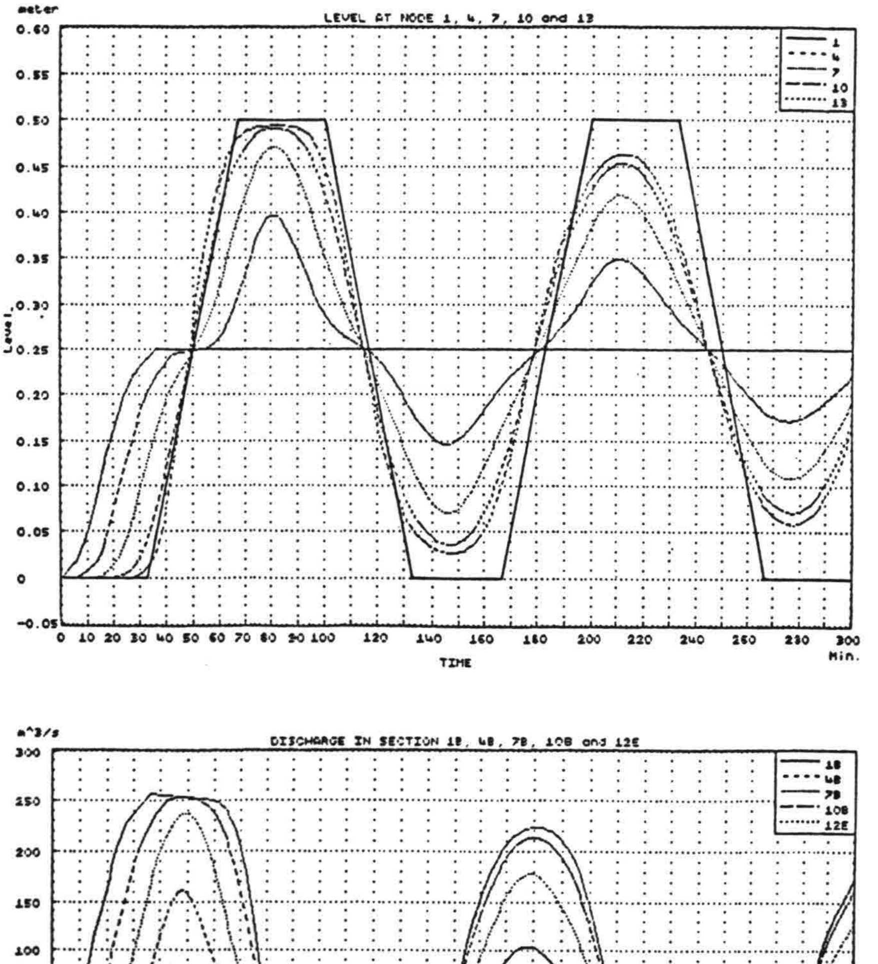
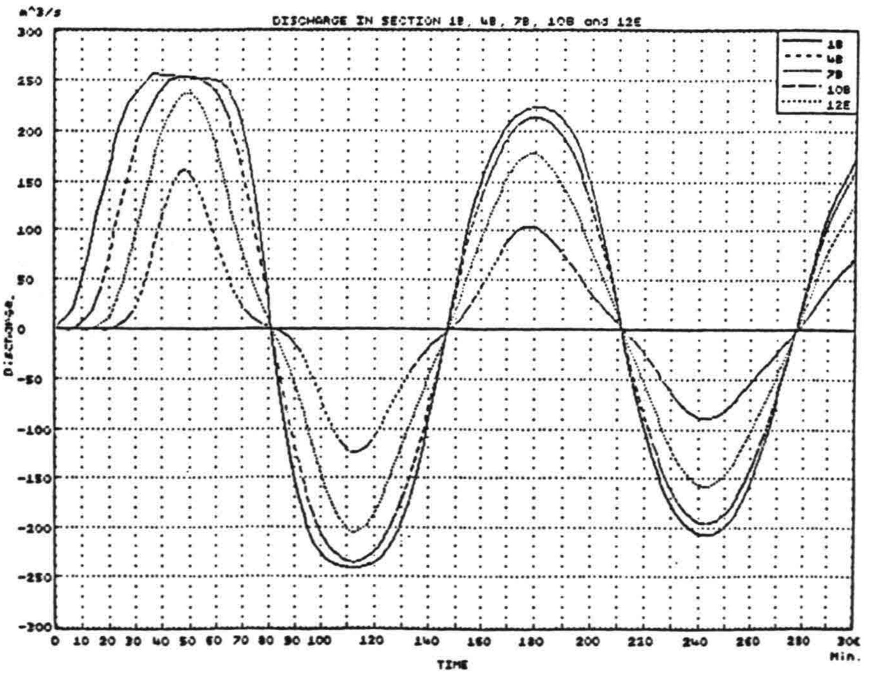


Figure 4.2. Boundary condition $h_1(t)$.

The first DUFLOW calculation concerning TRANSL without friction influences is found by an unrealistic high value for Chézy 's coefficient C = 180 $m^{1/2}/s$ (almost no friction).
The timestep Δt = 60 s = 1 minute and the coefficient θ is θ = 0.9.
The DUFLOW results are presented in Figures 4.3.a. and 4.3.b. and the solution is compared with the solution found by the Method of Characteristics





Figures 4.3.a. and 4.3.b. Functions h(t) and Q(t)

The mean discharge in section 1 and the waterlevels at node 1 and 2 are drawn in Figure 4.4. From this figure the ___ dominating influence of inertia will be clear : the water level difference is maximum for large values of $\frac{\delta Q}{\delta t}$ (see time level t = 20 minutes) and minimum for large values of Q (see time level t = 50 minutes).

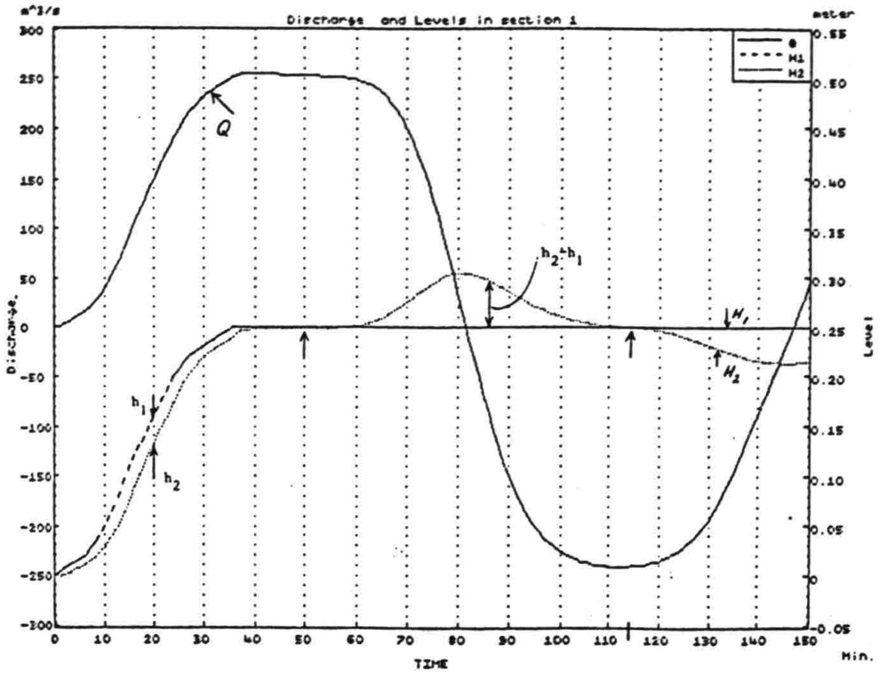


Figure 4.4. Discharge and waterlevels in section 1

ECDUFLOW Analysis – DETAILS of Calculation :

The DUFLOW results of Figure 4.4. can be analyzed by means of ECDUFLOW. In Table 9 the details of the calculation for the two time levels can be related with Figure 4.4.
In Table 10 and Table 11 the similar information is given for the time levels :

t = 80 minutes, t = 110 minutes and t = 140 minutes.

ECDUFLOW Analysis – TABLE :

The contributions of the terms of the momentum equation and of the functions h(t) and Q(t) for eight time levels near to the time levels mentioned before are given in Tables 12, 13 and 14.
This information concerns the magnitude of the terms of the momentum equation (8) for section 1 during the propagation of the translatory wave in the canal.

program DUFLOW — analysis - Details

CALCULATION TIME LEVEL 20 minutes — SECTION 1

L	length	=	1000.00	m
H1	level begin	=	0.150000	m
H2	level end	=	0.122480	m
Hav.	prev timestep	=	0.125925	m
Hav.	next timestep	=	0.146430	m
Q1	discharge begin	=	153.07001	m3/s
Q2	discharge end	=	124.42000	m3/s
Q	average disch.	=	138.74500	m3/s
Qav.	prev timestep	=	128.02000	m3/s
Qav.	next timestep	=	149.36499	m3/s
A1	area begin	=	626.25000	m^2
A2	area end	=	621.65411	m^2
A	average area	=	623.95203	m^2
R	hydr. radius	=	3.576218	m
SW	Storage width	=	167.00000	m
C	de Chezy coeff.	=	180.000	$m^{1/2}/s$
dt	time interval	=	60	sec
SW*L*dH/dt		=	28.5361	m3/s
Q1 - Q2		=	28.6500	m3/s

Friction term:

$$\frac{-Q*|Q|*L}{C^2*A^2*R} = -0.000427 \text{ m}$$

Acceleration term:

$$\frac{-L}{gA} * \frac{dQ}{dt} = -0.029060 \text{ m}$$

Advective term:

$$\frac{Q1^2/A1-Q2^2/A2}{gA} = 0.002044 \text{ m}$$

SUM of the 3 terms = -0.027443 m

H2 - H1 = -0.027520 m

program DUFLOW — analysis - Details

CALCULATION TIME LEVEL 50 minutes — SECTION 1

L	length	=	1000.00	m
H1	level begin	=	0.250000	m
H2	level end	=	0.249280	m
Hav.	prev timestep	=	0.249655	m
Hav.	next timestep	=	0.249630	m
Q1	discharge begin	=	253.85001	m3/s
Q2	discharge end	=	253.88000	m3/s
Q	average disch.	=	253.86501	m3/s
Qav.	prev timestep	=	254.09000	m3/s
Qav.	next timestep	=	253.64500	m3/s
A1	area begin	=	642.95001	m^2
A2	area end	=	642.82971	m^2
A	average area	=	642.88989	m^2
R	hydr. radius	=	3.679980	m
SW	Storage width	=	167.00000	m
C	de Chezy coeff.	=	180.000	$m^{1/2}/s$
dt	time interval	=	60	sec
SW*L*dH/dt		=	-0.0348	m3/s
Q1 - Q2		=	-0.0300	m3/s

Friction term:

$$\frac{-Q*|Q|*L}{C^2*A^2*R} = -0.001308 \text{ m}$$

Acceleration term:

$$\frac{-L}{gA} * \frac{dQ}{dt} = 0.000588 \text{ m}$$

Advective term:

$$\frac{Q1^2/A1-Q2^2/A2}{gA} = -0.000007 \text{ m}$$

SUM of the 3 terms = -0.000727 m

H2 - H1 = -0.000720 m

Table 9 ECDUFLOW Analysis - DETAILS of Calculation section 1

ECDUFLOW Analysis – GRAPH :

The contributions of three terms of the momentum equation (8) as a function of time are drawn in Figure 4.5. From this graph it is clear that the acceleration term is dominating.

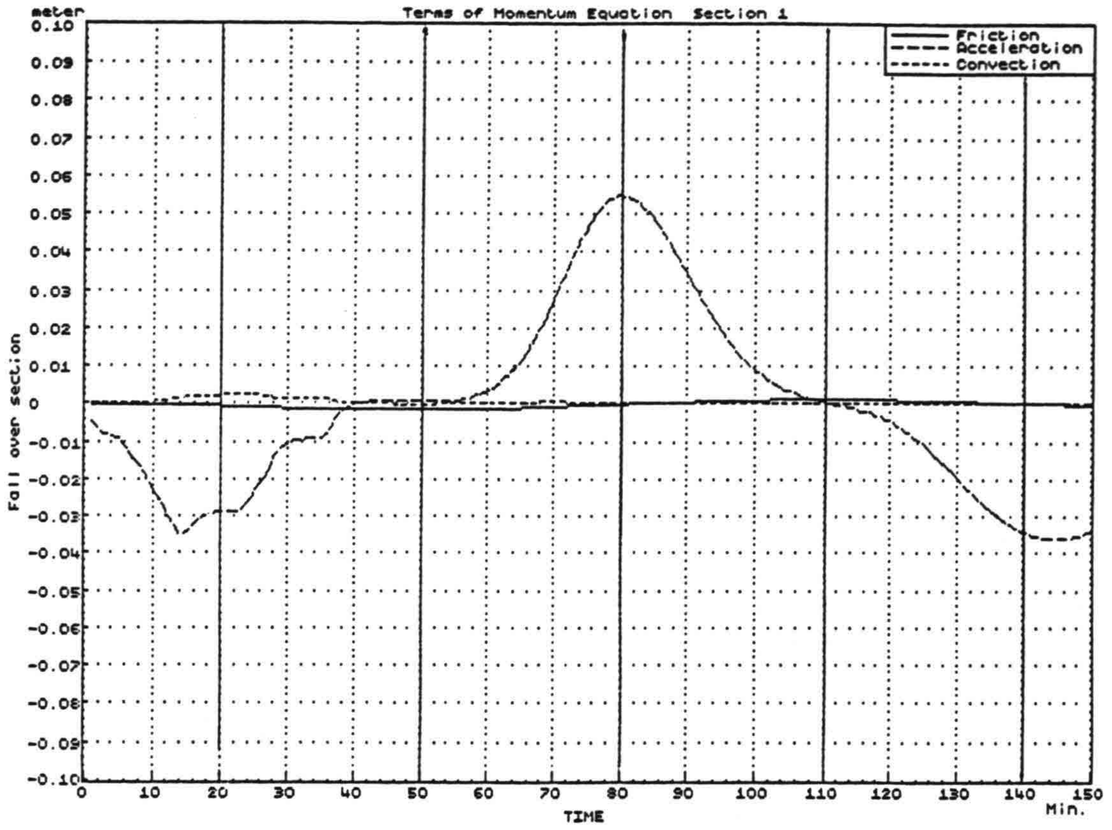
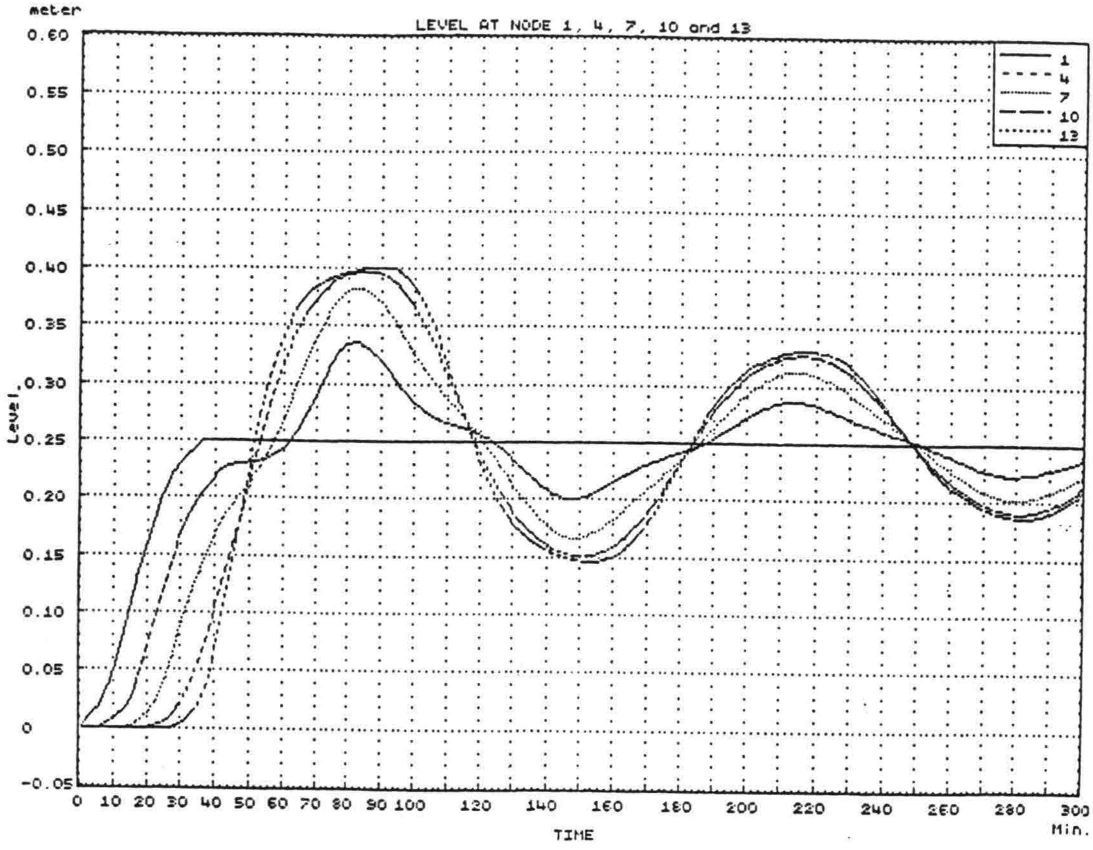
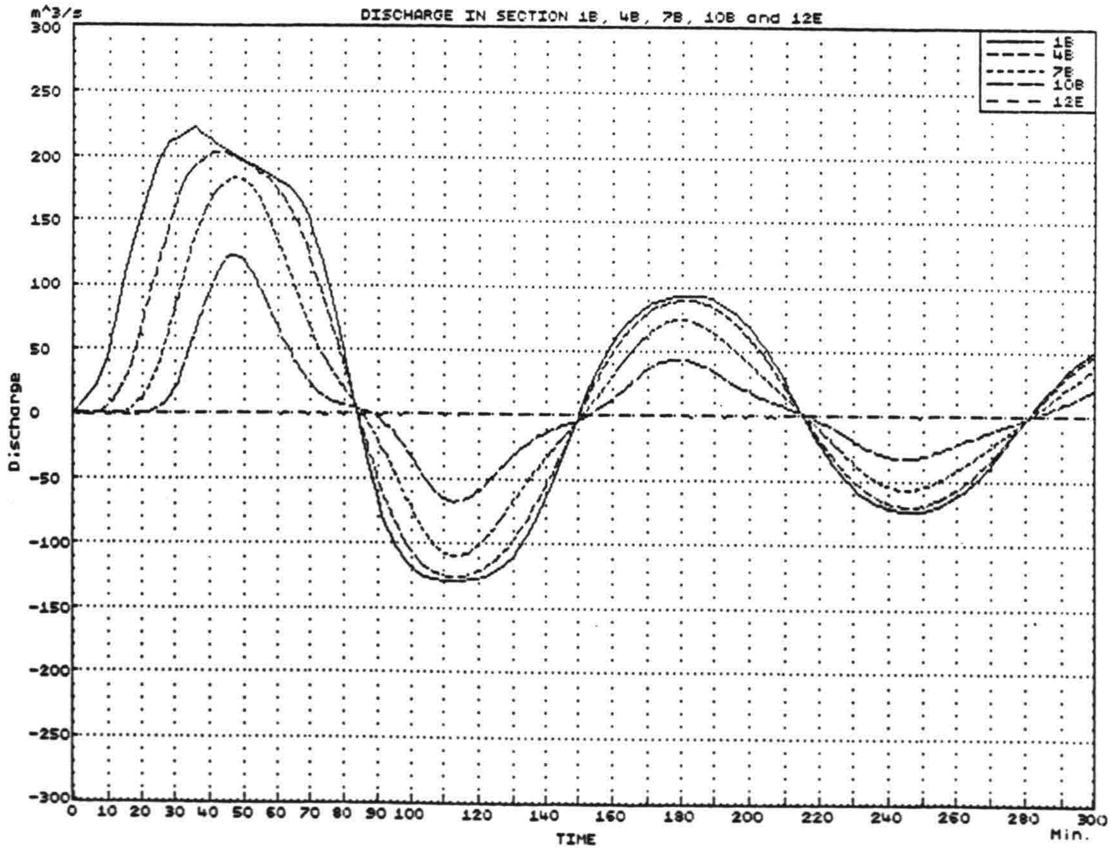


Figure 4.5. Three terms of momentum equation (8)

Another calculation with for all sections C = 50 $m^{1/2}/s$ is executed. From the DUFLOW solutions the functions h(t) and Q(t) are drawn in Figure 4.6. and Figure 4.7. on the next page 24. The DETAILS of the calculculations for five time levels t = 20, 50, 80, 110 and 140 minutes are given in the Table 15, 16 and 17 in Appendix II.

The information on page 21 ... 24 and in Appendix II makes it possible to get a complete physical insight (based on evaluation calculation by ECDUFLOW) concerning translatory waves which will be encountered over the first time interval (e.g. several houres) of any DUFLOW calculation (see Note at the end of Chapter 3).





Figures 4.6. and 4.7. Functions h(t) and Q(t) (TRANSL–friction)

5. FINAL REMARKS

In general a problem concerning tidal propagation will show that all the terms of the impuls and momentum balance are important. Besides the system IRRSYS with dominating friction the problem TRANSL with dominating inertia is considered. During the very first hours of a DUFLOW calculation translatory waves will be present in a system depending on the initial conditions in relation with the boundary conditions.
Therefore it is useful to recognize that type of shallow water waves.
ECDUFLOW makes it possible to analyse the DUFLOW results in detail and to get insight concerning the behaviour of the terms of the momentum equation for each of the sections of a network.
The user of DUFLOW is free to modify the scales of the graphical presentations so – depending on the characteristics of the problem involved – the behaviour of one, two or three terms can be studied. A graph can be completed with the sum of three terms which equals the fourth term and/or the difference between the water levels from the DUFLOW results. It is also possible to compare the water level difference calculated with ECDUFLOW (evaluation calculations) with the water level difference calculated by DUFLOW which can give small differences depending on the time step and the section length.
ECDUFLOW only calculates the terms of the differental equations concerning sections (exclusive of control structures etc.) of open channel systems.
Using ECDUFLOW immediately after the first calculation, mistakes (concerning open channel sections) eventually made in the first model will be encountered in an early stage and a more complete interpretation of these results is possible.
For an effective analysis of a system (see e.g. Ref. [7] and [8]) the new program is an important tool.

Delft, July 1991
Ir. C. Verspuy

REFERENCES

[1] DUFLOW USERS MANUAL,
1989, DUFLOW-Information : DUT, IHE, Delft, The Netherlands.

[2] DUFLOW SIMULATIONS I ,
Tidal Propagation in networks , DUFLOW - IRRSYS,
Ir. C. Verspuy,
IHE, DUT, Delft, The Netherlands. JULY 1991.

[3] DUFLOW SIMULATIONS II,
Flood Waves in River Systems, DUFLOW - RIVER,
Ir. C. Verspuy,
IHE, DUT, Delft, The Netherlands. 1991.

[4] DUFLOW SIMULATIONS III,
Unsteady flow in polders, DUFLOW - POLDER,
Ir, C, Verspuy,
IHE, DUT, DELFT, The Netherlands. AUGUST 1991.

[5] "TIDAL COMPUTATIONS, in Rivers and Coastal Waters",
Dr. J.J. Dronkers,
1964, North-Holland Publishing Company, Amsterdam.

[6] List of 150 DUFLOW Users (Groupes); Organisation :
"Bureau SAMWAT", Box 6067, 2600 JA DELFT, The Netherlands.

[7] "TIDAL PROPAGATION IN THE SCHELDT RHINE CANAL SYSTEM,
DUFLOW Calculations and Measurements in 1987,
Ir. C. Verspuy ,
Delft University of Technology (DUT),
Faculty of Civil Engineering. Report, March 1989 (in Dutch).

[8] "A MATHEMATCAL MODELLING STUDY FOR UPGRADING OF TIDAL
IRRIGATION/DRAINIGE SYSTEM OF BARAMBAI-SELUANG-BELAWANG-
MUHUR UNIT, SOUTH KALIMANTAN, INDONESIA",
Ir. F.X. Suryadi, August 1987,
MSc-Thesis International Institute for Hydraulic and
Environmental Engineering (IHE), Delft, The Netherlands.

Appendix I. Additional information concerning IRRSYS

- Additional information concerning water levels and discharges.

Some additional ECDUFLOW results concerning section 1 and time levels t = 3600 minutes and t = 3930 minutes are given in Table 4. The functions h(t) and Q(t) of branch 1 – 4 – 19 are drawn in Figure I.2. on page 4 of this Appendix I. These results can be compared with the results of Figure 3.2. in Chapter 3 to prove that the differences are very small. This is caused by the relatively small differences between the branches (only section 14 differs from section 4). The waterlevels and the flow rate in section 2 and section 3 is given in Figure I.3. and Figure I.4. These functions together with Table 5, 6, 7 and 8 on pages 8 ... 11 of this appendix have to be compared with the results for section 1.

- Simple analytical solution

The results for the system IRRSYS can be analysed with help of a simple analytic solution (see Ref. [2]). Because the results are very essential for a good physical insight concerning the properties of the system IRRSYS this solution is included briefly in this Appendix I.

The primary canal of the network IRRSYS is modelled as ONE section 1–4 with length L and a large reservoir connected at point 4 with the total internal storage area F (see Figure I.1.).

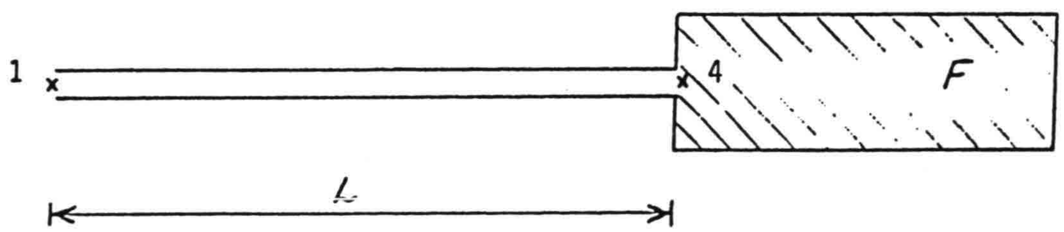


Figure I.1. Simple schematization of IRRSYS

The discharge at point 4 is calculated with the relation

$$Q_4(t) = F \frac{\delta h_4(t)}{\delta t} \qquad \text{(I-1)}$$

which is a good estimation of the discharge at the end of the primary canal. The storage area of the narrow primary canal is relatively small compared to F in (I-1) so the discharge calculated with (I-1) is also a good estimation of the discharge in the entire primary canal. This makes that the momentum equation can easily be integrated in x-direction over the only section 1-4.
We assume that $Q_4(t) = Q_1(t) = Q(t)$ so the reprentative discharge in the primary canal is called Q(t) from now on. Further assumptions are :

- the advective (or convective) term is neglected;
- the cross-section area of the primary canal is constant in x and also constant in time; this constant area is calculated for the mean water level and is called A;
- the friction term is linearized according to Lorentz' method which is applied also in the Harmonic Method so this term is written as : $K * Q(t)$, with $K =(8/(3\Pi)) * Q * L/(C^2 A^2 R)$.

With these assumptions the following equation with $M = L/(gA)$ has to be solved together with (I-1) for the entire system :

$$h_4(t) - h_1(t) = - M \frac{\delta Q}{\delta t} - K Q \qquad \text{(I-2)}$$

Substitution of (I-1) in (I-2) gives :

$$h_1(t) = h_4(t) + KF \frac{\delta h_4(t)}{\delta t} + MF \frac{\delta^2 h_4(t)}{\delta t^2} \qquad \text{(I-3)}$$

The function $h_1(t)$ is given (boundary condition) as a sinusoidal function in time with amplitude h_1 and phase angle which can be choosen $- \kappa_1 = 0$. The function $h_4(t)$ has to be solved as a sinusoidal function with amplitud h_4 and phase shift $-\kappa_4$. The analytic solution (by means of exponential functions) of (I-3) (see handbooks) results in the following expressions :

$$\kappa = \text{artg} \frac{\omega K F}{1 - \omega^2 M F} \tag{I-4}$$

$$\frac{\hat{h}_4}{\hat{h}_1} = \frac{1}{\sqrt{(1 - \omega^2 MF)^2 + \omega^2 K^2 F^2}} \tag{I-5}$$

With (I-4) and (I-5) the phase shift and the amplitude of the function $h_4(t)$ can be calculated by substituting the parameters ω, F, M and K which are representative for the system and are defined before. The discharge Q can be calculated with the solved function $h_4(t)$ by means of equation (I-1).

For the system IRRSYS the following values can be substituted :

$\omega = 0.73 * 10^{-4}$ rad./s , $F = 108 * 10^4 \ m^2$, L = 3000 m, $A = 30 \ m^2$,

and $K = 0.85 * 30 * 3000/(1600 * 900 *1.88) = 0.0283 \ s/m^2$.

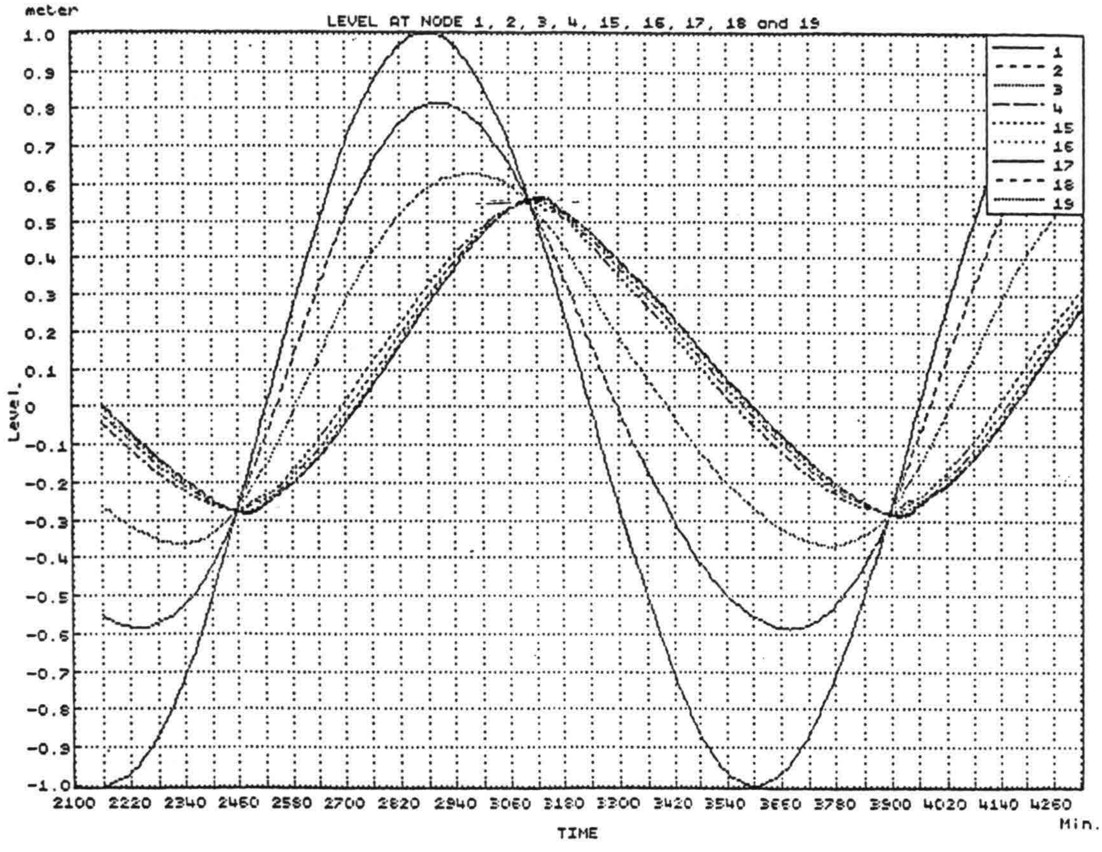
Note : For the calculation of K with given L, C, A and R we need a good estimation of the amplitude of Q(t). This means an iteration procedure. In this case we can substitute 30 m^3/s.

The general solution based on the model of Figure I.1 gives :

$$\kappa = \text{arctg} \frac{2.22}{0.942} = \text{arctg } 2.357 = 67^0 \tag{I-6}$$

$$\frac{\hat{h}_4}{\hat{h}_1} = 1 \ / \ \sqrt{0.887 + 4.928} \ = \ 0.41 \tag{I-7}$$

From the results of this simple model a phase shift of 67^0 and an amplification factor (see Chapter 3) of 0.41 is to be expected.
The results agree with the DUFLOW results of IRRSYS.
The expressions give a good insight in the role of the different parameters of the model like L, F, A, C and R .
For example the relative influence of friction, the influence of the large internal storage area, etc. can be "followed" in the analytic approach.
This analytic solution is very important to analyse and understand systems like IRRSYS.



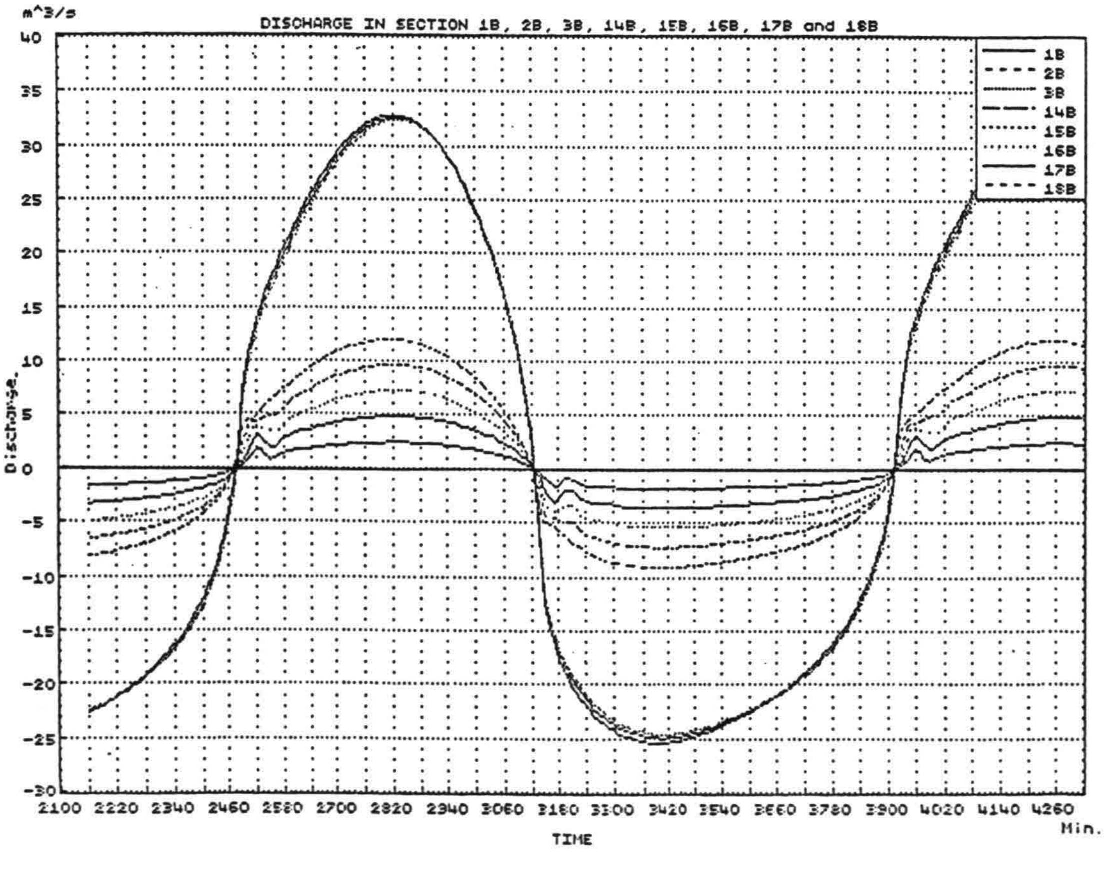


Figure I.2. Functions h(t) and Q(t) in branche 1 – 4 – 19

program DUFLOW analysis - Details

CALCULATION TIME LEVEL 3600 minutes SECTION 1

L	length	=	1000.00	m
H1	level begin	=	-0.999050	m
H2	level end	=	-0.548400	m
Hav.	prev timestep	=	-0.768005	m
Hav.	next timestep	=	-0.778095	m
Q1	discharge begin	=	-22.94000	m3/s
Q2	discharge end	=	-22.85500	m3/s
Q	average disch.	=	-22.89750	m3/s
Qav.	prev timestep	=	-23.10850	m3/s
Qav.	next timestep	=	-22.67850	m3/s
A1	area begin	=	20.00950	m^2
A2	area end	=	24.51600	m^2
A	average area	=	22.26275	m^2
R	hydr. radius	=	1.537036	m
SW	Storage width	=	10.00000	m
C	de Chezy coeff.	=	40.000	$m^{1/2}/s$
dt	time interval	=	600	sec

Friction term:

$$\frac{-Q*|Q|*L}{C^2*A^2*R} = 0.430145 \text{ m}$$

Acceleration term:

$$\frac{-L}{gA} * \frac{dQ}{dt} = -0.001641 \text{ m}$$

Advective term:

$$\frac{Q1^2/A1-Q2^2/A2}{gA} = 0.022863 \text{ m}$$

SW*L*dH/dt	=	-0.0841	m3/s
Q1 - Q2	=	-0.0850	m3/s

SUM of the 3 terms	=	0.451367	m
H2 - H1	=	0.450650	m

program DUFLOW analysis - Details

CALCULATION TIME LEVEL 3930 minutes SECTION 1

L	length	=	1000.00	m
H1	level begin	=	-0.173650	m
H2	level end	=	-0.203090	m
Hav.	prev timestep	=	-0.226220	m
Hav.	next timestep	=	-0.151985	m
Q1	discharge begin	=	2.92740	m3/s
Q2	discharge end	=	2.28590	m3/s
Q	average disch.	=	2.60665	m3/s
Qav.	prev timestep	=	-1.27923	m3/s
Qav.	next timestep	=	7.46605	m3/s
A1	area begin	=	28.26350	m^2
A2	area end	=	27.96910	m^2
A	average area	=	28.11630	m^2
R	hydr. radius	=	1.799632	m
SW	Storage width	=	10.00000	m
C	de Chezy coeff.	=	40.000	$m^{1/2}/s$
dt	time interval	=	600	sec

Friction term:

$$\frac{-Q*|Q|*L}{C^2*A^2*R} = -0.002985 \text{ m}$$

Acceleration term:

$$\frac{-L}{gA} * \frac{dQ}{dt} = -0.026422 \text{ m}$$

Advective term:

$$\frac{Q1^2/A1-Q2^2/A2}{gA} = 0.000422 \text{ m}$$

SW*L*dH/dt	=	0.6186	m3/s
Q1 - Q2	=	0.6415	m3/s

SUM of the 3 terms	=	-0.028985	m
H2 - H1	=	-0.029440	m

Table 4 ECDUFLOW Analysis - DETAILS of Calculation section 1

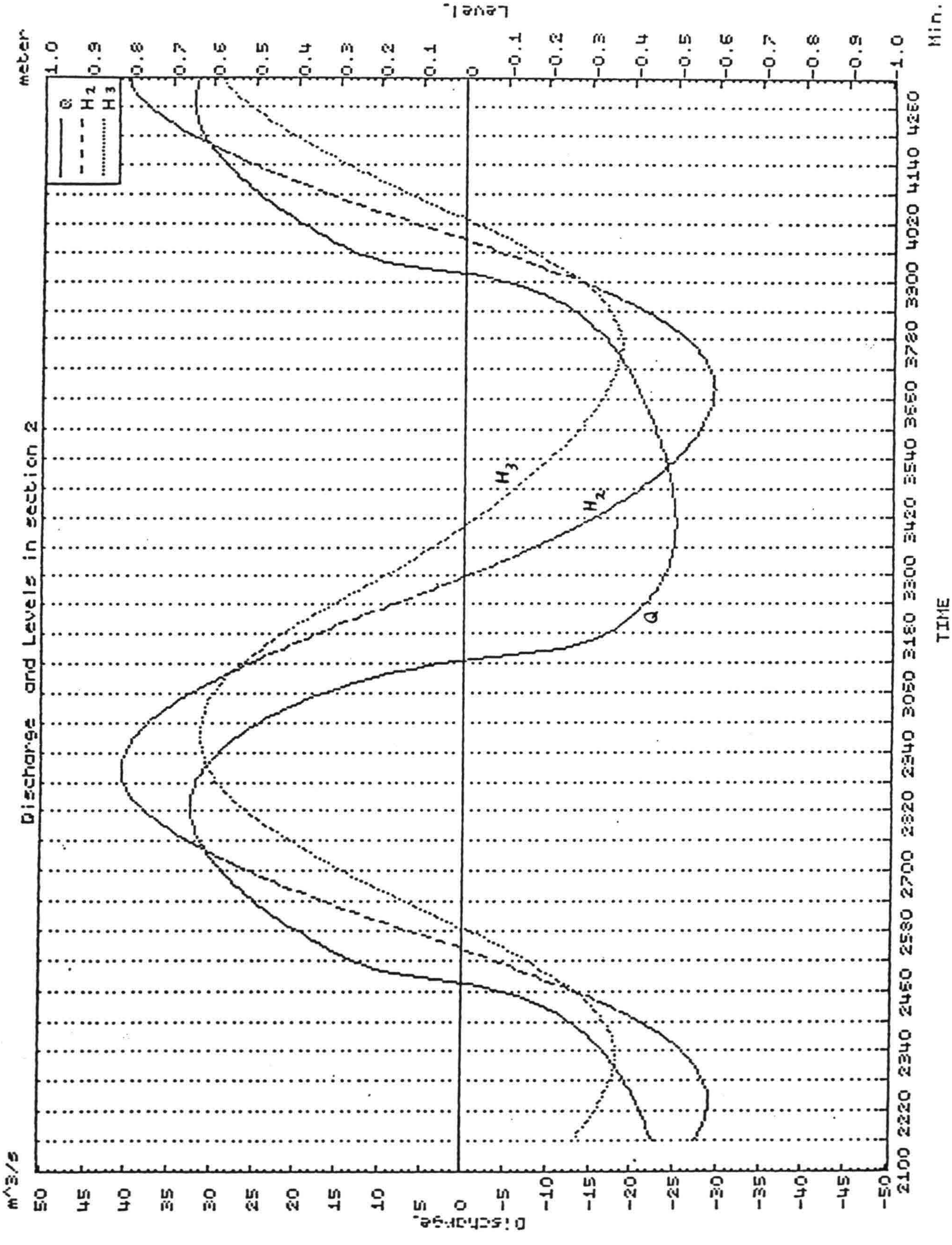


Figure I.3. Water levels and discharge section 2

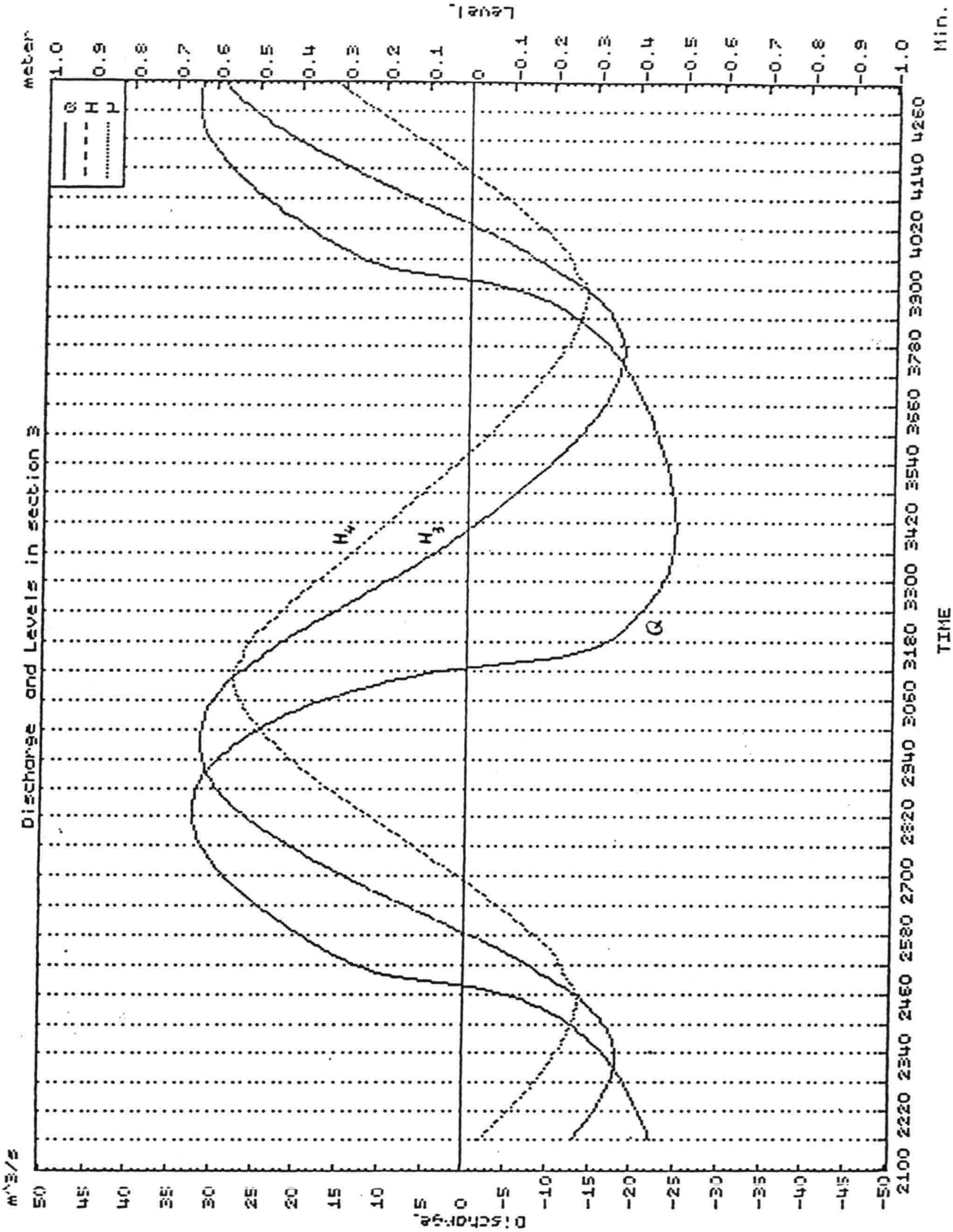


Figure I.4. Water levels and discharge section 3

program DUFLOW — analysis - Details

CALCULATION TIME LEVEL 2830 minutes — SECTION 2

L	length	=	1000.00	m
H1	level begin	=	0.756930	m
H2	level end	=	0.515370	m
Hav.	prev timestep	=	0.621965	m
Hav.	next timestep	=	0.649165	m
Q1	discharge begin	=	32.60300	m3/s
Q2	discharge end	=	32.37600	m3/s
Q	average disch.	=	32.48950	m3/s
Qav.	prev timestep	=	32.41450	m3/s
Qav.	next timestep	=	32.51500	m3/s
A1	area begin	=	37.56930	m^2
A2	area end	=	35.15370	m^2
A	average area	=	36.36150	m^2
R	hydr. radius	=	2.104625	m
SW	Storage width	=	10.00000	m
C	de Chezy coeff.	=	40.000	$m^{1/2}/s$
dt	time interval	=	600	sec
SW*L*dH/dt		=	0.2267	m3/s
Q1 - Q2		=	0.2270	m3/s

Friction term: $\frac{-Q*|Q|*L}{C^2*A^2*R}$ = -0.237087 m

Acceleration term: $\frac{-L}{gA}*\frac{dQ}{dt}$ = -0.000235 m

Advective term: $\frac{Q1^2/A1-Q2^2/A2}{gA}$ = -0.004274 m

SUM of the 3 terms = -0.241596 m
H2 - H1 = -0.241560 m

program DUFLOW — analysis - Details

CALCULATION TIME LEVEL 3550 minutes — SECTION 2

L	length	=	1000.00	m
H1	level begin	=	-0.497980	m
H2	level end	=	-0.200610	m
Hav.	prev timestep	=	-0.336860	m
Hav.	next timestep	=	-0.361205	m
Q1	discharge begin	=	-23.77300	m3/s
Q2	discharge end	=	-23.57000	m3/s
Q	average disch.	=	-23.67150	m3/s
Qav.	prev timestep	=	-23.82600	m3/s
Qav.	next timestep	=	-23.50800	m3/s
A1	area begin	=	25.02020	m^2
A2	area end	=	27.99390	m^2
A	average area	=	26.50705	m^2
R	hydr. radius	=	1.731093	m
SW	Storage width	=	10.00000	m
C	de Chezy coeff.	=	40.000	$m^{1/2}/s$
dt	time interval	=	600	sec
SW*L*dH/dt		=	-0.2029	m3/s
Q1 - Q2		=	-0.2030	m3/s

Friction term: $\frac{-Q*|Q|*L}{C^2*A^2*R}$ = 0.287931 m

Acceleration term: $\frac{-L}{gA}*\frac{dQ}{dt}$ = -0.001019 m

Advective term: $\frac{Q1^2/A1-Q2^2/A2}{gA}$ = 0.010548 m

SUM of the 3 terms = 0.297460 m
H2 - H1 = 0.297370 m

Table 5 ECDUFLOW Analysis – DETAILS of Calculation section 2

program DUFLOW analysis - Details

CALCULATION TIME LEVEL 2830 minutes SECTION 3

L	length	=	1000.00	m
H1	level begin	=	0.515370	m
H2	level end	=	0.224120	m
Hav.	prev timestep	=	0.353690	m
Hav.	next timestep	=	0.385270	m
Q1	discharge begin	=	32.37600	m3/s
Q2	discharge end	=	32.11200	m3/s
Q	average disch.	=	32.24400	m3/s
Qav.	prev timestep	=	32.15500	m3/s
Qav.	next timestep	=	32.28350	m3/s
A1	area begin	=	35.15370	m²
A2	area end	=	32.24120	m²
A	average area	=	33.69745	m²
R	hydr. radius	=	2.012147	m
SW	Storage width	=	10.00000	m
C	de Chezy coeff.	=	40.000	m½/s
dt	time interval	=	600	sec
SW*L*dH/dt		=	0.2632	m3/s
Q1 - Q2		=	0.2640	m3/s

Friction term:

$$\frac{-Q*|Q|*L}{C^2*A^2*R} = -0.284396 \text{ m}$$

Acceleration term:

$$\frac{-L}{gA} * \frac{dQ}{dt} = -0.000324 \text{ m}$$

Advective term:

$$\frac{Q1^2/A1-Q2^2/A2}{gA} = -0.006551 \text{ m}$$

SUM of the 3 terms = -0.291271 m
H2 - H1 = -0.291250 m

program DUFLOW analysis - Details

CALCULATION TIME LEVEL 3550 minutes SECTION 3

L	length	=	1000.00	m
H1	level begin	=	-0.200610	m
H2	level end	=	0.025347	m
Hav.	prev timestep	=	-0.074878	m
Hav.	next timestep	=	-0.100153	m
Q1	discharge begin	=	-23.57000	m3/s
Q2	discharge end	=	-23.35900	m3/s
Q	average disch.	=	-23.46450	m3/s
Qav.	prev timestep	=	-23.61250	m3/s
Qav.	next timestep	=	-23.30750	m3/s
A1	area begin	=	27.99390	m²
A2	area end	=	30.25347	m²
A	average area	=	29.12368	m²
R	hydr. radius	=	1.839746	m
SW	Storage width	=	10.00000	m
C	de Chezy coeff.	=	40.000	m½/s
dt	time interval	=	600	sec
SW*L*dH/dt		=	-0.2106	m3/s
Q1 - Q2		=	-0.2110	m3/s

Friction term:

$$\frac{-Q*|Q|*L}{C^2*A^2*R} = 0.220522 \text{ m}$$

Acceleration term:

$$\frac{-L}{gA} * \frac{dQ}{dt} = -0.000890 \text{ m}$$

Advective term:

$$\frac{Q1^2/A1-Q2^2/A2}{gA} = 0.006333 \text{ m}$$

SUM of the 3 terms = 0.225966 m
H2 - H1 = 0.225957 m

Table 6 ECDUFLOW Analysis - DETAILS of Calculation section 3

program DUFLOW Analysis - Table

Analysis section 2 Page 9

Time min.	H1 (m) H2 (m)	Q1 (m) Q2 (m)	A1 (m²) A2 (m²)	R (m)	C (m½/s)	FRICTION (m)	ACCELERA-TION (m)	CONVEC-TION (m)
2810	0.743	32.54	37.43	2.10	40.0	-0.2384	-0.0005	-0,0042
	0.500	32.29	35.00					
2820	0.757	32.60	37.57	2.10	40.0	-0.2371	-0.0002	-0.0043
	0.515	32.38	35.15					
2830	0.769	32.62	37.69	2.11	40.0	-0.2353	-0.0000	-0.0043
	0.529	32.41	35.29					
2840	0.780	32.58	37.79	2.11	40.0	-0.2330	0.0002	-0.0043
	0.542	32.40	35.42					
2850	0.789	32.50	37.89	2.12	40.0	-0.2302	0.0005	-0.0042
	0.555	32.33	35.55					
2860	0.796	32.36	37.96	2.12	40.0	-0.2268	0.0007	-0.0042
	0.566	32.21	35.66					
2870	0.802	32.17	38.02	2.12	40.0	-0.2230	0.0010	-0.0041
	0.576	32.04	35.76					
2880	0.807	31.92	38.07	2.12	40.0	-0.2187	0.0012	-0.0040
	0.585	31.81	35.85					

program DUFLOW Analysis - Table

Analysis section 2 Page 18

Time min.	H1 (m) H2 (m)	Q1 (m) Q2 (m)	A1 (m²) A2 (m²)	R (m)	C (m½/s)	FRICTION (m)	ACCELERA-TION (m)	CONVEC-TION (m)
3530	-0.486	-23.93	25.14	1.74	40.0	0.2881	-0.0010	0.0106
	-0.188	-23.72	28.12					
3540	-0.498	-23.77	25.02	1.73	40.0	0.2879	-0.0010	0.0105
	-0.201	-23.57	27.99					
3550	-0.510	-23.60	24.90	1.73	40.0	0.2874	-0.0011	0.0105
	-0.213	-23.41	27.87					
3560	-0.520	-23.43	24.80	1.72	40.0	0.2865	-0.0011	0.0104
	-0.225	-23.24	27.75					
3570	-0.530	-23.25	24.70	1.72	40.0	0.2852	-0.0012	0.0102
	-0.236	-23.07	27.64					
3580	-0.540	-23.06	24.60	1.71	40.0	0.2836	-0.0012	0.0101
	-0.248	-22.89	27.52					
3590	-0.548	-22.85	24.52	1.71	40.0	0.2816	-0.0013	0.0099
	-0.258	-22.70	27.42					
3600	-0.556	-22.65	24.44	1.70	40.0	0.2792	-0.0014	0.0097
	-0.269	-22.50	27.31					

Table 7 ECDUFLOW Analysis – TABLE section 2

program DUFLOW   Analysis - Table

Analysis section 3   Page 9

Time min.	H1 (m) H2 (m)	Q1 (m) Q2 (m)	A1 (m²) A2 (m²)	R (m)	C (m½/s)	FRICTION (m)	ACCELERATION (m)	CONVECTION (m)
2810	0.500 0.207	32.29 32.02	35.00 32.07	2.01	40.0	-0.2864	-0.0006	-0.0066
2820	0.515 0.224	32.38 32.11	35.15 32.24	2.01	40.0	-0.2844	-0.0003	-0.0066
2830	0.529 0.241	32.41 32.16	35.29 32.41	2.02	40.0	-0.2817	-0.0001	-0.0064
2840	0.542 0.258	32.40 32.15	35.42 32.58	2.02	40.0	-0.2783	0.0002	-0.0063
2850	0.555 0.275	32.33 32.09	35.55 32.75	2.03	40.0	-0.2742	0.0004	-0.0061
2860	0.566 0.291	32.21 31.99	35.66 32.91	2.03	40.0	-0.2695	0.0007	-0.0059
2870	0.576 0.307	32.04 31.82	35.76 33.07	2.04	40.0	-0.2640	0.0010	-0.0057
2880	0.585 0.323	31.81 31.61	35.85 33.23	2.04	40.0	-0.2579	0.0012	-0.0054

program DUFLOW   Analysis - Table

Analysis section 3   Page 18

Time min.	H1 (m) H2 (m)	Q1 (m) Q2 (m)	A1 (m²) A2 (m²)	R (m)	C (m½/s)	FRICTION (m)	ACCELERATION (m)	CONVECTION (m)
3530	-0.188 0.038	-23.72 -23.50	28.12 30.38	1.84	40.0	0.2208	-0.0008	0.0064
3540	-0.201 0.025	-23.57 -23.36	27.99 30.25	1.84	40.0	0.2205	-0.0009	0.0063
3550	-0.213 0.013	-23.41 -23.20	27.87 30.13	1.83	40.0	0.2201	-0.0009	0.0063
3560	-0.225 -0.000	-23.24 -23.04	27.75 30.00	1.83	40.0	0.2194	-0.0010	0.0063
3570	-0.236 -0.013	-23.07 -22.87	27.64 29.87	1.82	40.0	0.2185	-0.0010	0.0062
3580	-0.248 -0.025	-22.89 -22.69	27.52 29.75	1.82	40.0	0.2175	-0.0011	0.0061
3590	-0.258 -0.037	-22.70 -22.51	27.42 29.63	1.82	40.0	0.2162	-0.0011	0.0060
3600	-0.269 -0.049	-22.50 -22.31	27.31 29.51	1.81	40.0	0.2147	-0.0012	0.0060

Table 8 ECDUFLOW Analysis - TABLE section 3

Appendix II Additional information concerning TRANSL

Table 10, 11, 12, 13 and 14 give information additional to the pages 21, 22 and 23 of Chapter 4 concerning DUFLOW–TRANSL results.

```
program DUFLOW                                         analysis - Details
-------------------------------------------------------------------------------------
CALCULATION TIME LEVEL      80 minutes              SECTION     1

L    length            =     1000.00 m              Friction term:
H1   level begin       =    0.250000 m                     -Q*|Q|*L
H2   level end         =    0.304050 m                     --------      = -0.000053 m
Hav. prev timestep     =    0.276345 m                     C²*A²*R
Hav. next timestep     =    0.277380 m
Q1   discharge begin   =    52.56600 m3/s
Q2   discharge end     =    50.76600 m3/s           Acceleration term:
Q    average disch.    =    51.66600 m3/s                  -L    dQ
Qav. prev timestep     =    72.21650 m3/s                  -- *  --      =  0.054315 m
Qav. next timestep     =    30.81800 m3/s                  gA    dt
A1   area begin        =   642.95001 m²
A2   area end          =   651.97632 m²
A    average area      =   647.46313 m²             Advective term:
R    hydr. radius      =    3.704989 m                     Q1²/A1-Q2²/A2
SW   Storage width     =   167.00000 m                     -------------  =  0.000054 m
C    de Chezy coeff.   =     180.000 m½/s                       gA
dt   time interval     =          60 sec

SW*L*dH/dt             =      1.4403 m3/s           SUM of the 3 terms  =  0.054316 m
Q1 - Q2                =      1.8000 m3/s           H2 - H1             =  0.054050 m
```

```
program DUFLOW                                         analysis - Details
-------------------------------------------------------------------------------------
CALCULATION TIME LEVEL      110 minutes             SECTION     1

L    length            =     1000.00 m              Friction term:
H1   level begin       =    0.250000 m                     -Q*|Q|*L
H2   level end         =    0.252580 m                     --------      =  0.001165 m
Hav. prev timestep     =    0.251535 m                     C²*A²*R
Hav. next timestep     =    0.251075 m
Q1   discharge begin   =  -240.13000 m3/s
Q2   discharge end     =  -239.46001 m3/s           Acceleration term:
Q    average disch.    =  -239.79501 m3/s                  -L    dQ
Qav. prev timestep     =  -239.27499 m3/s                  -- *  --      =  0.001162 m
Qav. next timestep     =  -240.15500 m3/s                  gA    dt
A1   area begin        =   642.95001 m²
A2   area end          =   643.38086 m²
A    average area      =   643.16541 m²             Advective term:
R    hydr. radius      =    3.681488 m                     Q1²/A1-Q2²/A2
SW   Storage width     =   167.00000 m                     -------------  =  0.000089 m
C    de Chezy coeff.   =     180.000 m½/s                       gA
dt   time interval     =          60 sec

SW*L*dH/dt             =     -0.6402 m3/s           SUM of the 3 terms  =  0.002416 m
Q1 - Q2                =     -0.6700 m3/s           H2 - H1             =  0.002580 m
```

Table 10 ECDUFLOW Analysis – DETAILS of Calculation section 1

```
program DUFLOW                                      analysis - Details
--------------------------------------------------------------------------------
CALCULATION TIME LEVEL     140 minutes              SECTION     1

L    length              =      1000.00 m           Friction term:
H1   level begin         =     0.250000 m                  -Q*|Q|*L
H2   level end           =     0.217490 m                  ---------    =  0.000212 m
Hav. prev timestep       =     0.234350 m                  C²*A²*R
Hav. next timestep       =     0.233225 m
Q1   discharge begin     =   -102.34000 m3/s
Q2   discharge end       =   -100.69000 m3/s        Acceleration term:
Q    average disch.      =   -101.51500 m3/s               -L     dQ
Qav. prev timestep       =   -113.83500 m3/s               --  *  --    = -0.033188 m
Qav. next timestep       =    -88.82150 m3/s               gA     dt
A1   area begin          =    642.95001 m²
A2   area end            =    637.52081 m²
A    average area        =    640.23541 m²          Advective term:
R    hydr. radius        =     3.665450 m                  Q1²/A1-Q2²/A2
SW   Storage width       =    167.00000 m                  -------------  =  0.000062 m
C    de Chezy coeff.     =      180.000 m½/s                    gA
dt   time interval       =           60 sec

SW*L*dH/dt               =      -1.5656 m3/s        SUM of the 3 terms  = -0.032915 m
Q1 - Q2                  =      -1.6500 m3/s        H2 - H1             = -0.032510 m
   Esc = menu                  PgUp = Previous          PgDn or <─┘  =  next
```

Table 11 ECDUFLOW Analysis – DETAILS of Calculation section 1

program DUFLOW Analysis - Table

Analysis section 1 Page 3

Time min.	H1 (m) H2 (m)	Q1 (m) Q2 (m)	A1 (m^2) A2 (m^2)	R (m)	C ($m^{½}/s$)	FRICTION (m)	ACCELERA-TION (m)	CONVEC-TION (m)
17	0.130	132.23	622.91	3.56	180.0	-0.0003	-0.0304	0.0018
	0.101	101.98	618.03					
18	0.140	142.63	624.58	3.57	180.0	-0.0004	-0.0295	0.0019
	0.112	113.41	619.88					
19	0.150	153.07	626.25	3.58	180.0	-0.0004	-0.0291	0.0020
	0.122	124.42	621.65					
20	0.160	163.53	627.92	3.59	180.0	-0.0005	-0.0288	0.0022
	0.133	135.20	623.39					
21	0.170	174.01	629.59	3.59	180.0	-0.0006	-0.0286	0.0023
	0.143	145.86	625.10					
22	0.180	184.52	631.26	3.60	180.0	-0.0006	-0.0285	0.0024
	0.153	156.47	626.79					
23	0.190	195.06	632.93	3.61	180.0	-0.0007	-0.0285	0.0025
	0.163	167.07	628.48					
24	0.200	205.62	634.60	3.62	180.0	-0.0008	-0.0265	0.0027
	0.173	177.66	630.17					

Esc = menu PgUp = Previous PgDn or <—┘ = next

program DUFLOW Analysis - Table

Analysis section 1 Page 7

Time min.	H1 (m) H2 (m)	Q1 (m) Q2 (m)	A1 (m^2) A2 (m^2)	R (m)	C ($m^{½}/s$)	FRICTION (m)	ACCELERA-TION (m)	CONVEC-TION (m)
49	0.250	253.85	642.95	3.68	180.0	-0.0013	0.0006	-0.0000
	0.249	253.88	642.83					
50	0.250	253.63	642.95	3.68	180.0	-0.0013	0.0006	-0.0000
	0.249	253.66	642.83					
51	0.250	253.42	642.95	3.68	180.0	-0.0013	0.0006	-0.0000
	0.249	253.44	642.82					
52	0.250	253.23	642.95	3.68	180.0	-0.0013	0.0006	-0.0000
	0.249	253.21	642.83					
53	0.250	253.03	642.95	3.68	180.0	-0.0013	0.0006	0.0000
	0.249	252.97	642.83					
54	0.250	252.81	642.95	3.68	180.0	-0.0013	0.0007	0.0000
	0.249	252.69	642.84					
55	0.250	252.56	642.95	3.68	180.0	-0.0013	0.0009	0.0000
	0.250	252.36	642.87					
56	0.250	252.25	642.95	3.68	180.0	-0.0013	0.0011	0.0000
	0.250	251.95	642.90					

Table 12 ECDUFLOW Analysis – TABLE section 1 (TRANSL)

program DUFLOW   Analysis - Table

Analysis section 1   Page 10

Time min.	H1 (m) H2 (m)	Q1 (m) Q2 (m)	A1 (m²) A2 (m²)	R (m)	C (m½/s)	FRICTION (m)	ACCELERATION (m)	CONVECTION (m)
73	0.250	165.16	642.95	3.70	180.0	-0.0005	0.0394	0.0005
	0.288	159.68	649.27					
74	0.250	149.32	642.95	3.70	180.0	-0.0004	0.0430	0.0004
	0.292	144.10	649.90					
75	0.250	132.06	642.95	3.70	180.0	-0.0003	0.0463	0.0003
	0.295	127.28	650.48					
76	0.250	113.55	642.95	3.70	180.0	-0.0002	0.0492	0.0003
	0.298	109.35	650.99					
77	0.250	93.96	642.95	3.70	180.0	-0.0002	0.0515	0.0002
	0.301	90.48	651.42					
78	0.250	73.55	642.95	3.70	180.0	-0.0001	0.0532	0.0001
	0.303	70.88	651.75					
79	0.250	52.57	642.95	3.70	180.0	-0.0001	0.0543	0.0001
	0.304	50.77	651.98					
80	0.250	31.27	642.95	3.71	180.0	-0.0000	0.0548	0.0000
	0.305	30.37	652.09					

Esc = menu   PgUp = Previous   PgDn or <—┘ = next

program DUFLOW   Analysis - Table

Analysis section 1   Page 11

Time min.	H1 (m) H2 (m)	Q1 (m) Q2 (m)	A1 (m²) A2 (m²)	R (m)	C (m½/s)	FRICTION (m)	ACCELERATION (m)	CONVECTION (m)
81	0.250	9.93	642.95	3.71	180.0	-0.0000	0.0546	0.0000
	0.305	9.91	652.11					
82	0.250	-11.21	642.95	3.71	180.0	0.0000	0.0538	0.0000
	0.304	-10.40	652.02					
83	0.250	-31.91	642.95	3.70	180.0	0.0000	0.0525	0.0000
	0.303	-30.33	651.84					
84	0.250	-51.96	642.95	3.70	180.0	0.0001	0.0507	0.0001
	0.302	-49.69	651.58					
85	0.250	-71.17	642.95	3.70	180.0	0.0001	0.0485	0.0001
	0.300	-68.33	651.24					
86	0.250	-89.41	642.95	3.70	180.0	0.0002	0.0459	0.0002
	0.297	-86.10	650.85					
87	0.250	-106.56	642.95	3.70	180.0	0.0002	0.0431	0.0002
	0.295	-102.88	650.41					
88	0.250	-122.54	642.95	3.70	180.0	0.0003	0.0401	0.0003
	0.292	-118.59	649.94					

Table 13 ECDUFLOW Analysis – TABLE section 1 (TRANSL)

program DUFLOW   Analysis - Table

Analysis section 1   Page 14

Time min.	H1 (m) H2 (m)	Q1 (m) Q2 (m)	A1 (m²) A2 (m²)	R (m)	C (m½/s)	FRICTION (m)	ACCELERA-TION (m)	CONVEC-TION (m)
105	0.250	-237.10	642.95	3.68	180.0	0.0011	0.0035	0.0002
	0.255	-235.87	643.79					
106	0.250	-238.18	642.95	3.68	180.0	0.0011	0.0028	0.0001
	0.254	-237.13	643.67					
107	0.250	-239.02	642.95	3.68	180.0	0.0012	0.0021	0.0001
	0.254	-238.12	643.56					
108	0.250	-239.66	642.95	3.68	180.0	0.0012	0.0016	0.0001
	0.253	-238.89	643.46					
109	0.250	-240.13	642.95	3.68	180.0	0.0012	0.0012	0.0001
	0.253	-239.46	643.38					
110	0.250	-240.45	642.95	3.68	180.0	0.0012	0.0008	0.0001
	0.252	-239.86	643.31					
111	0.250	-240.64	642.95	3.68	180.0	0.0012	0.0004	0.0001
	0.252	-240.11	643.25					
112	0.250	-240.70	642.95	3.68	180.0	0.0012	0.0000	0.0001
	0.251	-240.20	643.19					

Table 14 ECDUFLOW Analysis - TABLE section 1 (TRANSL)

program DUFLOW — analysis - Details

CALCULATION TIME LEVEL 20 minutes — SECTION 1

L	length	=	1000.00 m
H1	level begin	=	0.150000 m
H2	level end	=	0.120580 m
Hav.	prev timestep	=	0.125130 m
Hav.	next timestep	=	0.145320 m
Q1	discharge begin	=	148.08000 m3/s
Q2	discharge end	=	119.86000 m3/s
Q	average disch.	=	133.97000 m3/s
Qav.	prev timestep	=	124.21500 m3/s
Qav.	next timestep	=	143.48999 m3/s
A1	area begin	=	626.25000 m²
A2	area end	=	621.33685 m²
A	average area	=	623.79346 m²
R	hydr. radius	=	3.575348 m
SW	Storage width	=	167.00000 m
C	de Chezy coeff.	=	50.000 m½/s
dt	time interval	=	60 sec
SW*L*dH/dt		=	28.0977 m3/s
Q1 - Q2		=	28.2200 m3/s

Friction term:

$$\frac{-Q*|Q|*L}{C^2*A^2*R} = -0.005160 \text{ m}$$

Acceleration term:

$$\frac{-L}{gA} * \frac{dQ}{dt} = -0.026248 \text{ m}$$

Advective term:

$$\frac{Q1^2/A1-Q2^2/A2}{gA} = 0.001943 \text{ m}$$

SUM of the 3 terms = -0.029465 m

H2 - H1 = -0.029420 m

program DUFLOW — analysis - Details

CALCULATION TIME LEVEL 50 minutes — SECTION 1

L	length	=	1000.00 m
H1	level begin	=	0.250000 m
H2	level end	=	0.243620 m
Hav.	prev timestep	=	0.246790 m
Hav.	next timestep	=	0.246825 m
Q1	discharge begin	=	198.12000 m3/s
Q2	discharge end	=	198.07001 m3/s
Q	average disch.	=	198.09500 m3/s
Qav.	prev timestep	=	199.62000 m3/s
Qav.	next timestep	=	196.60501 m3/s
A1	area begin	=	642.95001 m²
A2	area end	=	641.88452 m²
A	average area	=	642.41724 m²
R	hydr. radius	=	3.677394 m
SW	Storage width	=	167.00000 m
C	de Chezy coeff.	=	50.000 m½/s
dt	time interval	=	60 sec
SW*L*dH/dt		=	0.0487 m3/s
Q1 - Q2		=	0.0500 m3/s

Friction term:

$$\frac{-Q*|Q|*L}{C^2*A^2*R} = -0.010343 \text{ m}$$

Acceleration term:

$$\frac{-L}{gA} * \frac{dQ}{dt} = 0.003987 \text{ m}$$

Advective term:

$$\frac{Q1^2/A1-Q2^2/A2}{gA} = -0.000011 \text{ m}$$

SUM of the 3 terms = -0.006367 m

H2 - H1 = -0.006380 m

Table 15 ECDUFLOW Analysis-DETAILS section 1 (TRANSL-friction)

program DUFLOW analysis - Details

CALCULATION TIME LEVEL 80 minutes SECTION 1

L	length	=	1000.00 m
H1	level begin	=	0.250000 m
H2	level end	=	0.280110 m
Hav.	prev timestep	=	0.264495 m
Hav.	next timestep	=	0.265455 m
Q1	discharge begin	=	56.06200 m3/s
Q2	discharge end	=	54.54200 m3/s
Q	average disch.	=	55.30200 m3/s
Qav.	prev timestep	=	67.04650 m3/s
Qav.	next timestep	=	43.36300 m3/s
A1	area begin	=	642.95001 m²
A2	area end	=	647.97833 m²
A	average area	=	645.46417 m²
R	hydr. radius	=	3.694062 m
SW	Storage width	=	167.00000 m
C	de Chezy coeff.	=	50.000 m½/s
dt	time interval	=	60 sec
SW*L*dH/dt		=	1.3360 m3/s
Q1 - Q2		=	1.5200 m3/s

Friction term:
$$\frac{-Q*|Q|*L}{C^2*A^2*R} = -0.000795 \text{ m}$$

Acceleration term:
$$\frac{-L}{gA} * \frac{dQ}{dt} = 0.031169 \text{ m}$$

Advective term:
$$\frac{Q1^2/A1-Q2^2/A2}{gA} = 0.000047 \text{ m}$$

SUM of the 3 terms = 0.030421 m
H2 - H1 = 0.030110 m

program DUFLOW analysis - Details

CALCULATION TIME LEVEL 110 minutes SECTION 1

L	length	=	1000.00 m
H1	level begin	=	0.250000 m
H2	level end	=	0.255330 m
Hav.	prev timestep	=	0.252820 m
Hav.	next timestep	=	0.252530 m
Q1	discharge begin	=	-128.30000 m3/s
Q2	discharge end	=	-127.87000 m3/s
Q	average disch.	=	-128.08501 m3/s
Qav.	prev timestep	=	-127.69500 m3/s
Qav.	next timestep	=	-128.36499 m3/s
A1	area begin	=	642.95001 m²
A2	area end	=	643.84009 m²
A	average area	=	643.39502 m²
R	hydr. radius	=	3.682744 m
SW	Storage width	=	167.00000 m
C	de Chezy coeff.	=	50.000 m½/s
dt	time interval	=	60 sec
SW*L*dH/dt		=	-0.4036 m3/s
Q1 - Q2		=	-0.4300 m3/s

Friction term:
$$\frac{-Q*|Q|*L}{C^2*A^2*R} = 0.004305 \text{ m}$$

Acceleration term:
$$\frac{-L}{gA} * \frac{dQ}{dt} = 0.000885 \text{ m}$$

Advective term:
$$\frac{Q1^2/A1-Q2^2/A2}{gA} = 0.000033 \text{ m}$$

SUM of the 3 terms = 0.005222 m
H2 - H1 = 0.005330 m

Table 16 ECDUFLOW Analysis-DETAILS section 1 (TRANSL-friction)

program DUFLOW — analysis - Details

CALCULATION TIME LEVEL 140 minutes — SECTION 1

L	length	=	1000.00 m
H1	level begin	=	0.250000 m
H2	level end	=	0.236210 m
Hav.	prev timestep	=	0.243525 m
Hav.	next timestep	=	0.242720 m
Q1	discharge begin	=	-67.98300 m3/s
Q2	discharge end	=	-66.81800 m3/s
Q	average disch.	=	-67.40050 m3/s
Qav.	prev timestep	=	-73.08500 m3/s
Qav.	next timestep	=	-61.50400 m3/s
A1	area begin	=	642.95001 m²
A2	area end	=	640.64709 m²
A	average area	=	641.79858 m²
R	hydr. radius	=	3.674008 m
SW	Storage width	=	167.00000 m
C	de Chezy coeff.	=	50.000 m½/s
dt	time interval	=	60 sec

SW*L*dH/dt = -1.1203 m3/s
Q1 - Q2 = -1.1650 m3/s

Friction term:

$$\frac{-Q*|Q|*L}{C^2*A^2*R} = 0.001201 \text{ m}$$

Acceleration term:

$$\frac{-L}{gA} * \frac{dQ}{dt} = -0.015328 \text{ m}$$

Advective term:

$$\frac{Q1^2/A1-Q2^2/A2}{gA} = 0.000035 \text{ m}$$

SUM of the 3 terms = -0.014093 m
H2 - H1 = -0.013790 m

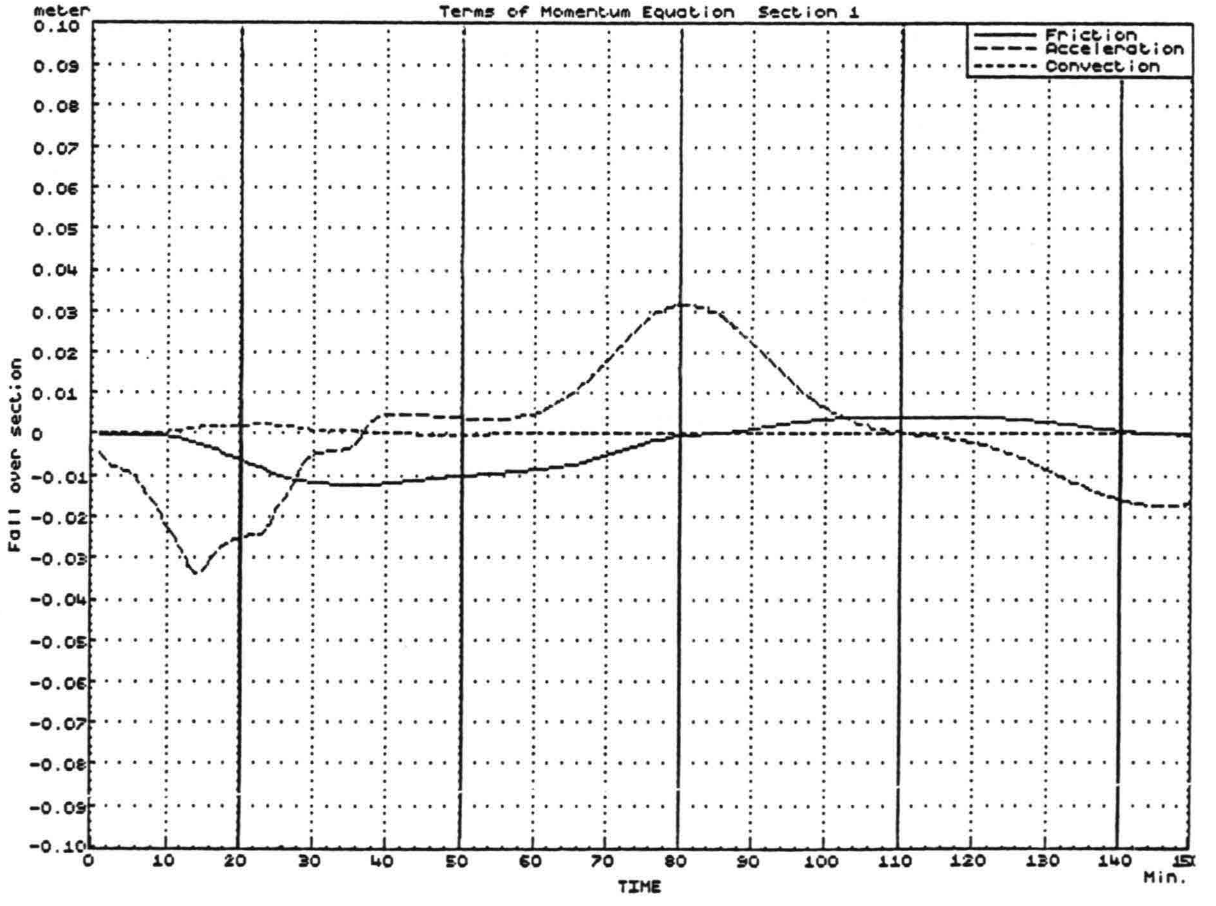


Table 17 ECDUFLOW Analysis–DETAILS section 1 (TRANSL–friction)

IHE
DELFT

Oude Delft 95
P.O. Box 3015
2601 DA Delft
The Netherlands

Tel. : +31-15-78 80 21
Telex : 38099 ihe nl
Cable: interwater
Fax : +31-15-12 29 21