Mike11

WATEREUROPE

Hydroinformatics for water resources and water related hazards management in Europe

Hydraulic Modelling

1D River Modelling with Mike11

Introduction Mike11

Overview

Software Tools for 1D River Modelling

- examples for numerical simulation tools

1D Hydrodynamic Simulation

- assumptions
- river modelling elements

Theoretical Background

- unsteady flow, Saint-Venant equations
- numerical method Abbott-Ionesco scheme

Mike 11 Product

- components
- exercise: simple academic test case, simplified river model

Part 1

Software Tools
1D River Modelling

Examples

1D River Modelling Software Tools

Numerical Simulation Tools

- physics: based on the Saint-Venant Equations
- numerics: mainly Finite Difference Method
- examples

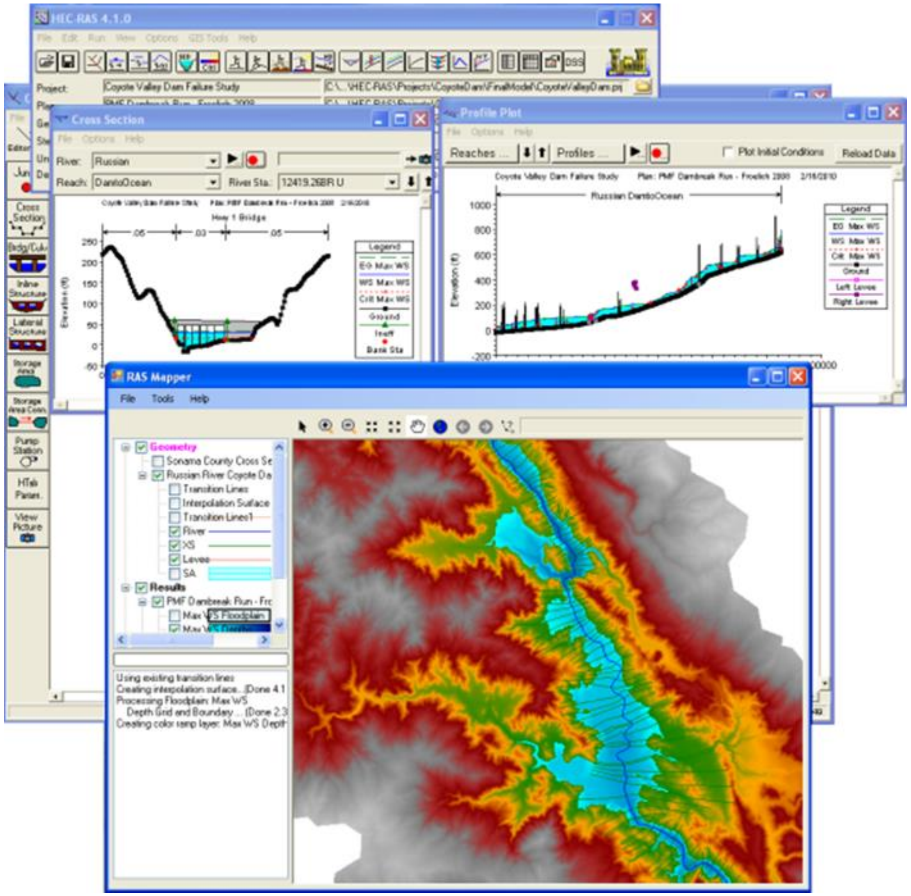
Mike11	DHI (DK)	-> MIKE HYDRO River
HEC-RAS	U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center (HEC)	
ISIS1D	Halcrow/CH2M/Jacobs(UK)	-> FloodModeller
SOBEK	Deltares (NL)	
Kalypso1D	TU Hamburg-Harburg Björnsen Consulting Engineers (D)	

1D River Modelling Software Tools

HEC-RAS

Overview

- numerical simulation of
  1D hydraulic water flow in
  natural and artificial channels
  subcritical, supercritical, mixed flow regime,
  bridges, culverts, weirs and structures



- simulation of:
  - steady flow
  - unsteady flow
  - sediment transport
  - mobile bed computations
  - water quality

1D River Modelling Software Tools

HEC-RAS

Overview

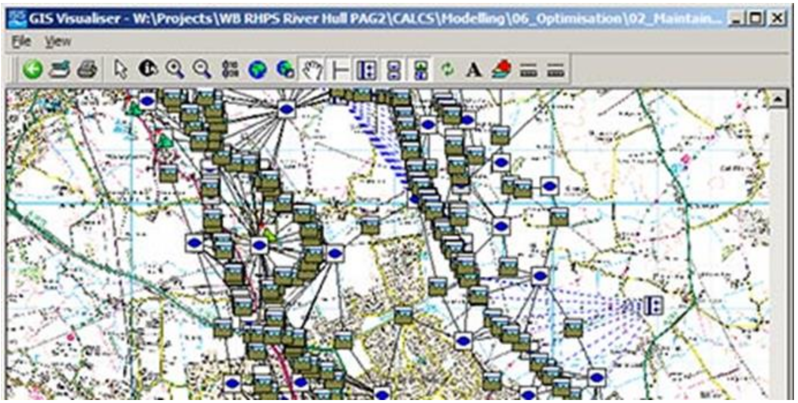
- provider: U.S. Army Corps of Engineers
  Hydrologic **E**ngineering **C**enter
- license: public release (see web page for details) since 1995
- version: 5.0.6 (2018)
- approach: unsteady flow: 1D Saint-Venant equations
  finite difference method
  Preissmann implicit scheme or 4-point Box scheme
- Web page: http://www.hec.usace.army.mil/software/hec-ras/

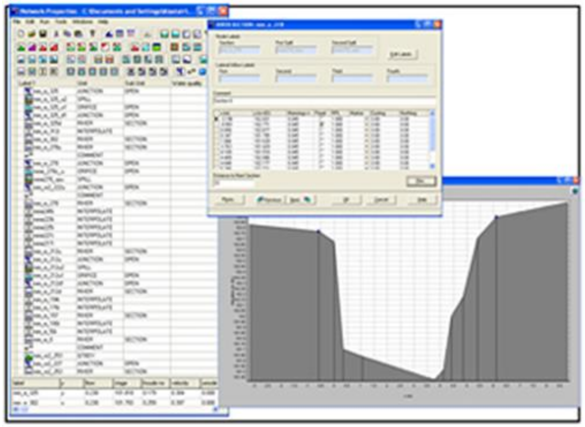
1D River Modelling Software Tools

ISIS1D

Overview

- full hydrodynamic simulator for flows and levels in open channels and estuaries, complex looped and branched networks
- complex structures and operating rules
- unsteady, steady, subcritical, supercritical and transitional flows
- water quality and sediment transport modules





ISIS1D -> Flood Modeller Suite

Overview

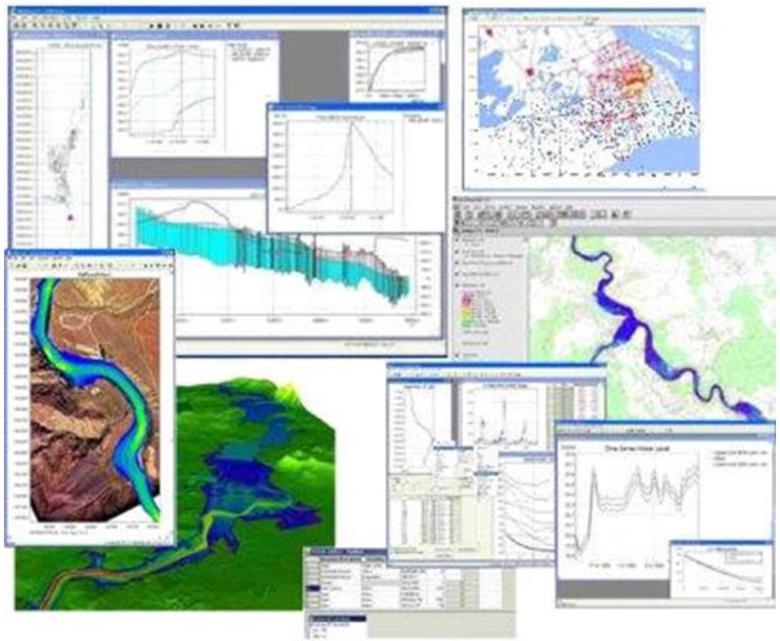
- provider: Jacobs / CH2M / Halcrow (UK)
- license: ISISFree and ISIS1D (see web page for details)
- approach: unsteady flow: 1D Saint-Venant equations
  finite difference method
  Preissmann implicit scheme or 4-point Box scheme
- Web page: https://www.floodmodeller.com

  integration in Flood Modeller Suite

MIKE11

Overview

- steady and unsteady flow in branched and looped channel networks, and flood plains
- flow through a variety of structures
- subcritical and supercritical flow
- additional modules:
  - advection-dispersion
  - water quality and ecology
  - sediment transport
  - rainfall-runoff
  - flood forecasting
  - real-time operations
  - dam break



1D River Modelling Software Tools

MIKE11-> MIKE HYDRO River

Overview

- provider: DHI (DK)
- license: commercial and DEMO mode
- approach: unsteady flow: 1D Saint-Venant equations
  finite difference method
  Abbott-Ionescu implicit scheme (6-points)
- Web page: http://www.mikepoweredbydhi.com
  Mike11 succeeded in the Mike2016 edition by:
  MIKE HYDRO River

1D River Modelling Software Tools

Conclusion

- several similar tools available
    commercial, freeware, open source
- similar functionality
- same theoretical background
    e.g. Saint -Venant Equations
- similar numerical approaches
    e.g. implicit FDM scheme

-> software is no problem

- key factor of success
    - data availability
    - knowledge and expertise of the user!

Part 2

1D River Modelling

by

1D Hydrodynamic Numerical Simulation

1D River Modelling

Approach

- reduction of the real-world flow processes to a 1D problem

Basic Assumptions

- water is incompressible and homogeneous
  no significant variations in density
- the bottom slope is small
  $\sin(\alpha) = \alpha$ and $\cos(\alpha) = 1$
- wave lengths are large compared to the water depth
  flow everywhere can be regarded as having a direction parallel to the bottom
  vertical acceleration can be neglected
  hydro-static pressure variation along the vertical can be assumed
- horizontal water level and equal velocity in a cross-section

1D River Modelling

River Var Flood Modelling

- What do we need ?
  - steady or unsteady flow ?
  - subcritical or supercritical flow ?
  - sediment transport, morphodynamics ?
  - water quality ?
- Which physical state variables we are looking for ?
- Which coordinates (space/time) are relevant ?

Steady and Unsteady Flow

- steady -> all the time derivatives of a flow field vanish

$$\frac{\partial Q}{\partial t} = 0 \qquad \frac{\partial h}{\partial t} = 0$$

- unsteady (transient) -> some time derivatives $\neq 0$

$$\frac{\partial Q}{\partial t} \neq 0 \qquad \frac{\partial h}{\partial t} \neq 0$$

examples for time derivatives

Var Flood Modelling - Assumptions

- unsteady flow
- subcritical flow
- supercritical flow nearby structures only
- no morphodynamics (assumption!)
- no water quality study and or impact to HD
- physical state variables: water level and discharge
- coordinates: 1D along the river and time
  2D cross-section vertical to river: value integration / average

River Model Information Components

• geometry	river location by points (geospatial location) cross section vertical to river branches
• topology	connection of branches -> channel network
• physics	parameter for physical descriptions of phenomena's such as gravitation, friction, …
• structures	description of different hydraulics structures, e.g. weir, culverts, bridges, pumps, …
• boundary cond.	physical state variables at spatial model boundary
• initial condition	physical state variables at begin of simulation period
• simulation	period, time step, spatial approximation, numerical parameter, stability criteria

Geometry and Topology Data

- list of points in a 2D earth surface coordinate reference system
  -> global 2D geospatial coordinates
- connection of points to a line as river branch
  -> local 1D coordinate along river -> chainage
- upstream/downstream connections -> river network
  -> topological network structure
- cross section -> cut vertical to local 1D river longitudinal axis
  -> 2D: local horizontal coordinate, global vertical coordinate
- structures: bridge, culvert, weir, pump stations, …
  -> location by 1D river coordinate (chainage)
  -> relevant geometry of structure

Physics – Bed Resistance

- friction between river bed and water flow due to gravity in channels
- depends on bed type and slope
  - -> less friction for smooth concrete
  - -> typical friction for normal gravel
  - -> high friction for rough stones/rocks and vegetation
- part of Saint-Venant equation
  - head loss (potential energy) due to friction along a channel

Physics – Bed Resistance

- Gauckler–Manning–Strickler formula (empiric)

$$\mathrm{v} = \frac{1}{n} R_h{}^{2/3} S^{1/2}$$

v cross-sectional average velocity
n Manning coefficient
R_h hydraulic radius (-> wetted area / wetted perimeter)
S slope of the hydraulic grade line, channel bed slope (constant water depth)

- coefficients

Chezy coefficient	$C = 1/n\ R^{1/6}$
Manning coefficient	n
Strickler coefficient	$K_s = 1/n$ (-> in Mike11 called Manning value M)

- mathematical relation between values
- North American / UK and European point of view

Physics – Bed Resistance

- Manning values - examples

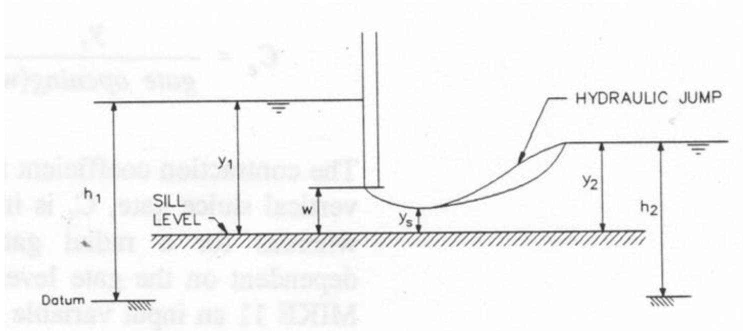
Minor Streams (top width at flood stage < 30 m)

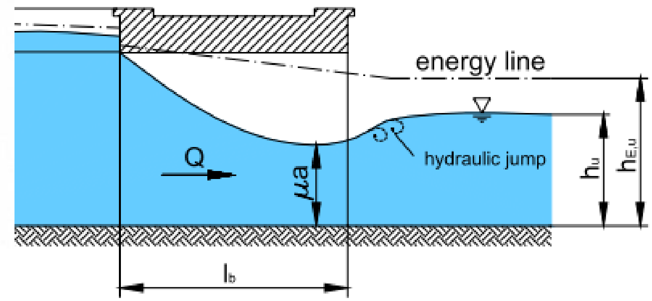
Streams on Plain	Manning n	Strickler K_s
1. Clean, straight, full stage, no rifts or deep pools	0.025–0.033	30-40
2. Same as above, but more stones and weeds	0.030–0.040	25-33
3. Clean, winding, some pools and shoals	0.033–0.045	22-30
4. Same as above, but some weeds and stones	0.035–0.050	20-29
5. Same as above, lower stages, more ineffective slopes and sections	0.040–0.055	18-25
6. Same as 4, but more stones	0.045–0.060	17-22
7. Sluggish reaches, weedy, deep pools	0.050–0.080	12-20
8. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075–0.150	07-13

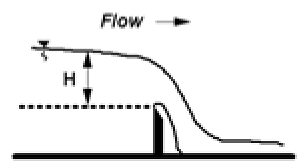
1D River Modelling

Structures

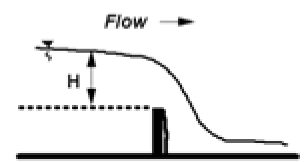
- weirs
- culverts
- control structures
- bridges
- pumps
- dams





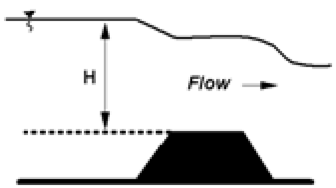


Sharp-Crested Weir



Not Sharp-Crested Weir

integration of empirical equations
in the numerical scheme
-> Q/h relationships, empiric parameters



Broad Crested Weir

example weir –> Poleni equation $Q = \frac{2}{3}\,\mu\,\sqrt{2g}\,B\,h^{\frac{3}{2}}$

Boundary Conditions

- location: at the border / boundary of model
- time: at any time within the simulation period
- types of boundary conditions:

-> 1st type	Dirichlet	-> water level is given
-> 2nd type	Neumann	-> discharge is given
-> 3rd type	Cauchy	-> Q/h relationship: rating curve water level depending discharge

- values for boundary conditions
  - -> constant values
  - -> time series
- additional application: external sources as lateral inflow

Boundary Conditions for Rivers

- typical examples for upstream boundaries
  - -> constant discharge from a reservoir
  - -> discharge hydrograph for a specific event
- typical examples for downstream boundaries
  - -> constant water level, e.g. in a large receiving water body
  - -> time series of water level, e.g. tidal cycle
  - -> rating curve (Q/h), e.g. from a gauging station
- What do we need for lower part of the river Var ?

Initial Conditions

- location: everywhere in the model
- time: for the begin of the simulation period
- methods to specify initial conditions
  -> manual specification of local and global values
  -> steady state calculation
  -> result of another simulation: "hotstart"
- impact of initial conditions to results
- strategies to specify initial conditions

Simulation

- time: simulation period, time steps
- space: simulation grid points
- numerics: scheme parameter, iteration parameter, …
  stability criteria
  implicit/explicit schemes -> solver type
- results: storage frequency,
  type of physical state variables
  location of physical state variables

Part 3

Theoretical Background

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Mike11: Theoretical Background

Simulation Abstraction Steps

- **reality**
  abstraction by physical system using assumptions, simplifications
- **physical system**
  physical behavior described by physical laws and principles
- **physical laws**
  described by differential equations
- **numerical method**
  differential equations -> system of algebraic equations
- **mathematical algorithm**
  solving the system of algebraic equations

Mike11: Theoretical Background

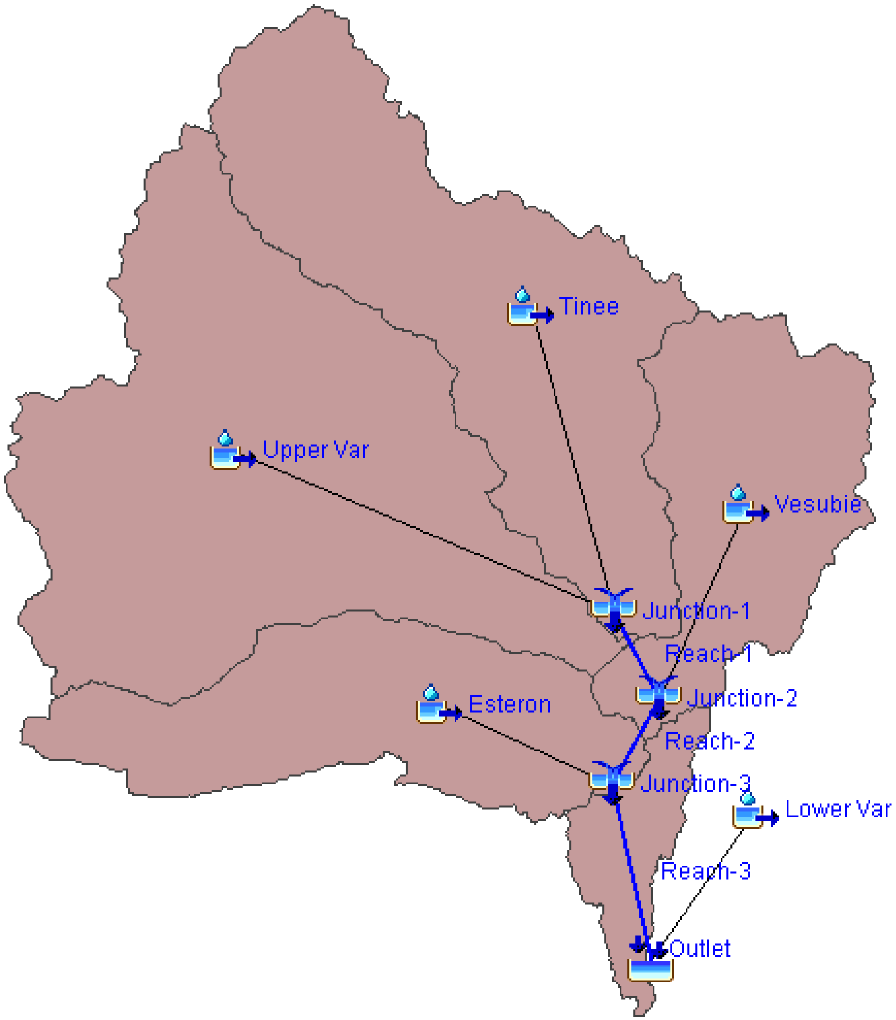
Reality

River Var

Mike11: Theoretical Background

Physical System

- river network
- cross sections
- flood plains
- structures



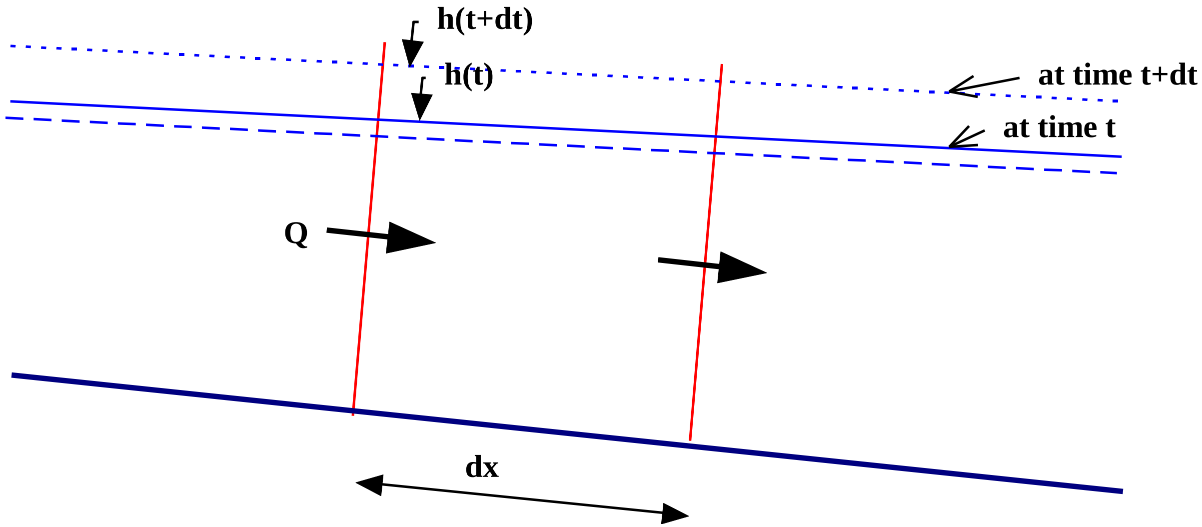
Mike11: Theoretical Background

Physical Laws

- 1D Saint-Venant Equations
  simplification of the shallow water equations in 2D
  depth-integrated Navier-Stokes equations
  Continuity Equation (Conservation of Mass)
  Momentum Equation (Conservation of Momentum)
- assumptions
  - incompressible and homogeneous fluid
  - flow is mainly one-dimensional
  - bottom slope is small
  - small longitudinal variation of cross-sectional parameters
  - hydrostatic pressure distribution

Physical Laws - 1D Saint-Venant Equations

Continuity Equation (Conservation of Mass)

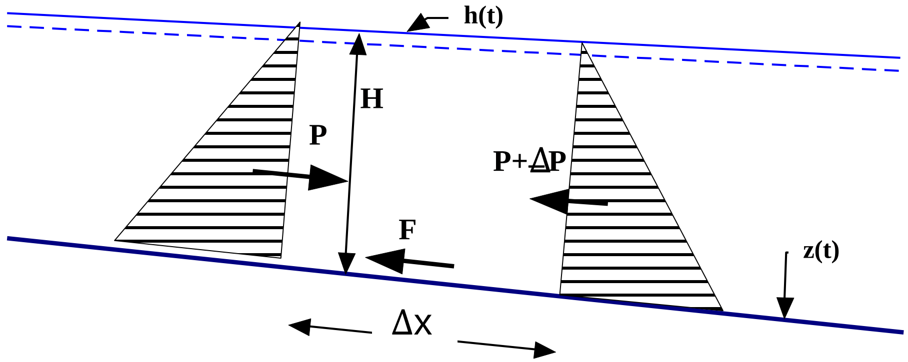


$$\rho \cdot Q \cdot dt - \rho \cdot (Q + \frac{\partial Q}{\partial x} dx) dt = \rho \cdot dA \cdot dx = \rho \cdot \frac{\partial A}{\partial t} dx \cdot dt \qquad \frac{\partial Q}{\partial x} - B \cdot \frac{\partial h}{\partial t} = 0$$

increase of mass from t to Δt =
mass flux into control volume (t->t+Δt) + mass flux out of control volume (t->t+Δt)

Physical Laws - 1D Saint-Venant Equations

Momentum Equation (Conservation of Momentum)



Momentum	= Mass per unit length * velocity
Momentum Flux	= Momentum * velocity
Pressure Force	= Hydrostatic Pressure P
Friction Force	= Force due to Bed Resistance
Gravity Force	= Contribution in X-direction

$$\frac{\Delta M}{\Delta t} = \frac{(M * U)}{\Delta x} + \frac{\Delta P}{\Delta x} - \frac{\Delta F_f}{\Delta x} + \frac{\Delta F_g}{\Delta x}$$

Momentum = Momentum Flux + Pressure - Friction + Gravity

increase of momentum t -> t+Δt = momentum flux into control volume + sum of external forces

$$\frac{\partial Q}{\partial t} + \frac{\partial QV}{\partial x} + gA\frac{\partial H}{\partial x} + g\,A\,S_f + gA\frac{\partial z}{\partial x} = 0$$

Physical Laws - 1D Saint-Venant Equations

Momentum Equation (Conservation of Momentum)

$$\frac{\partial Q}{\partial t} + \frac{\partial QV}{\partial x} + gA\left(\frac{\partial h}{\partial x} + S_f\right) = 0$$

$$v = \frac{1}{n} R^{\frac{2}{3}} S_f^{\frac{1}{2}} \qquad C = \frac{1}{n} R^{\frac{1}{6}} \qquad S_f = \frac{Q|Q|n^2}{R^{\frac{4}{3}} A^2} = \frac{Q|Q|}{C^2 R\, A^2}$$

Manning equation   Chezy/Manning   -> rearranging for S_f

$$\frac{\partial Q}{\partial t} + \frac{\partial (Q\frac{Q}{A})}{\partial x} + gA\frac{\partial h}{\partial x} + g\frac{Q|Q|}{C^2 R\, A} = 0$$

acceleration

local   convective   pressure   friction

Physical Laws - 1D Saint-Venant Equations

- Continuity Equation (Conservation of Mass)

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = q_l \qquad q_l = lateral\ inflow$$

- Momentum Equation (Conservation of Momentum)

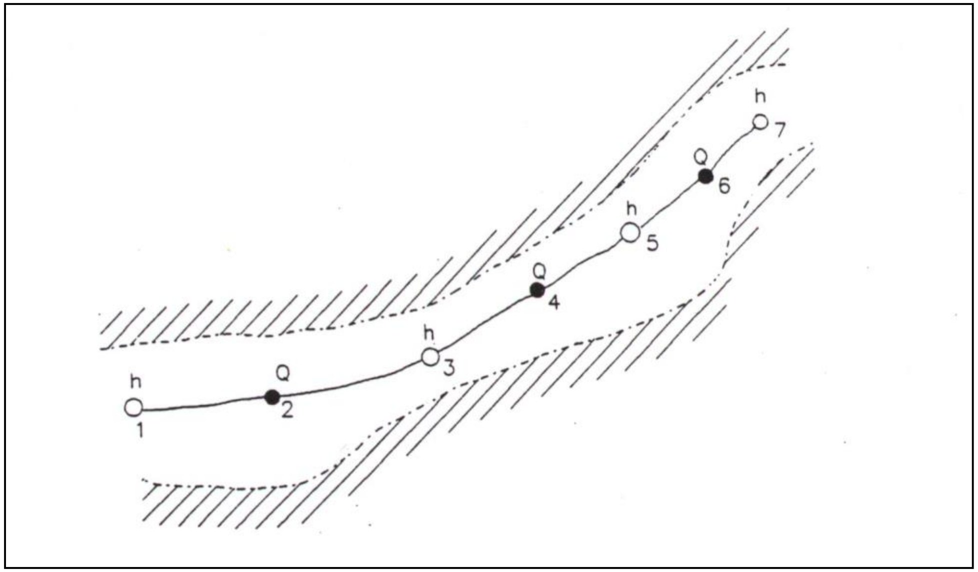
$$\frac{\partial Q}{\partial t} + \frac{\partial (Q\frac{Q}{A})}{\partial x} + gA\frac{\partial h}{\partial x} + g\frac{Q|Q|}{C^2 R\ A} = 0$$

- two partial differential equations
  two unknowns - two coordinates

Numerical Methods

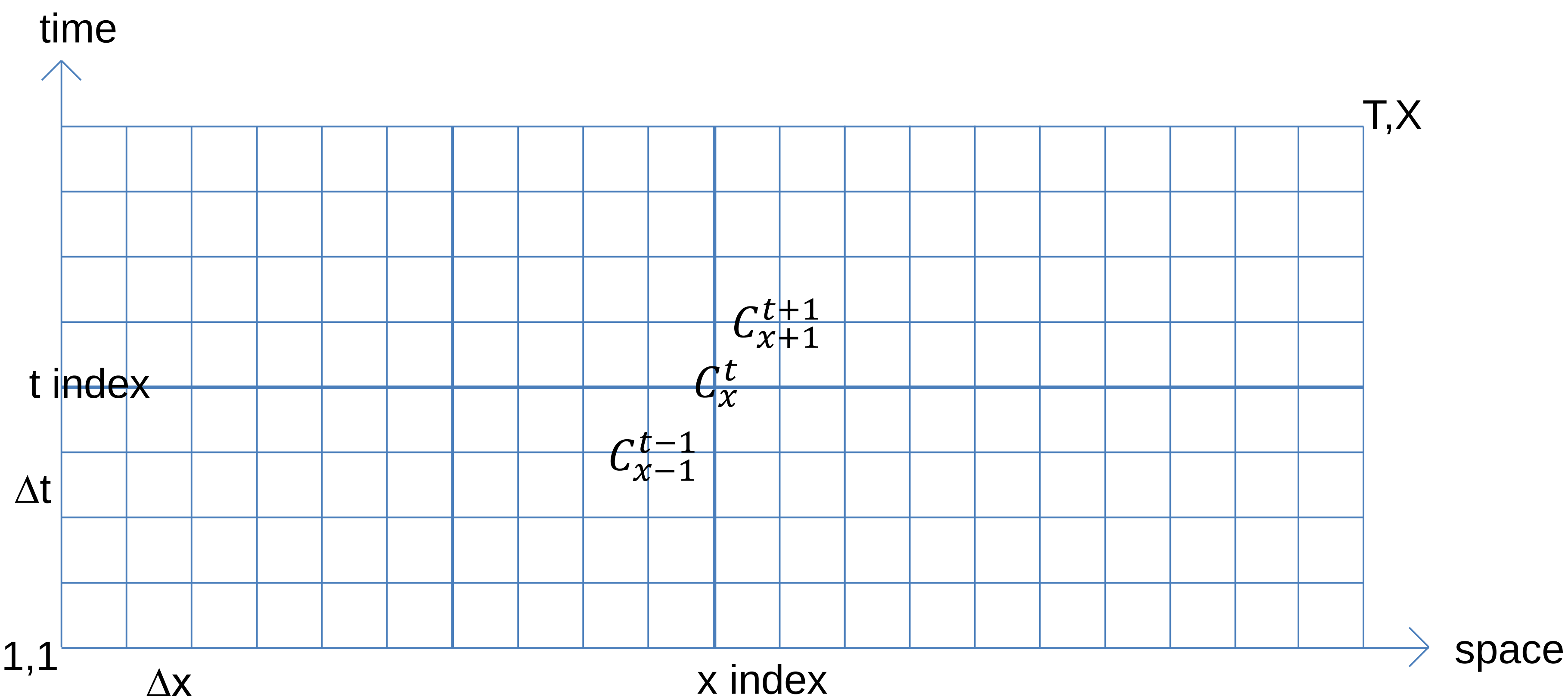
- Finite Difference Method
  implicit Abbott-Ionescu 6-point scheme
- two time levels
  three space levels

  staggered grid
  alternate h, Q



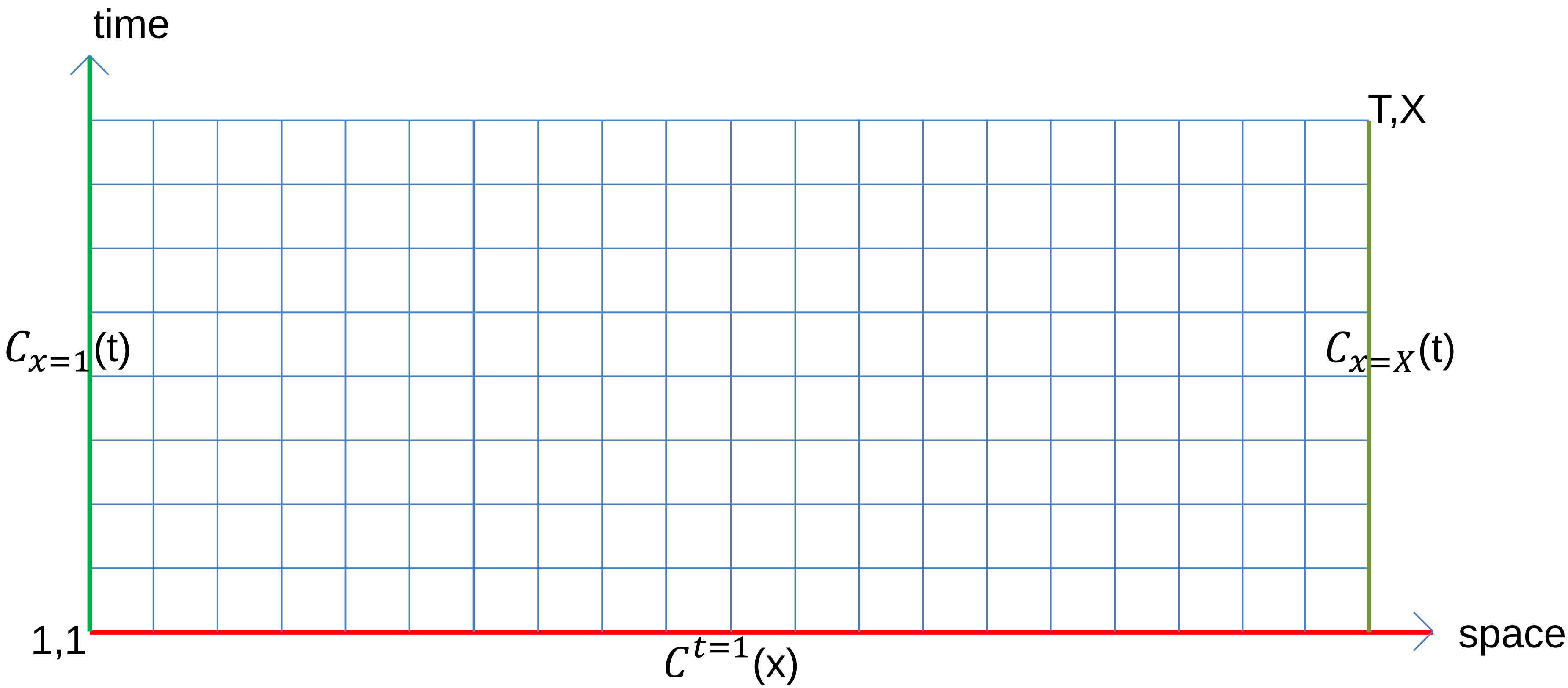
Numerical Methods

Time and Space for one unknown variable C



Numerical Methods

Initial and Boundary Conditions



Mike11: Theoretical Background

Numerical Methods

Finite Difference Method

Discretisation in Time

$$\frac{\partial c}{\partial t} \Rightarrow \frac{c_x^{t+1} - c_x^t}{\Delta t}$$ forward difference in time

$$\frac{\partial c}{\partial t} \Rightarrow \frac{c_x^{t} - c_x^{t-1}}{\Delta t}$$ backward difference in time

$$\frac{\partial c}{\partial t} \Rightarrow \frac{c_x^{t+1} - c_x^{t-1}}{2\,\Delta t}$$ central difference in time

Numerical Methods

Finite Difference Method

Discretisation in Space

$$\frac{\partial c}{\partial x} \Rightarrow \frac{c_{x+1}^{t} - c_{x}^{t}}{\Delta x}$$ forward difference in space

$$\frac{\partial c}{\partial x} \Rightarrow \frac{c_{x}^{t} - c_{x-1}^{t}}{\Delta x}$$ backward difference in space

$$\frac{\partial c}{\partial x} \Rightarrow \frac{c_{x+1}^{t} - c_{x-1}^{t}}{2\,\Delta x}$$ central difference in space

Numerical Methods

Crank–Nicolson method

linear superposition of difference on old and new time level

superposition parameter $0 \leq \Theta \leq 1$

example central difference in space

$$\frac{\partial c}{\partial x} \Rightarrow \theta \frac{c_{x+1}^{t+1} - c_{x-1}^{t+1}}{2\Delta x} + (1-\theta) \frac{c_{x+1}^{t} - c_{x-1}^{t}}{2\Delta x}$$

stability given for $\Theta \geq 0.5$ (Saint Venant equation)

in Mike11: $\Theta = 0.5$

$$\frac{\partial c}{\partial x} \Rightarrow 0.5 \frac{c_{x+1}^{t+1} - c_{x-1}^{t+1}}{2\Delta x} + 0.5 \frac{c_{x+1}^{t} - c_{x-1}^{t}}{2\Delta x} = \frac{\frac{c_{x+1}^{t+1} + c_{x+1}^{t}}{2} - \frac{c_{x-1}^{t+1} + c_{x-1}^{t}}{2}}{2\Delta x}$$

Numerical Methods

Continuum Equation

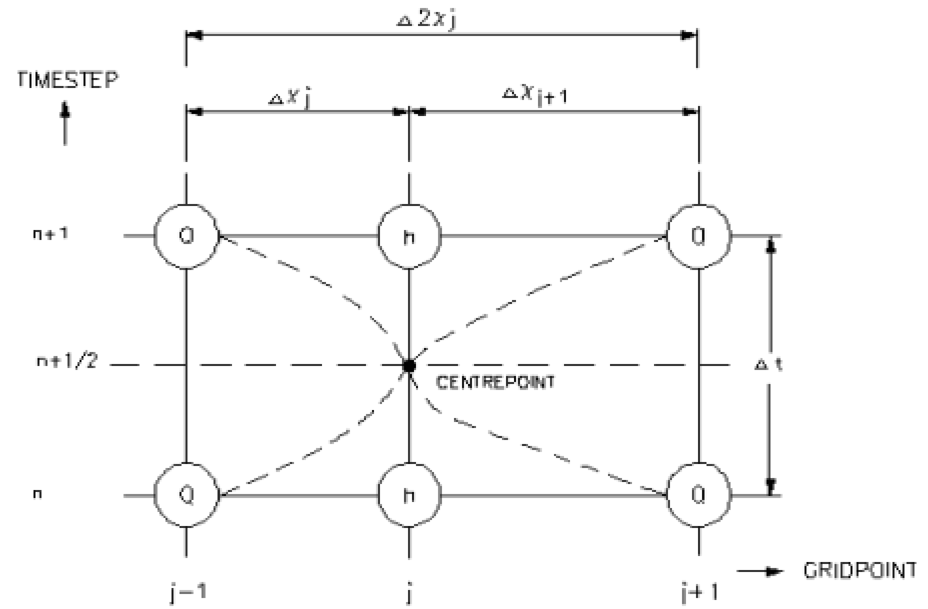
$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = q \qquad \frac{\partial A}{\partial t} = b_s \frac{\partial h}{\partial t} \qquad \frac{\partial Q}{\partial x} + b_s \frac{\partial h}{\partial t} = q$$

$$\frac{\partial Q}{\partial x} \approx \frac{\frac{(Q_{j+1}^{n+1} + Q_{j+1}^{n})}{2} - \frac{(Q_{j-1}^{n+1} + Q_{j-1}^{n})}{2}}{\Delta 2x_j}$$

$$\frac{\partial h}{\partial t} \approx \frac{(h_j^{n+1} - h_j^{n})}{\Delta t}$$

$$b_s = \frac{A_{o,j} + A_{o,j+1}}{\Delta 2x_j}$$

$$\alpha_j Q_{j-1}^{n+1} + \beta_j h_j^{n+1} + \gamma_j Q_{j+1}^{n+1} = \delta_j$$



Mike11: Theoretical Background

Numerical Methods

Momentum Equation

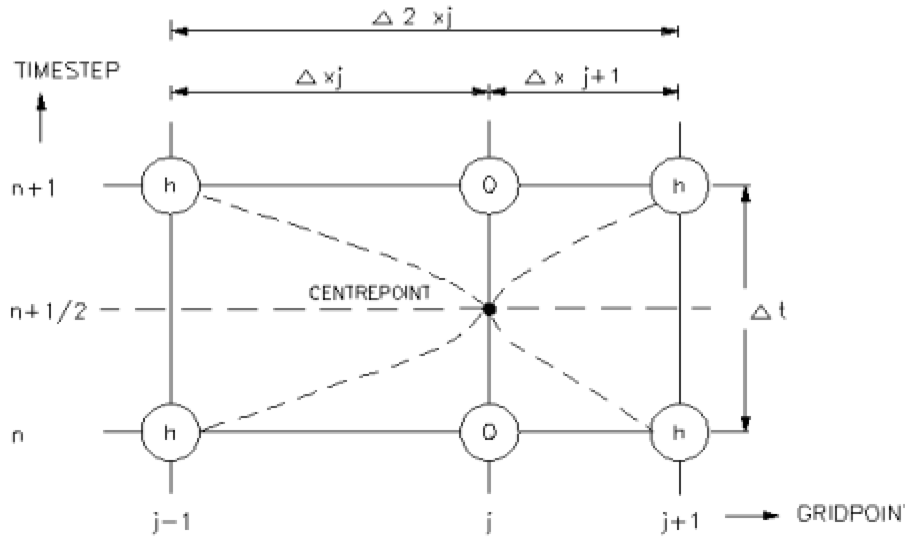
$$\frac{\partial Q}{\partial t} + \frac{\partial\left(\alpha \frac{Q^2}{A}\right)}{\partial x} + gA\frac{\partial h}{\partial x} + \frac{gQ|Q|}{C^2 AR} = 0$$

$$\frac{\partial Q}{\partial t} \approx \frac{Q_j^{n+1} - Q_j^n}{\Delta t}$$

$$\frac{\partial\left(\alpha \frac{Q^2}{A}\right)}{\partial x} \approx \frac{\left[\alpha \frac{Q^2}{A}\right]_{j+1}^{n+½} - \left[\alpha \frac{Q^2}{A}\right]_{j-1}^{n+½}}{\Delta 2x_j}$$

$$\frac{\partial h}{\partial x} \approx \frac{\frac{(h_{j+1}^{n+1} + h_{j+1}^n)}{2} - \frac{(h_{j-1}^{n+1} + h_{j-1}^n)}{2}}{\Delta 2x_j}$$

$$\alpha_j h_{j-1}^{n+1} + \beta_j Q_j^{n+1} + \gamma_j h_{j+1}^{n+1} = \delta_j$$



$$\alpha_j = f(A)$$

$$\beta_j = f(Q_j^n, \Delta t, \Delta x, C, A, R)$$

$$\gamma_j = f(A)$$

$$\delta_j = f(A, \Delta x, \Delta t, \alpha, q, v, \theta, h_{j-1}^n, Q_{j-1}^{n+½}, Q_j^n, h_{j+1}^n, Q_{j+1}^{n+½})$$

Mathematical Algorithm

- equation system structure(one branch, no connection)

$$\alpha_j h_{j-1}^{n+1} + \beta_j Q_j^{n+1} + \gamma_j h_{j+1}^{n+1} = \delta_j$$

$$\alpha_j Q_{j-1}^{n+1} + \beta_j h_j^{n+1} + \gamma_j Q_{j+1}^{n+1} = \delta_j$$

$$\begin{bmatrix}
\alpha_1 & \beta_1 & \gamma_1 & & & & & & & & & \delta_1 \\
& \alpha_2 & \beta_2 & \gamma_2 & & & & & & & & \delta_2 \\
& & \alpha_3 & \beta_3 & \gamma_3 & & & & & & & \delta_3 \\
& & & \alpha_4 & \beta_4 & \gamma_4 & & & & & & \delta_4 \\
& & & & \alpha_5 & \beta_5 & \gamma_5 & & & & & \delta_5 \\
& & & & & \cdot & \cdot & \cdot & & & & \cdot \\
& & & & & & \cdot & \cdot & \cdot & & & \cdot \\
& & & & & & & \alpha_{n-2} & \beta_{n-2} & \gamma_{n-2} & & \delta_{n-2} \\
& & & & & & & & \alpha_{n-1} & \beta_{n-1} & \gamma_{n-1} & \delta_{n-1} \\
& & & & & & & & & \alpha_n & \beta_n \quad \gamma_n & \delta_n
\end{bmatrix}$$

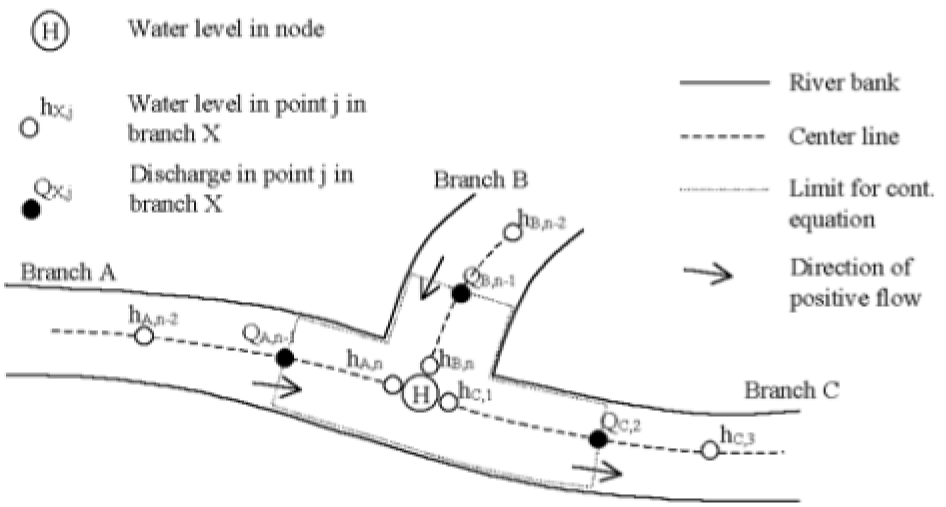
Mathematical Algorithm

- equation system transformation

$$
\begin{bmatrix}
\alpha_1 & \beta_1 & \gamma_1 & & & & & & & & & & \delta_1 \\
& \alpha_2 & \beta_2 & \gamma_2 & & & & & & & & & \delta_2 \\
& & \alpha_3 & \beta_3 & \gamma_3 & & & & & & & & \delta_3 \\
& & & \alpha_4 & \beta_4 & \gamma_4 & & & & & & & \delta_4 \\
& & & & \alpha_5 & \beta_5 & \gamma_5 & & & & & & \delta_5 \\
& & & & & \cdot & \cdot & \cdot & & & & & \cdot \\
& & & & & & \cdot & \cdot & \cdot & & & & \cdot \\
& & & & & & & \alpha_{n-2} & \beta_{n-2} & \gamma_{n-2} & & & \delta_{n-2} \\
& & & & & & & & \alpha_{n-1} & \beta_{n-1} & \gamma_{n-1} & & \delta_{n-1} \\
& & & & & & & & & \alpha_n & \beta_n & \gamma_n & \delta_n
\end{bmatrix}
\begin{bmatrix}
a_1 & 1 & & & & & & & & & & b_1 & c_1 \\
a_2 & & 1 & & & & & & & & & b_2 & c_2 \\
a_3 & & & 1 & & & & & & & & b_3 & c_3 \\
a_4 & & & & 1 & & & & & & & b_4 & c_4 \\
a_5 & & & & & 1 & & & & & & b_5 & c_5 \\
\cdot & & & & & & \cdot & & & & & \cdot & \cdot \\
\cdot & & & & & & & \cdot & & & & \cdot & \cdot \\
a_{n-2} & & & & & & & & 1 & & & b_{n-2} & c_{n-2} \\
a_{n-1} & & & & & & & & & 1 & & b_{n-1} & c_{n-1} \\
a_n & & & & & & & & & & 1 & b_n & c_n
\end{bmatrix}
$$

Mathematical Algorithm

- node point solution
  -> branch network
- boundary equations
  -> h known
  -> Q known
  -> Q/h relationship
- matrix bandwidth minimization
- Double Sweep algorithm



Part 4

MIKE11 Components

Mike11 File Structure (HD Simulation)

• Simulation File	*.sim11 file
• Network File	*.nwk11 file
• Crossection File	*.xns11 file
• Boundary File	*.bnd11 file
• Hydrodynamics Parameter File	*.hd11 file
• Time Series File	*.dfs0 file
• Result File	*.res11 file (MikeView)

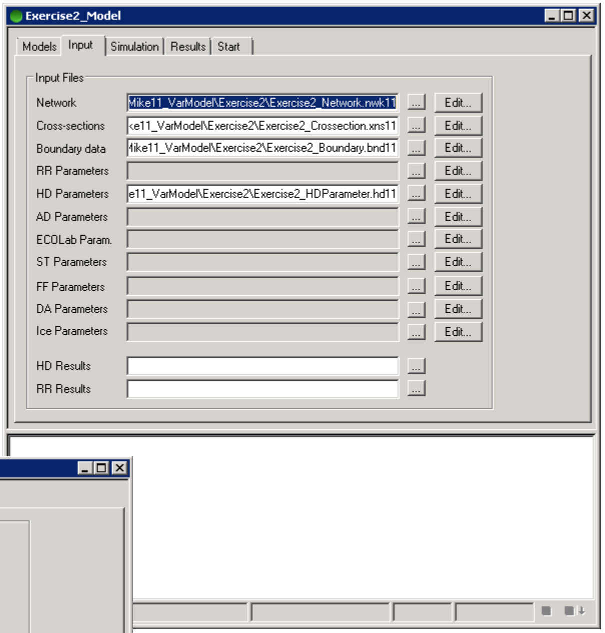
-> each file type do have a related editor tool within MikeZero

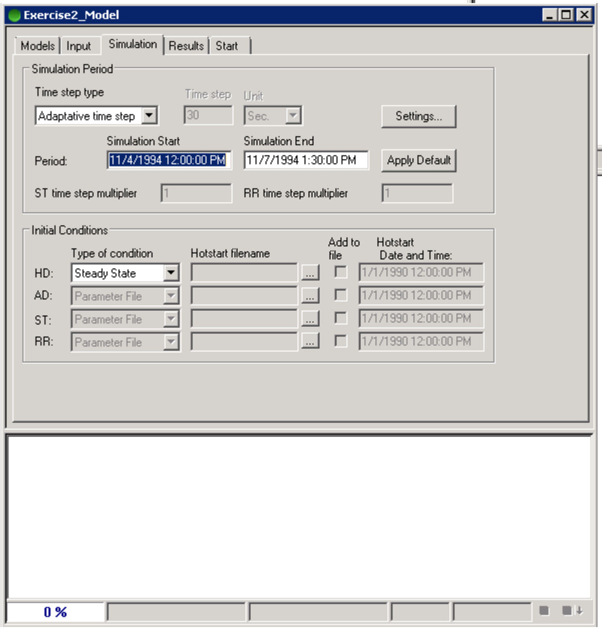
-> central core file is always the *.sim11 file (file to start modelling)

Mike11 Components

Simulation File

- simulation type/mode hydrodynamic/steady
- input files
- simulation data
  - time window
  - time step
  - initial conditions
- simulation results
  - result file, storage frequency
- simulation run control
  - warnings and errors

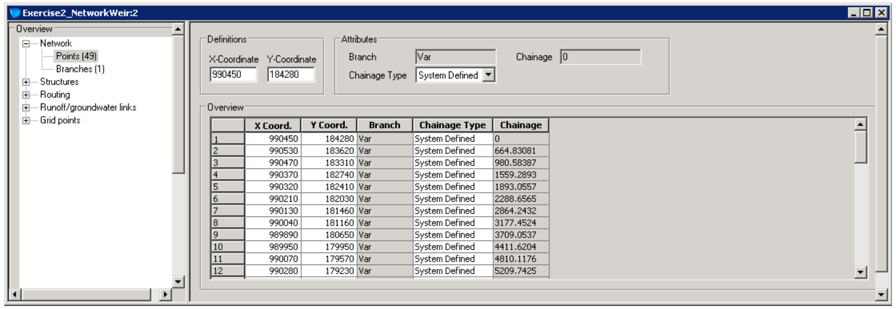


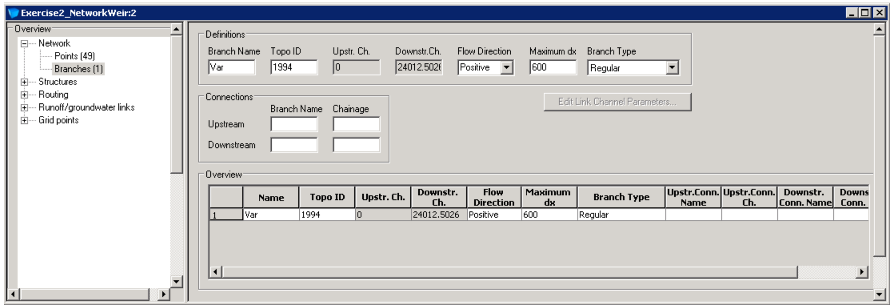


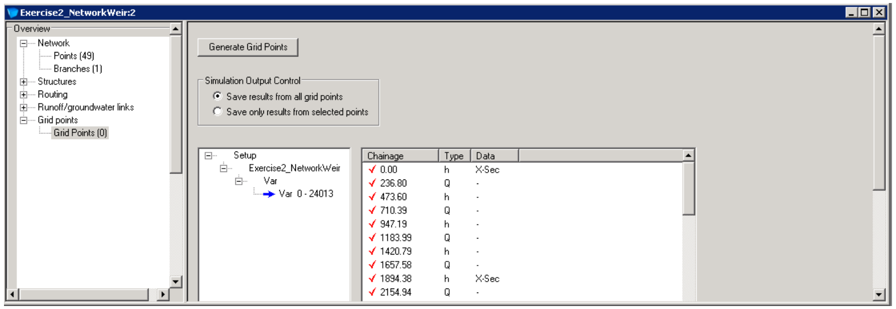
Mike11 Components

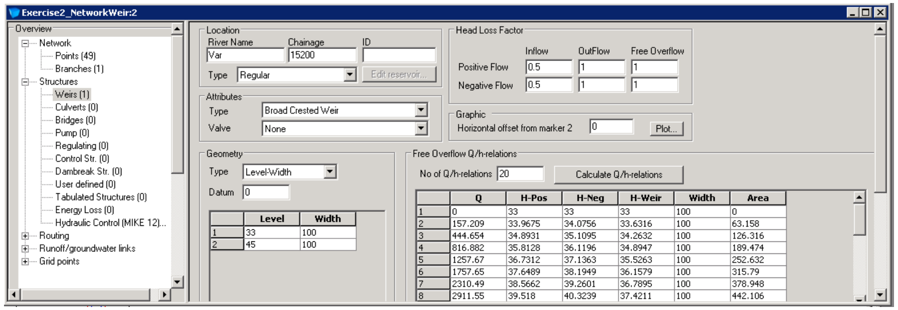
Network File

- river branch(s) geospatial location
  - branch name
  - topological id (e.g. year of measurement)
  - geospatial points (x-y system)
- control structure
  examples: weirs
- grid points
  - generated points for numerical simulation
    staggered grid for h and Q nodes (grid points)







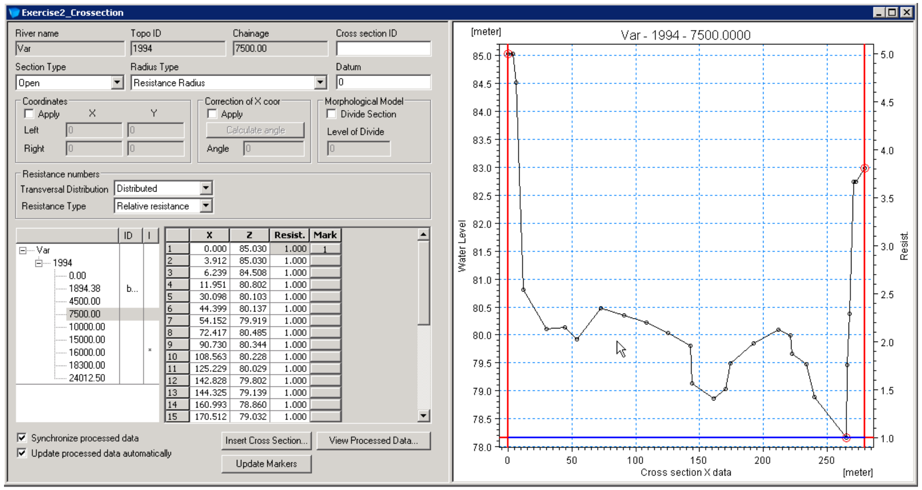


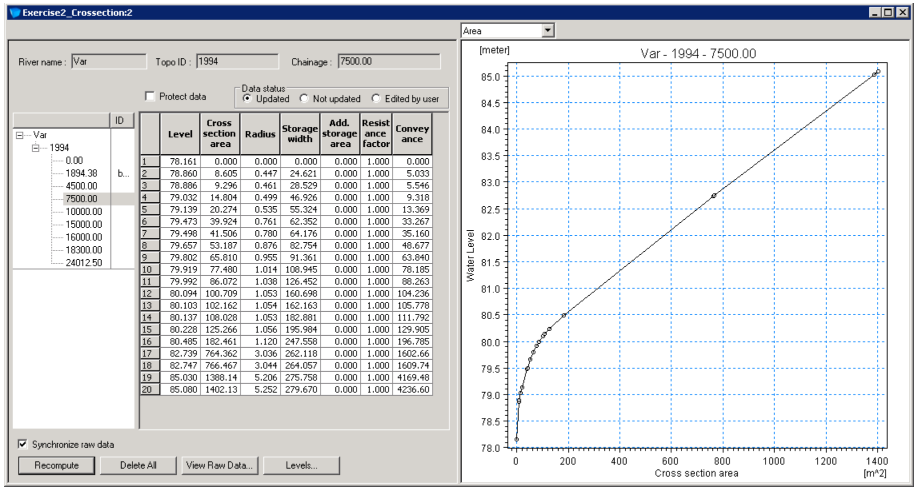
Mike11 Components

Crossection File

- crossection location
  - branch name
  - chainage
  - topological id (e.g. year of measurement)
- crossection points
  - profile coordinate (x)
  - vertical elevation (z)
- marker

  examples:
  - left levee bank
  - lowest point (bed)
  - right levee bank
- processed data
  - e.g. A/h relationship

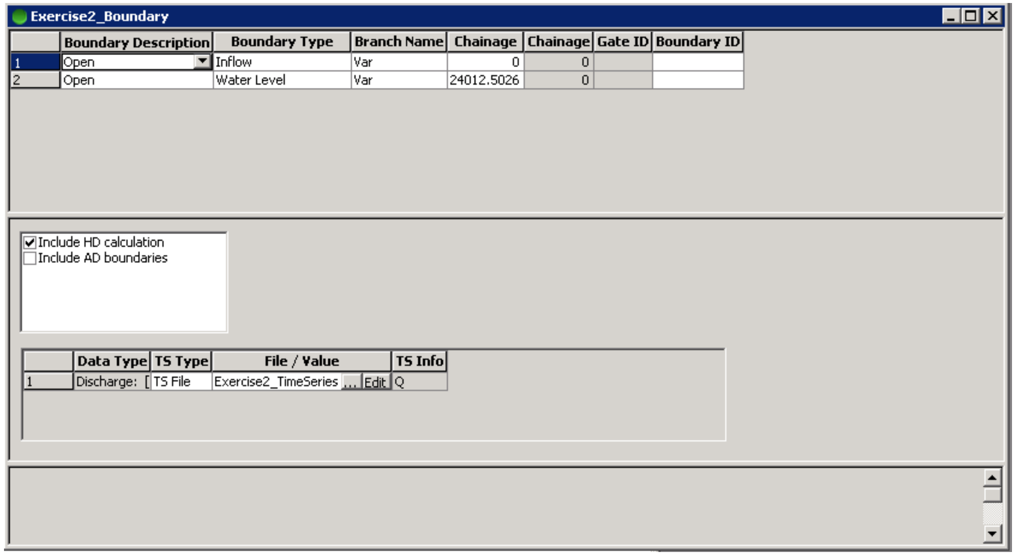




Mike11 Components

Boundary File

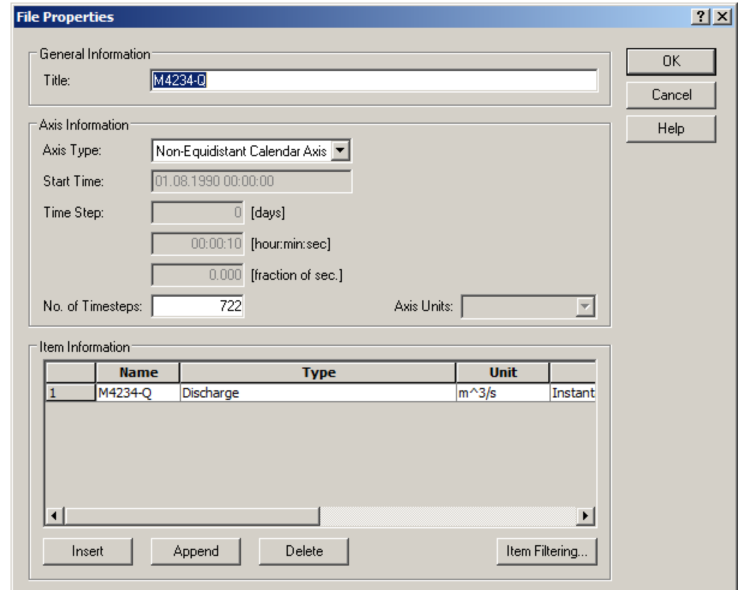
- boundary condition
  - type of boundary condition
  - branch name
  - chainage
- boundary condition values
  - constant value
  - time series item

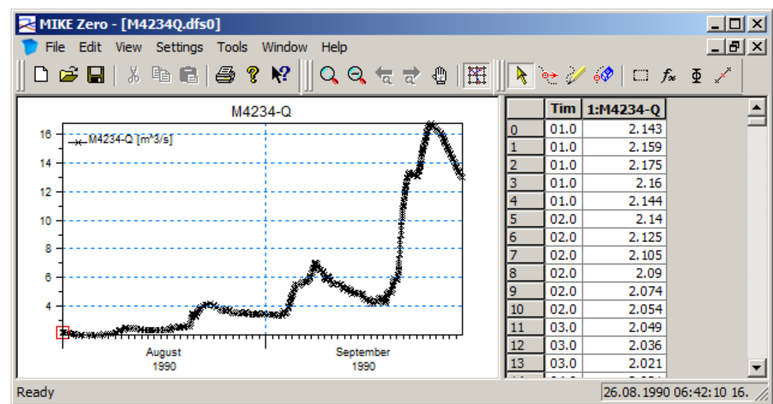


Mike11 Components

Time Series File

- type of time series
  - equidistant, non-equidistant
  - start time, time step,
    number of time steps
- items
  - item name
  - type of value, unit

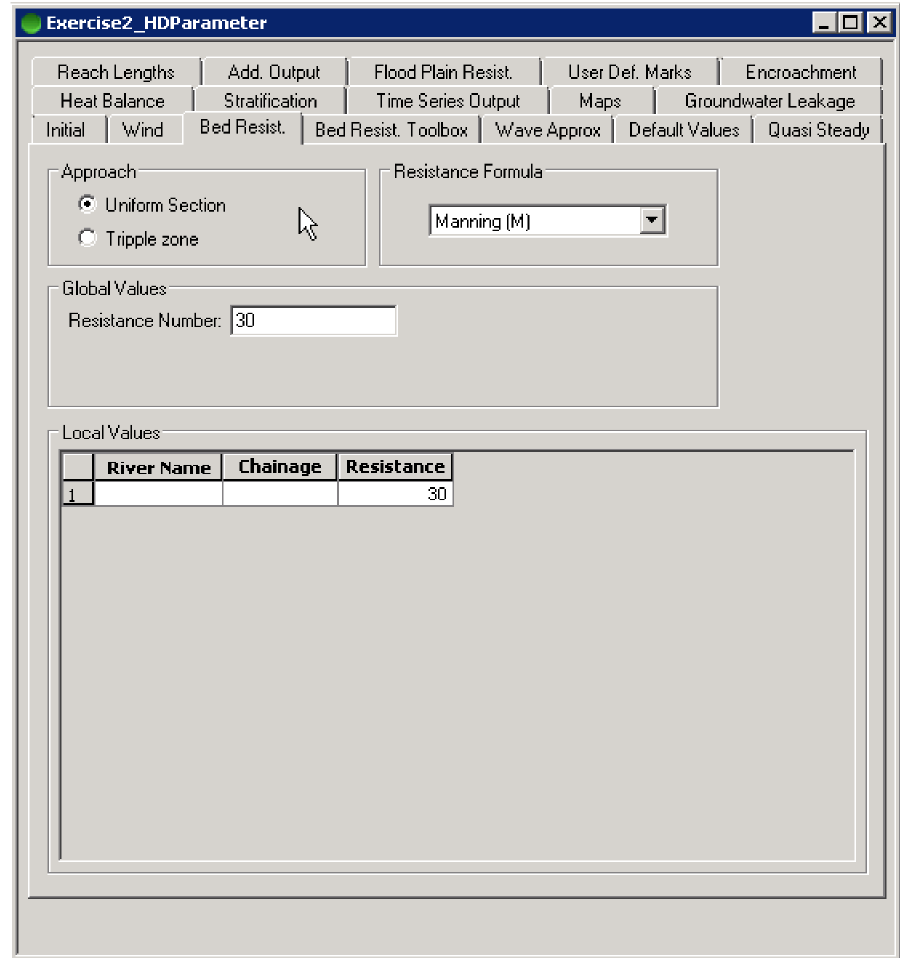




Mike11 Components

Hydrodynamic Parameter

- Bed Resistance
  - global or branch oriented
  - Manning (m), Strickler (M) or Chezy (C)
- Additional Output
  examples:
  - velocity
  - Froude number
  - mass error
- several other options/parameters
  - …

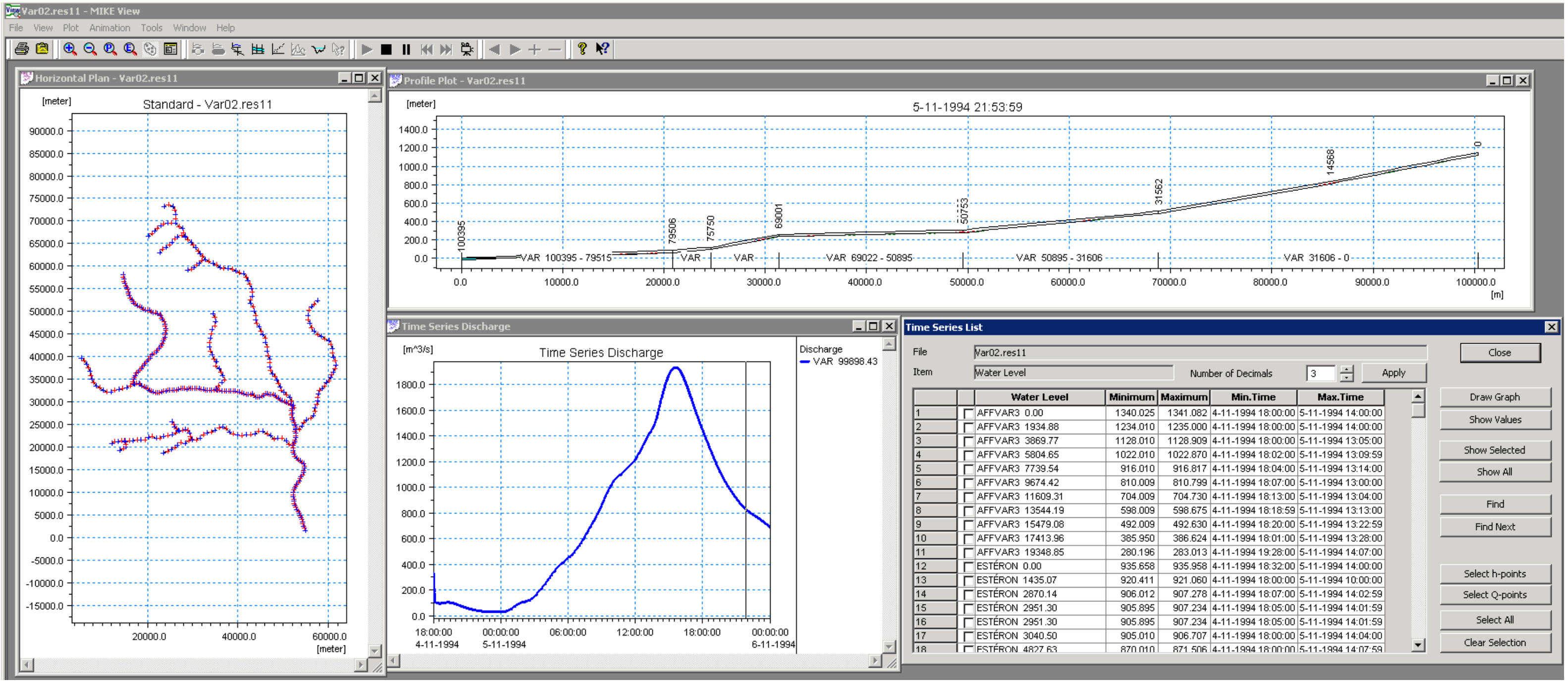


Mike11 Components

Result File

The results are stored in a file with the suffix *res11*.

MikeView is used to visualize and analyse the results of Mike11.



Part 5

MIKE11 Exercises

Exercise 1: Simple Academic Test Case

Set-up of a new model (see tutorial)

- straight channel

  5 km length

  cross section width = 50 m, height = 10 m

  slope: 0%

  material: concrete

- initial condition

  horizontal water level 4 m, discharge 0 m/s

- boundary condition:

  upstream: water level time series 4 m with 6m peak

  downstream: discharge = 0 m^3/s (wall)

Exercise 2: Simplified River Model Case Study

Running a given model (see tutorial)

- given Mike11 model files:

network	Exercise2_Network.nwk11
cross sections	Exercise2_Crossection.xns11
parameter file	Exercise2_HDParameters.hd11
boundary conditions	Exercise2_Boundary.bnd11
	Exercise2_TimeSeries.dfs0
simulation model	Exercise2_Model.sim11

- boundary conditions

upstream:	discharge time series
	1) Q = 300 m**3/s
	2) Q with synthetic flood peak wave
downstream:	water level h = 0 (sea level)

- initial conditions   steady state calculation
- roughness   Strickler value of 30

Exercise 2: Simplified River Var Model Case Study

Simulation Task

- analyse the given river model for normal flow condition
- analyse the given river model for the 1994 flood event
- analyse the impact of the roughness parameter
- analyse the impact of a weir