ARTS hydraulics software

Technical scope and problem solving examples

Introduction

ARTS is a Windows-based hydraulic analysis/design software package, developed with the analytical needs of water and wastewater engineers in mind. It has a broad analytical scope, covering the spectrum of hydraulic problems encountered in the design of water and wastewater engineering infrastructure as well as incorporating special features related to the hydraulic design of wastewater treatment systems. It is operated through a user-friendly graphical interface, that has been designed to minimise user learning effort and, thereby, to encourage its routine use as a computational design aid. The software provides the user with a toolbox of hydraulic objects that can be placed on the screen and linked together to generate a schematic outline of the hydraulic system under consideration. The coding recognises the connectivity of the system and its boundary conditions and carries out the appropriate analysis. This document contains an overview of ARTS and illustrates the methodology used in solving some typical problems.

Scope

ARTS caters for a comprehensive range of hydraulic analysis/design tasks, including:

Steady Pipe Flow

- water/wastewater flow in:
  - pipe links
  - pipe networks
  - pipe manifolds
- flow of sewage sludge in pipes/networks

Open Channel Flow

- uniform flow in a single channel
- gradually and rapidly varied flow in single and multiple channels in series
- decanting channels with distributed lateral inflow
- storm-overflow channels with lateral outflow

Flow Measurement Structures

- hydraulic design of flumes
- hydraulic design of weirs

Pumping Installations

- hydraulic analysis of pump/rising main systems
- multiple pump systems, variable speed pumps

Wastewater Treatment Systems

- hydraulic design of individual process units
- hydraulic design of a group of interconnected process units
- computation of hydraulic profiles

Waterhammer Analysis

- analysis and control of waterhammer pressure transients due to pump trip-out

Features

ARTS comes with in-built features that have been developed to enhance design office productivity and upgrade design office record-keeping. These include a unique easy-to-use graphical interface, incorporating Auto Design and Tool-tip features, and a facility to generate design reports, including text and graphics. Design reports can be printed in hard copy form and can also be stored as ARTS computer files for future reference. Text and graphics from ARTS can be exported to word processing documents for inclusion in technical reports.

USER INTERFACE

ARTS has a unique graphical design interface that enables the user to produce a schematic representation of the hydraulic system on the computer screen, just as simply as it would be sketched on paper. Figure 1 shows a picture of the main design screen, which includes a design sheet, on which the hydraulic system schematic is drawn, and a tool palette from which the component elements of the hydraulic system are selected.

The design sheet sub-window is the ARTS workspace on which the user constructs schematic representations of hydraulic systems, using the objects contained on the tool palette. Multiple design sheets can open at the same time and their simultaneous display on screen can be arranged, using the commands on the Windows menu.

The tool palette contains a selection of buttons, which either select a tool for drawing hydraulic objects or execute commands that carry out specific tasks.

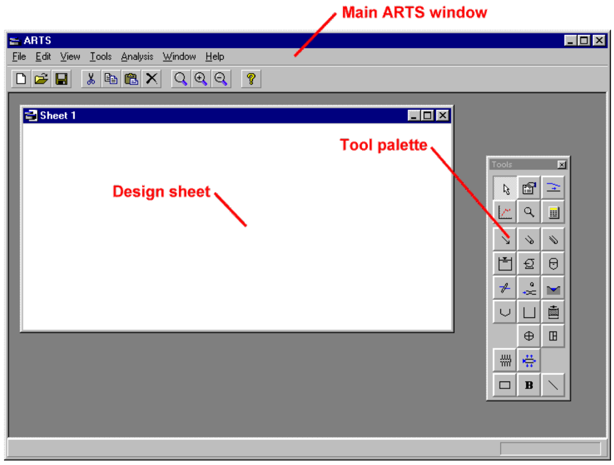


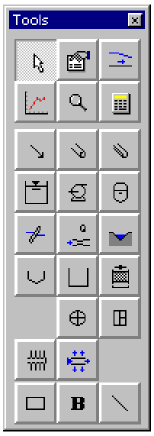
Figure 1 The ARTS workspace

SKETCHING THE SYSTEM LAYOUT

In the same way that an engineer sketches a system being analysed on a sheet of paper, the system to be analysed by ARTS is sketched on the computer screen. ARTS provides a set of hydraulic objects, which are the building blocks for creating hydraulic systems on the screen. These objects can be placed on the design sheet using the mouse, in a similar fashion to any Windows drawing package. Once the hydraulic system is drawn on the screen, the appropriate Analysis command is selected and executed, and the results are printed on the screen graphic.

The first step is to draw a sketch of the system on the design sheet. This applies whether the hydraulic system is a single pipe or channel or a complex series of process units linked by pipes. In all cases, the system components and configuration are communicated to ARTS by drawing a sketch diagram on the design sheet.

Each component is placed on the design sheet by clicking on its tool button, moving the cursor over the design sheet and clicking at the desired location. Objects can be drawn to the desired size and can subsequently re-sized and/or moved to a new location.



Selection tool: For selecting and manipulating objects	**Properties Command Icon:** Displays the properties of the currently selected object.	**Activated Sludge Tool:** For creating an open tank type unit
GVF Command Icon: Displays the gradually varied flow plotter, applied to the currently selected channel	**Graph Command Icon:** Displays a graph. Used with channels, pipes and flumes	**Detritor:** For creating grit removal objects
Zoom Tool: equivalent to selecting Zoom Area from the View menu	**Calculator Command Icon:** Displays the calculator	**Manifold Tool:** For creating flow distribution unit
Flow Tool: Used to create an inflow or outflow from a system	**Pipe Tool:** For creating pipes of constant diameter	**Rectangle Tool:** For creating rectangle (Graphic only)
Channel Tool: For creating channels of constant shape and slope	**Reservoir Tool:** For creating reservoirs of fixed water level	**Biofilter Tool:** For creating a biofilter wastewater treatment unit
Pump Tool: For creating rotodynamic pumps	**Air Vessel Tool:** For creating pressure vessels with air cushions for use in waterhammer control	**Divider Tool:** For creating a flow-dividing chamber
Screen Tool: For creating a water/wastewater screening device	**Flume Tool:** For creating a flow measurement device	**Storm Overflow:** For creating a storm overflow channel with side-weirs
Weir Tool: For creating a flow measurement device	**Sedimentation Tool:** For creating a primary or secondary sedimentation unit	**Text Tool:** For creating text (graphic only)
		Line Tool: For creating lines

ARTS reads the connectivity of an hydraulic system from its design sheet sketch. Thus, pipe and channel links start and end, either in another object such as a sedimentation tank or reservoir, or at the end of another link. The code includes a built-in facility for verifying that the software is correctly interpreting the connectivity presented graphically on the design sheet.

Examples of typical hydraulic systems, as sketched on the design sheet, are shown on Figure 2 and Figure 3.

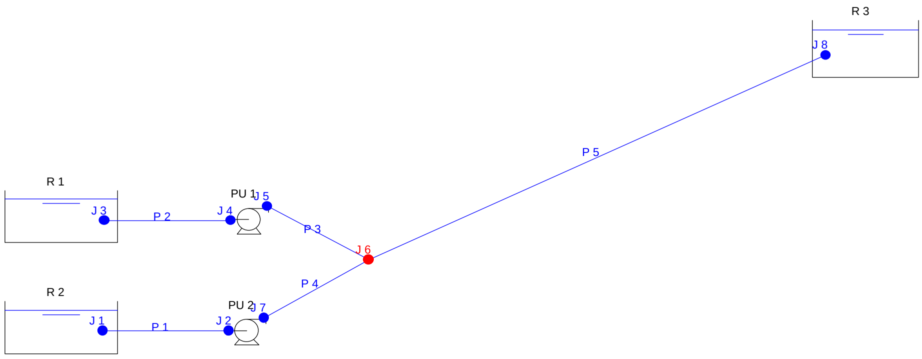


Figure 2 Design sheet sketch of pump-rising main system

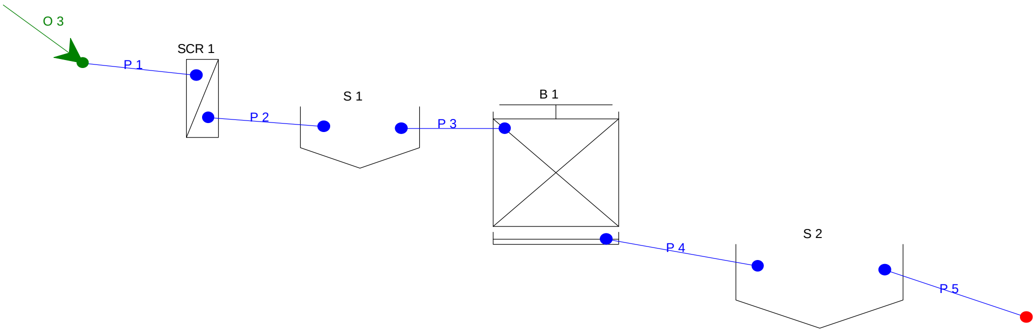


Figure 3 Design sheet schematic of a simple wastewater treatment plant

Every hydraulic object that is placed on the design sheet has properties associated with it. These properties are accessible via dialog boxes known as Property Pages. For example, a pipe object has a length property, a diameter property, a surface roughness property etc. When you place an object on the design sheet you are essentially creating a virtual version of a real world object. For example, when you place a pipe on the screen and then display its Property Pages, you will find that the pipe has initial values for all parameters relevant to its hydraulic performance. The same holds true for all other objects. Thus, the system drawn on the design sheet is not just a bare graphic, such as a similar image drawn on paper, but is backed up by a full complement of parameter values.

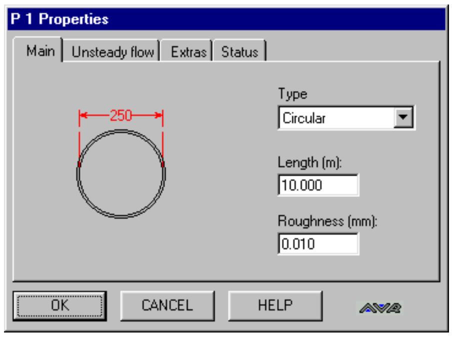


Figure 4 Pipe Main Page

Property pages come replete with graphic images, object shape options (circular or rectangular sedimentation tank, channel shape, etc.), editable initial parameter values, and, most importantly, a comprehensive computational capability related to the internal hydraulic behaviour of the object. Typical examples are shown on Figure 5 and Figure 6.

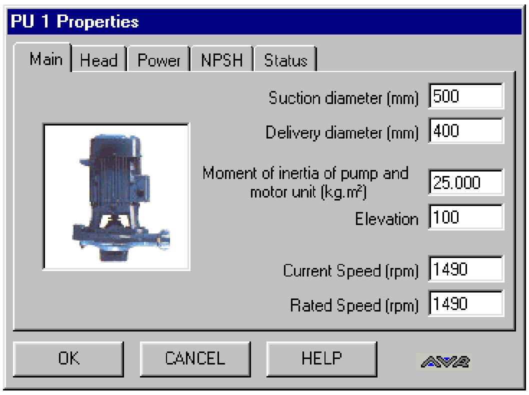


Figure 5 Pump Main page

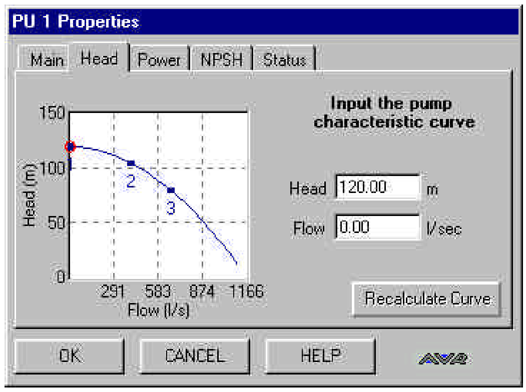


Figure 6 Pump HQ Page

STEADY PIPE FLOW

ARTS provides a comprehensive suite of analytical tools for solving steady pipe flow problems, giving the user maximum flexibility in system specification, including the insertion of fittings, such as bends, valves etc. Provided the interconnected system of pipes is drawn correctly on the design sheet and has a feasible set of boundary conditions, ARTS will compute the flow and pressure distribution and print the results on the sheet graphic.

Steady flow of water/wastewater in pipe links

ARTS incorporates two computational tools, either of which may be used to display the relevant hydraulic parameters for a pipe link, for a user-specified flow condition.

Procedure:

- Draw a pipe on the design sheet and edit its relevant properties on the **Main** (Figure 4) and **Extras** pages.
- Click on the **Status** page.

The **Status** page, indicated in Figure 7, displays several parameters for a given flow. The flow value can be altered, and the other parameters will be updated accordingly.

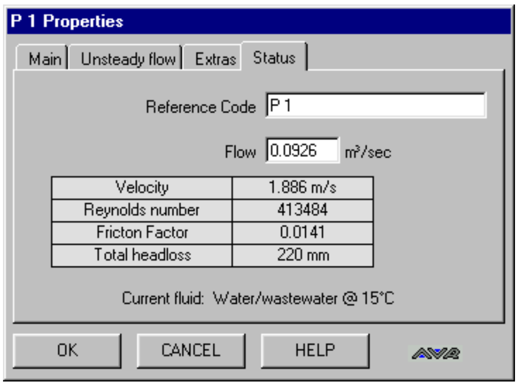


Figure 7 Pipe Status page

As an alternative to this, the **Pipe Calculator** can be used to calculate any parameter, based on all other inputs, as illustrated in Figure 8.

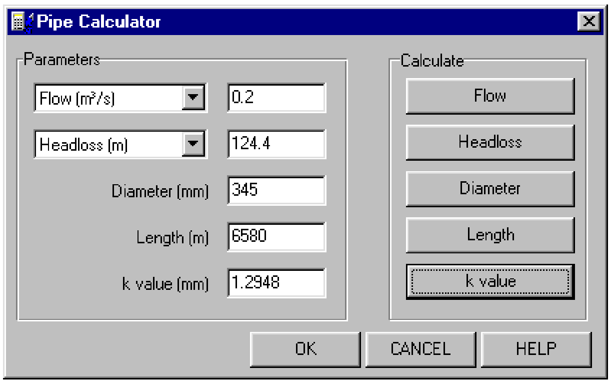
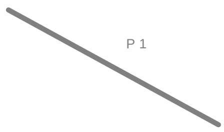


Figure 8 The Pipe Calculator

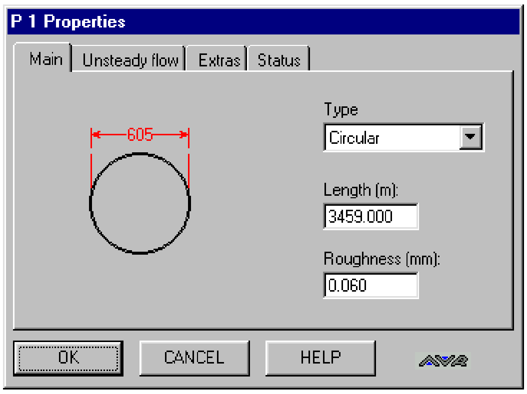
Example 1 Pipe headloss

Calculate the headloss in a pipe, having an ID of 605mm and a surface roughness of 0.06mm, at a flow of 0.85m³/s. The pipe length is 3,459m and it includes four 90° short-radius bends.

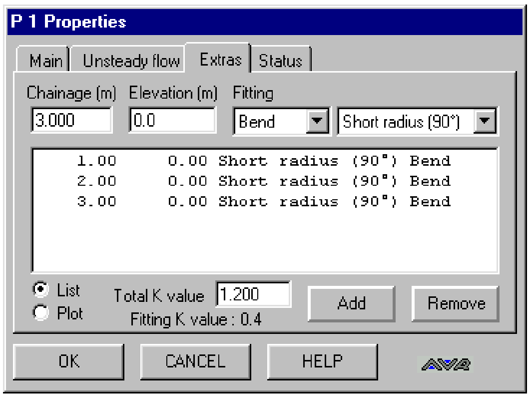
1 Draw a pipe on the design sheet (the pipe is grey until you set some of it's properties)



2 Edit the **Main** property page:

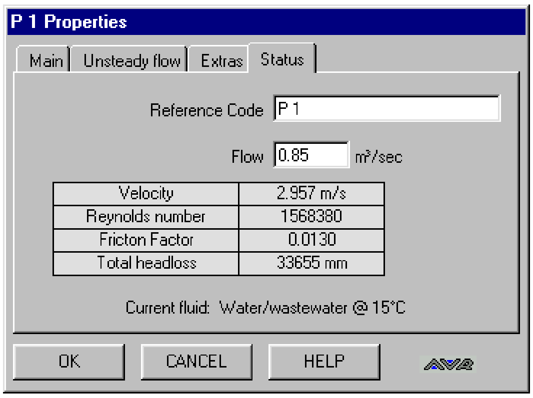


3 Edit the **Extras** property page:



Example 1 Pipe headloss (contd)

4 Click on the **Status** page:



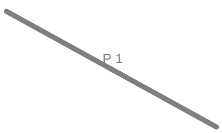
Solution: The headloss through this pipe is **33.65m** at **0.85m^3/s**.

Example 2 Computation of effective roughness

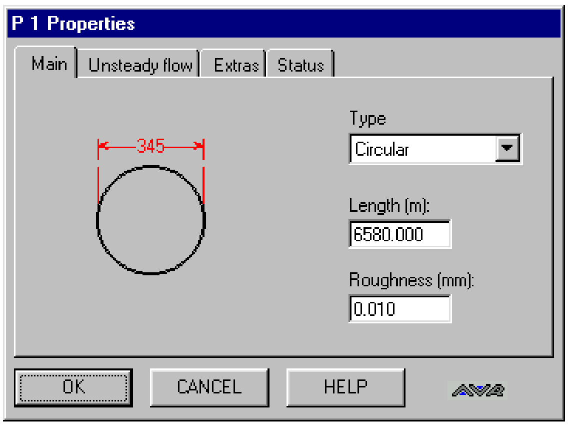
An old rising main is 6580m long and has an internal diameter of 345mm. Under normal steady state operational conditions, the flow has been measured at 0.2m^3/s and the corresponding headloss has been measured at 124.4m. Compute the effective pipe wall roughness.

This computation can be done most conveniently using the **Pipe Calculator**.

1 Draw a pipe on the design sheet

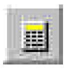


2 Edit the **Main** property page:

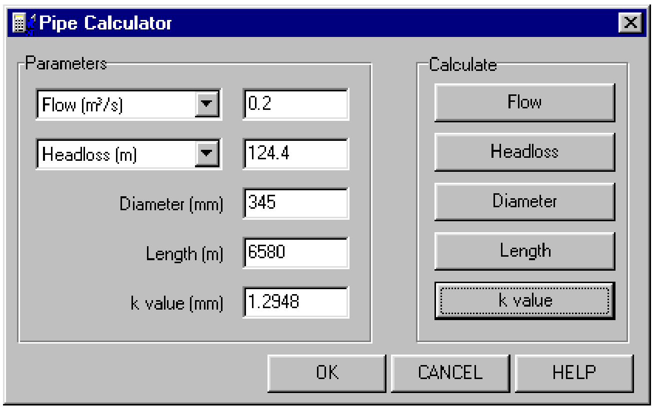


Example 2 Computation of effective roughness (contd)

3 Select the **Pipe Calculator**, from the tools palette



4 Click on the *Calculate* **k value** button



Solution: the effective k value of the old rising main is **1.29mm**

Pipe Networks

The ARTS graphical interface is very convenient for the analysis of flow and pressure in water distribution networks, which may include ancillary features such as booster pumps, non-return valves etc.

Procedure:

- Draw the system under consideration on the sheet and edit the pertinent properties of the objects on the sheet, i.e. pipe diameters, pipe lengths, reservoir levels, pump characteristics, etc.
- Select **Steady pipe flow** from the **Analysis** Menu.

The results of the analysis are printed on the design sheet, indicating flows in pipes, and potential heads at nodes. This display can be modified to display velocities, headlosses, gauge pressures etc.

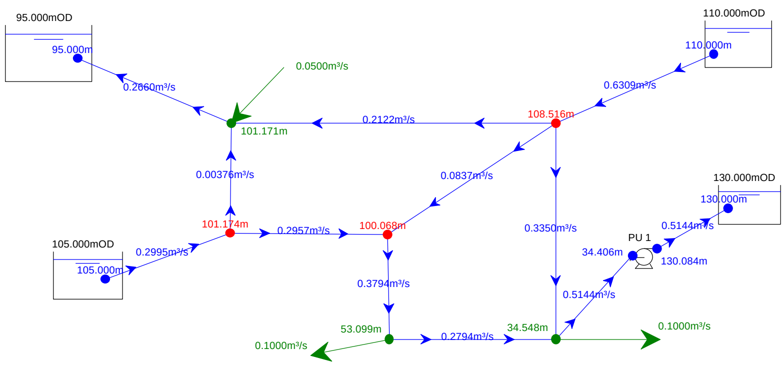
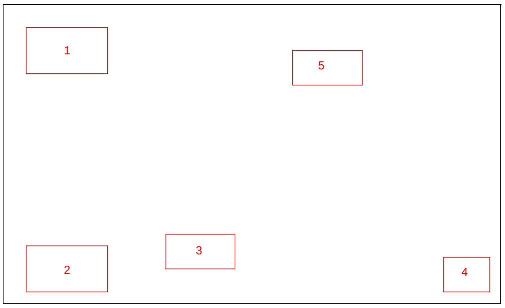


Figure 9 Analysed network

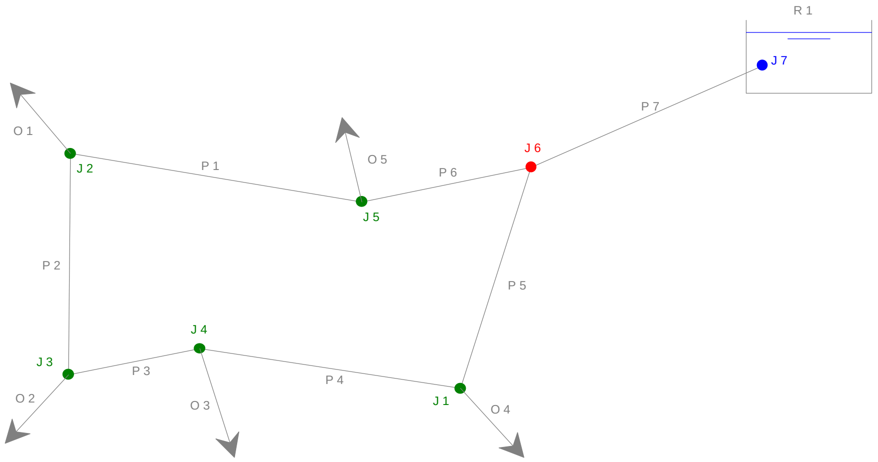
Example 3 Network analysis

A small industrial estate requires a water distribution system to feed the demand points illustrated. The system will be fed from a reservoir at 23mOD, which is 3km away. The required minimum residual head in the system is 3m, at the following maximum demands:

1: 0.02m^3/s, at 10mOD
2: 0.03m^3/s, at 10.6mOD
3: 0.026m^3/s, at 9mOD
4: 0.012m^3/s, at 8.5mOD
5: 0.031m^3/s, at 8mOD



1 Draw a suitable network on the sheet:



2 Edit the relevant properties of the objects on the sheet as follows:

Pipes

Ref	Diameter (mm)	Length (m)	k (mm)
P 1	100	60.00	0.010
P 2	100	50.00	0.010
P 3	150	10.00	0.010
P 4	220	70.00	0.010
P 5	250	55.00	0.010
P 6	200	10.00	0.010
P 7	375	3000.00	0.010

Reservoirs

Ref	Surface Level(m)
R 1	23.0000

Supplies/Demands

Ref	Current (m^3/s)
O 1	0.020
O 2	0.030
O 3	0.026
O 4	0.012
O 5	0.031

Nodes

Ref	Elevation (mOD)
J 1	8.500
J 2	10.000
J 3	10.600
J 4	9.000
J 5	8.000
J 6	7.000
J 7	23.000

3 Select **Steady Pipe Flow** from the **Analysis** Menu

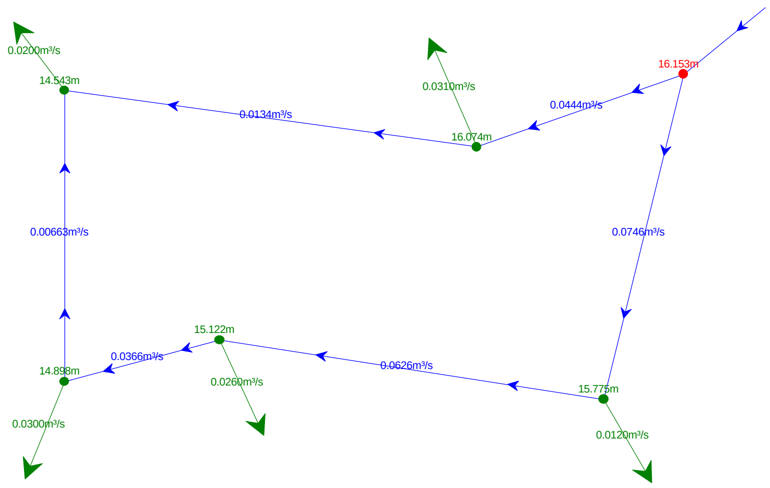


Figure 10 Flows and Pot. heads displayed

ARTS prints the flow and head values on the design sheet graphic, as illustrated in Figure 10.

Alternatively, you may wish to display pipe velocities and joint gauge pressures. Select the properties tool (with no design sheet object selected); the design sheet properties page is displayed. Select ***pipe/velocity*** *and* ***joint/gauge pressure*** *options and press the* ***Update display*** *button; the design sheet textual output is changed accordingly, as illustrated in Figure 11.*

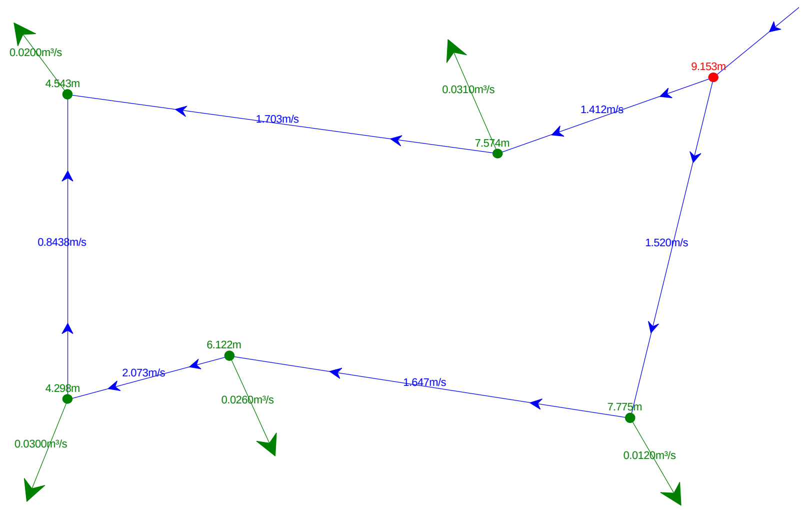


Figure 11 Velocities and gauge pressures

Solution: The minimum residual head is **4.29m** at demand point 2 (J 3), which is greater than 3m => OK!

Pipe manifolds with lateral branches may be designed and/or analysed in ARTS.

Procedure:

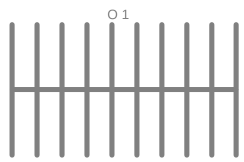
- Draw a manifold on the sheet and edit the pertinent properties.
- Click on the **Status** page.

The **Status** page displays several parameters for a given flow. The flow value can be altered, and the other parameters will be updated accordingly.

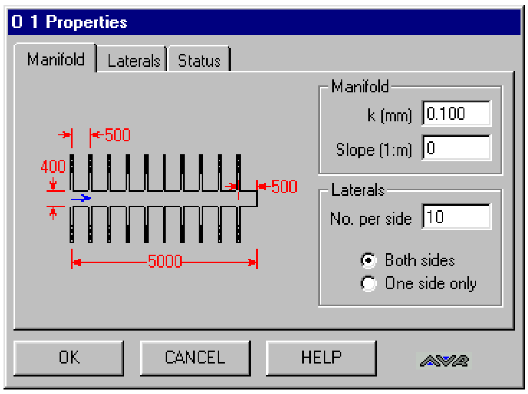
Example 4 Manifold design example

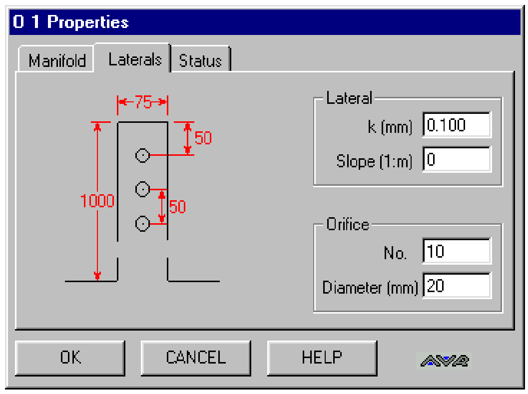
Design a manifold to distribute 0.07m^3/s, over a 10m^2 area, with a maximum headloss of 200mm

1 Draw a manifold on the design sheet



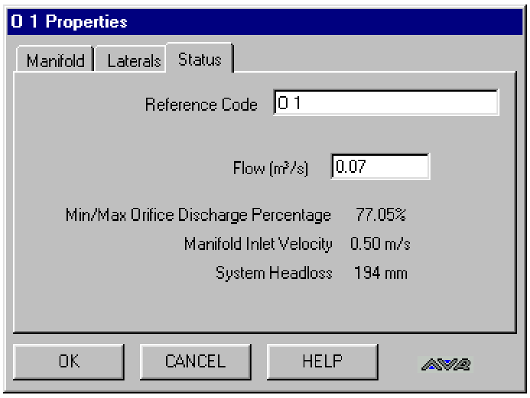
2 Edit the properties, so that the manifold covers a 10m^2 area:





Example 4 Manifold design example (contd)

3 Click on the **Status** page, to check that the headloss is no more than 200mm



Solution: The headloss through the manifold is **194mm**, so design is OK.

Steady flow of sewage sludge in pipes/networks

The hydraulic resistance to flow of sewage sludge in pipes is generally greater than the hydraulic resistance of water or wastewater, at the same velocity. In particular, the suspended solids concentration of sludge influences its viscosity and hence also its flow resistance. ARTS caters for the normal range of sludge types, including primary, activated, humus and digested sludges.

Procedure:

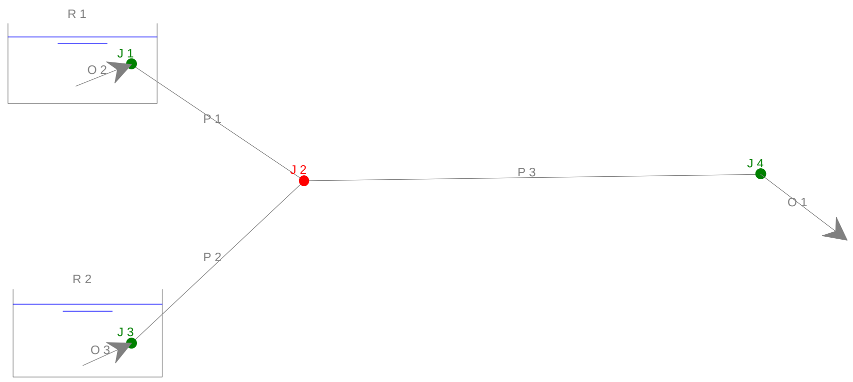
- Draw the system under consideration on the sheet and edit the pertinent properties of the objects on the sheet, i.e. pipe diameters, pipe lengths, reservoir levels, pump characteristics, etc.
- Place a supply of sewage sludge into the system - this is done by drawing the flow object pointing towards a node on the sheet and by setting the fluid type of the flow object to sewage sludge and also setting the solids concentration of the sludge.
- Select **Steady pipe flow** from the **Analysis** Menu.

The results of the analysis are printed on the design sheet, indicating flows in pipes, and potential heads at nodes. This display can be modified to display velocities, headlosses, gauge pressures etc. The included sludge types are primary sludge, activated sludge, humus sludge and digested sludge.

Example 5 Sludge flow

Waste primary sludge from two sedimentation units is to be intermittently transferred to a sludge thickening tank by gravity at a minimum rate of 0.01m^3/s. The sedimentation tank TWLs are 24.1mOD. The sludge thickening tank cannot be located closer than 35m from the sedimentation units. The TWL of the sludge thickening tank is 22.2m. The sludge is expected to have a solids concentration of 30kg/m^3. Allow for three 90^o elbows in the pipework.

1 Draw the following system on the screen



2 Edit the properties of the objects on the screen*:

Pipes

Ref	Diameter (mm)	Length (m)	k (mm)	Total K	No. Fittings
P 1	75	5.00	0.010	0.000	0
P 2	75	5.00	0.010	0.000	0
P 3	110	30.00	0.010	3.750	3

Nodes

Ref	Elevation (mOD)
J 1	24.100
J 2	20.000
J 3	24.100
J 4	20.000

Supplies/Demands

Ref	Current (m^3/s)	Maximum (m^3/s)	Minimum (m^3/s)	Type
O 1	0.010	0.150	0.004	Primary sludge @ 30.000kg/m^3
O 2	0.005	0.150	0.000	Primary sludge @ 30.000kg/m^3
O 3	0.005	0.150	0.002	Primary sludge @ 30.000kg/m^3

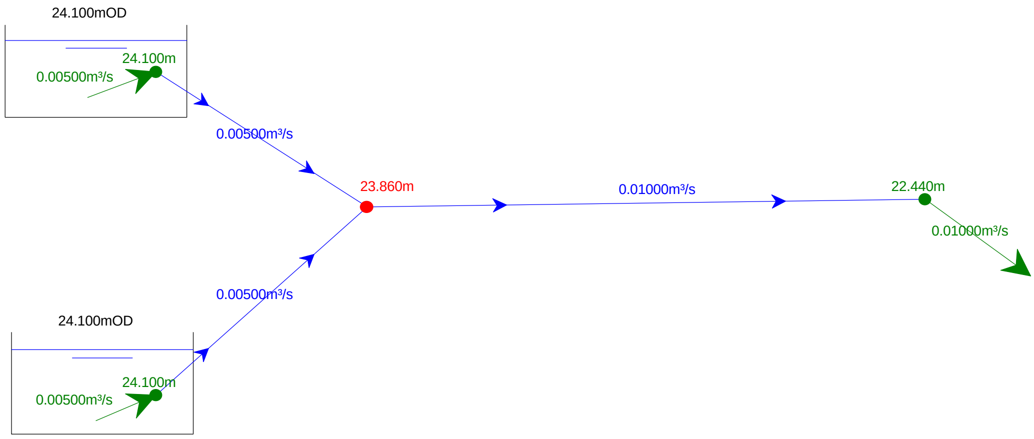
Reservoirs

Ref	Surface Level(m)
R 1	24.1000
R 2	24.1000

* this listing, which follows this heading, is a copy of the printed textual output from ARTS for this example.

Example 5 Sludge flow (contd)

3 Select **Steady Pipe Flow** from the **Analysis** menu



Solution: The calculated TWL at the thickening tank is **22.440mOD**, so the current design is OK.

OPEN CHANNEL FLOW

The ARTS open channel analysis/design capability extends to the computation of uniform flow, gradually varied and rapidly varied flow in channels of rectangular, trapezoidal, U-shaped, V-shaped, parabolic and circular sections. It includes plotting of flow profiles in single channels and also multiple channels in series.

Uniform flow

ARTS provides a uniform flow analysis capability through the channel object's property pages.

Procedure:

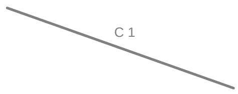
- Draw a channel on the design sheet and edit its relevant properties on the **Main** page.
- Click on the **Status** page

The **Status** page displays several parameters for a given flow. When a new value is entered in the flow box, ARTS automatically updates the dependent parameter values.

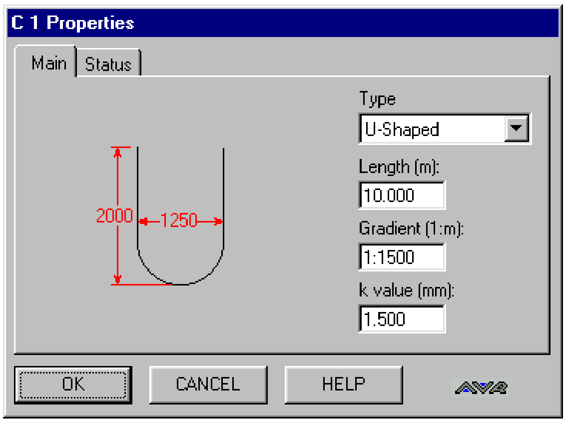
Example 6 Uniform flow in an open channel

Calculate the normal depth in a concrete U-shaped channel, which has a base width of 1200mm, a gradient of 1 to 1500 and is used to convey sewage at a flow rate of flow 1.65m³/s.

1 Place a channel on the design sheet (the channel is grey until you set some of it's properties)

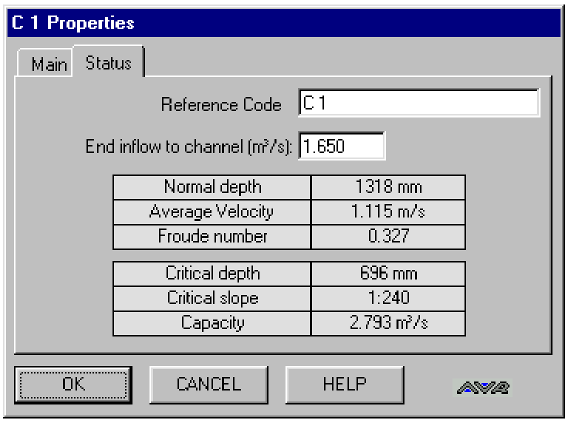


2 Display the **Main** property page and edit its parameter values:



Example 6 Uniform flow in an open channel (contd)

3 Display the **Status** page and change the flow value to **1.65 m^3/s**; ARTS automatically updates the remaining parameter values:



Solution: The uniform flow depth is **1318mm** at 1.65m^3/s.

Computation of water surface profiles in gradually varied flow

ARTS provides means of calculating gradually and rapidly varied surface profiles in channels.

Procedure:

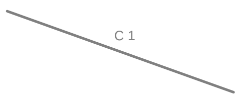
- Draw a channel on the design sheet and edit its relevant properties on the **Main** page.
- With the channel selected, click on the **Channel GVF** tool

This displays a dialog box which enables you to examine the surface profile in the channel with various boundary conditions, such as upstream depth and/or downstream depth and/or lateral flow.

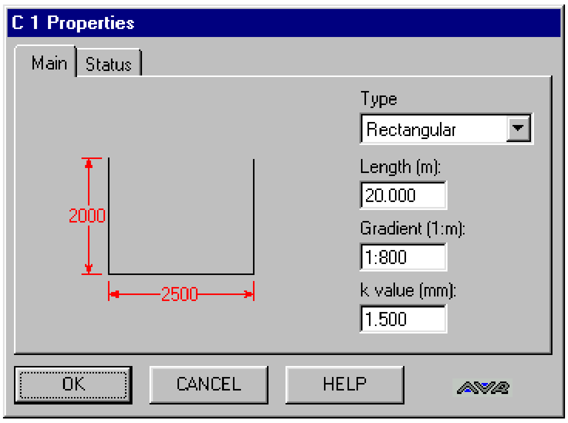
Example 7 Gradually varied flow in an open channel

A sluice gate has a gate opening of 375mm and a discharge of 2.85m^3/s. Check if a hydraulic jump occurs downstream in a concrete rectangular channel, which has a base width of 2500mm, a gradient of 1 to 800 and is 20m long. The channel discharges freely to a sump.

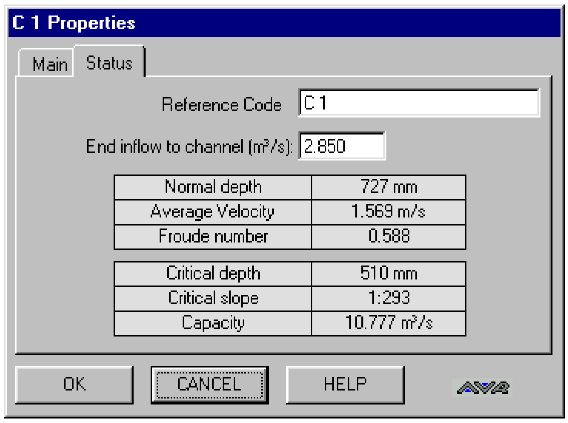
1 Place a channel on the design sheet (the channel is grey until you set some of it's properties)



2 Display the Main property page and edit its property values:



3 Display the **Status** page and enter the flow value of **2.85 m^3/s**; ARTS updates the remaining parameter values:

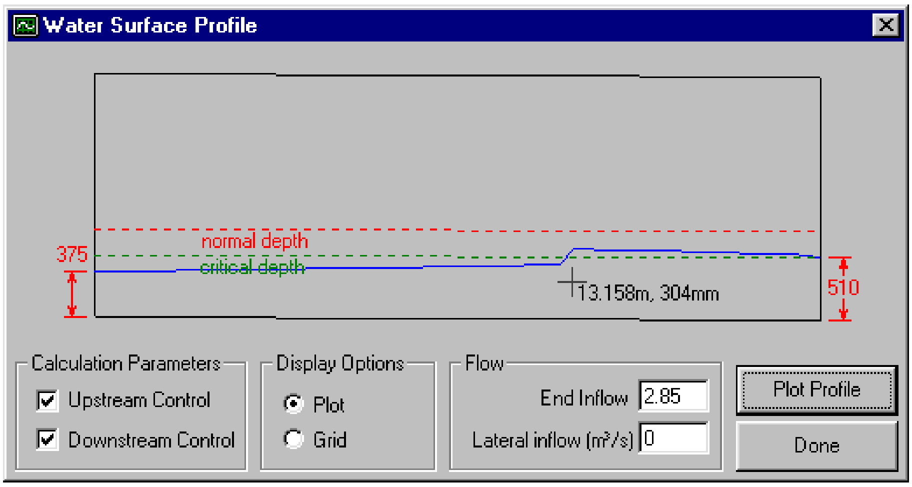


NB: *The critical depth is* ***510mm*** *at 2.85m^3/s.*

4 With the channel selected (has handles), click on the **Channel GVF** tool

Example 7 Gradually varied flow in an open channel (contd)

5 Set the boundary conditions for the channel as displayed:

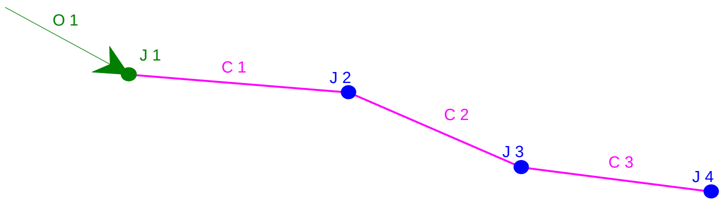


Solution: A jump occurs at **13.1m** downstream from the sluice gate.

Example 8 Gradually varied flow in a series of channels

An open channel culvert, which has a free discharge at its outlet end, is 30m long and is made up of three segments, each of which has a different slope. Determine the water surface profile in the culvert at a discharge of 3.5 m^3/s.

1 Place a series of channels on the design sheet:



Example 8 Gradually varied flow in a series of channels (contd)

2 Edit the properties of the channels as follows:

Channels

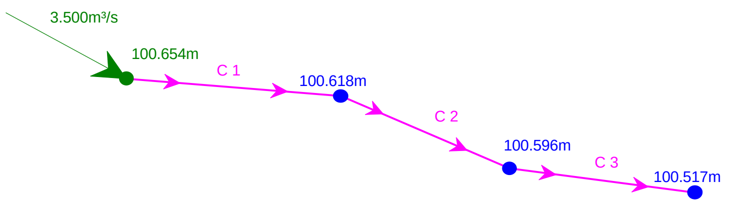
Ref	Type	Width (mm)	Height (mm)	Length (m)	Angle (deg)	k value (mm)	Slope
C 1	Rectangular	3000	2500	10.00	n/a	1.000	1:1000
C 2	Rectangular	3000	2500	10.00	n/a	1.000	1:500
C 3	Rectangular	3000	2500	10.00	n/a	1.000	1:800

Supplies/Demands

Ref	Current (m^3/s)	Maximum (m^3/s)	Minimum (m^3/s)
O 1	0.100	3.500	0.050

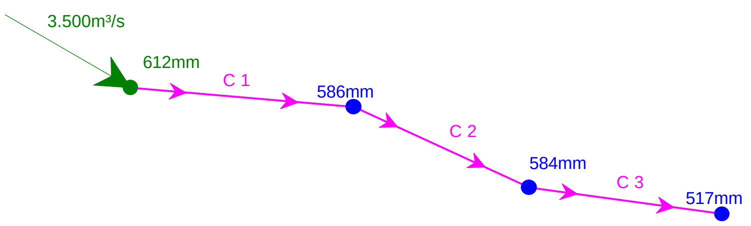
3 Select **Hydraulic Profile @ max flow** from the **Analysis** menu

ARTS computes the water surface profile, starting from a control depth and specified channel invert elevation at the downstream end of the system. In this example, the control depth is the calculated critical depth (free discharge) and the default channel invert elevation of 100 mOD. This latter value can be edited, using the property pages for the outlet node point, J4.



The potential heads are displayed at each joint

4 Select the **Properties tool** (with no object selected) and the sheet properties will be displayed. You can then choose to display **Joint Depths**, as indicated:



Decanting channels are normally built in features of treatment process units, such as sedimentation tanks. Where a treatment unit incorporates a decanting channel, ARTS provides for its hydraulic design as an integral part of the hydraulic design of the treatment unit as a whole. Where a designer wants to analyse/design a decanting channel as a standalone object, this can be done using the **Channel GVF** plotter as illustrated in Example 9.

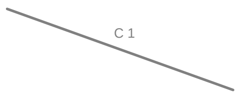
Procedure:

- Draw a channel on the design sheet and edit its properties.
- Select the **Channel GVF** tool
- Set the boundary conditions and click **Plot Profile**.

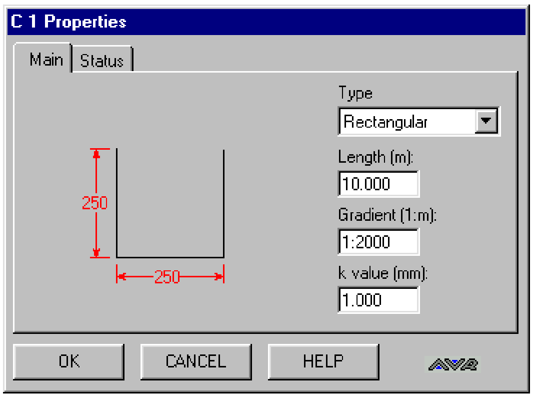
Example 9 Decanting channel design

Design a 10m long decanting channel to accommodate 0.02m^3/s at peak flow.

1 Place a channel on the design sheet (the channel is grey until you set some of it's properties)

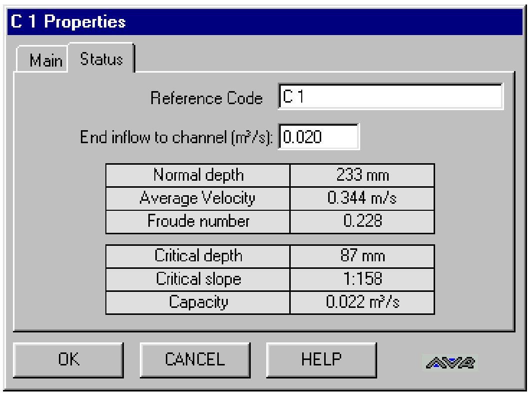


2 Display the Main property page and edit its property values:



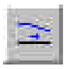
Example 9 Decanting channel design (contd)

3 Display the **Status** page and enter the flow value of **0.02m^3/s**; ARTS updates the remaining parameter values:

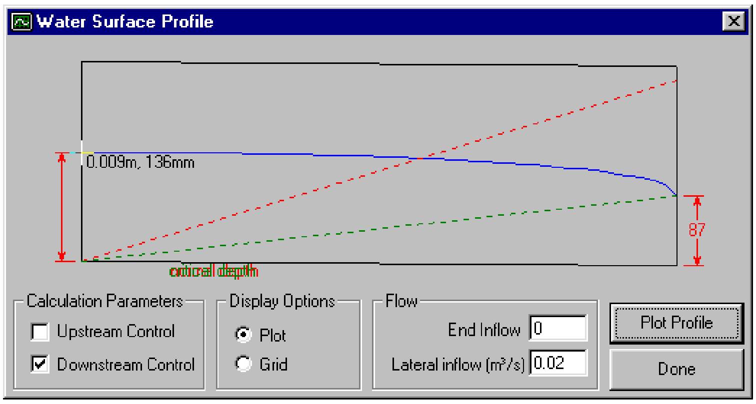


NB: The critical depth is **87mm** at 0.02m^3/s.

4 With the channel selected (has handles), click on the **Channel GVF** tool



5 Set the boundary conditions for the channel as displayed:



Solution: A decanting channel of 250 x 250 with a slope of 1:2000 will pass 0.02m^3/s, with a freeboard at the upstream end of 114mm.

Storm-overflow channels with lateral outflow

The ARTS storm overflow weir object tool has been coded to facilitate the interactive design of lateral overflows, such as used to regulate the maximum forward flow to full treatment at wastewater treatment plants. Based on a specified downstream control depth (such as might be provided by a flow measurement flume), a specified forward flow to treatment and a specified weir length, ARTS computes the required weir crest level.

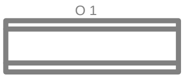
Procedure:

- Draw a storm channel on the design sheet.
- Edit the various properties.
- Click on the **Status** page to check the storm overflow.

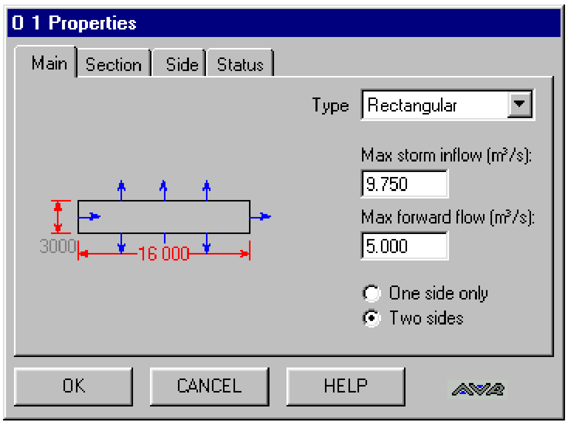
Example 10 Design of a storm overflow weir

Design a 16m long channel with side weirs to limit the FFT to 5.0m^3/s, at a peak storm flow of 9.75 m^3/s. Downstream of the channel is a flume, which creates an upstream depth of 1500mm at 9.75m^3/s.

1 Draw a storm channel on the design sheet.

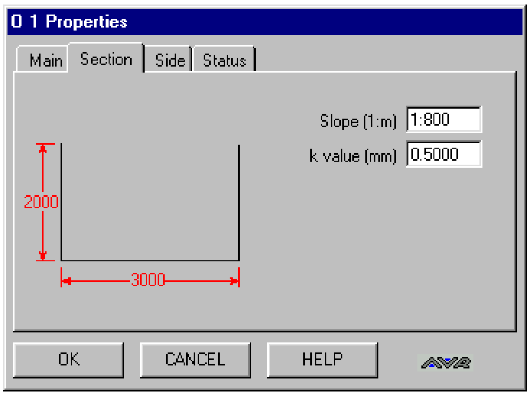


2 Edit the properties on the **Main** page:

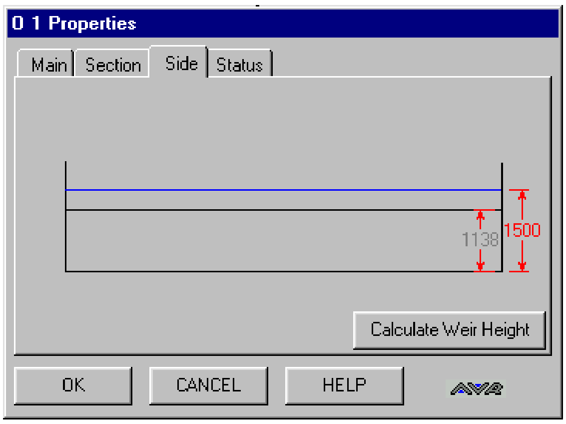


Example 10 Design of a storm overflow weir (contd)

3 Edit the properties on the **Section** page:

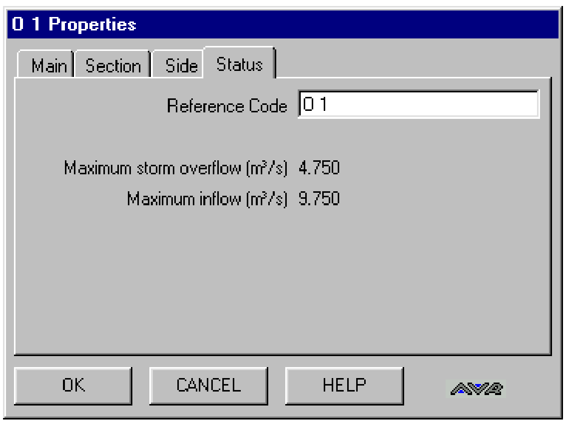


4 Edit the properties on the **Side** page and press the **Calculate Weir Height** button



*The required weir height is **1138mm**.*

5 Click on the **Status** page to display the computed performance:



Solution: A weir height of **1138mm** produces a storm overflow of **4.75m^3/s** as required.

FLOW MEASUREMENT STRUCTURES

ARTS enables the design of a wide range of open channel flow measurement structures, including flumes and weirs. The range of flumes catered for includes long-throated flumes of rectangular, trapezoidal and U-shaped section, short-throated flumes of rectangular section, and Parshall flumes. The range of weirs catered for includes rectangular, broad-crested, v-notch and sutro weirs. Both flumes and weirs can be design/analysed on a stand alone basis or incorporated into a system.

Hydraulic design of flumes

ARTS incorporates an easy-to-use design procedure for flumes. The software creates an initial valid design which can then be altered by following limits which are displayed via tooltips. This ensures a final valid design, in accordance with specified design rules.

Procedure:

- Draw a flume on the design sheet.
- Edit the various properties in sequence, starting at **Main**, then **Channels**, then **Throat**, then **Side** and **Plan**.
- Click on the **Status** page to check that the design is valid.

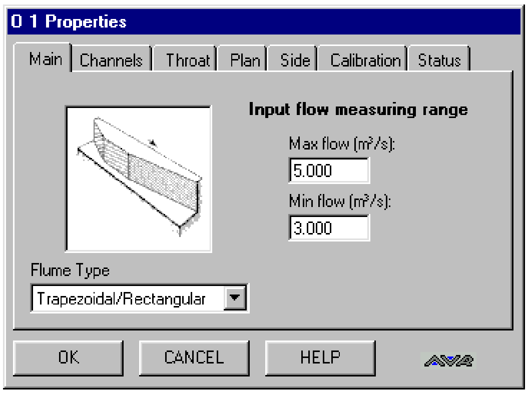
Example 11 Designing a flume

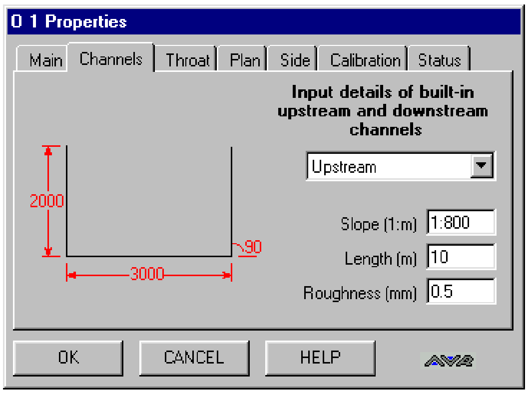
Design a rectangular flume to measure flow in the range 3 - 5 m^3/s. The flume is to fit into a 3m wide by 2m deep channel which has a slope of 1:800.

1 Place a flume on the design sheet.

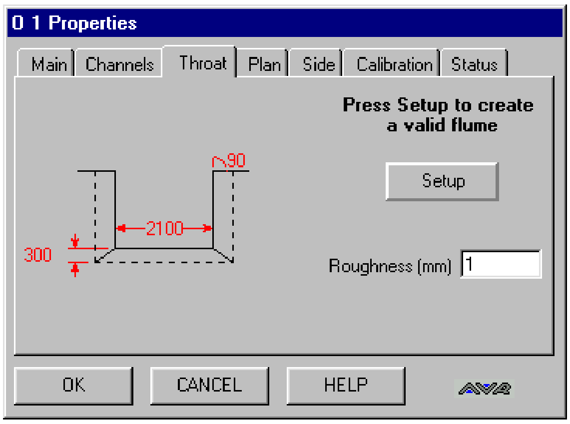
Example 11 Designing a flume (contd)

2 Edit the Main and Channels pages:

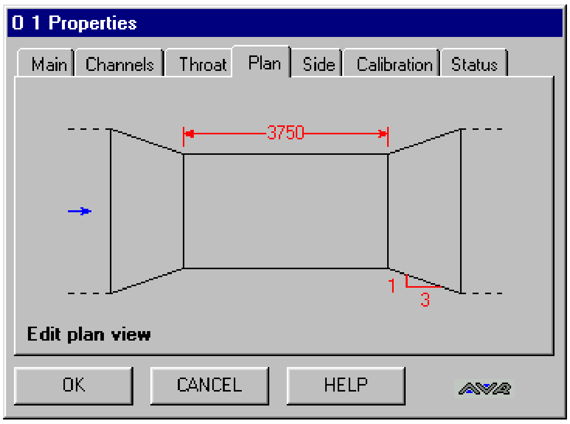




3 Press the **Setup** button and then edit the properties on the **Throat** page:

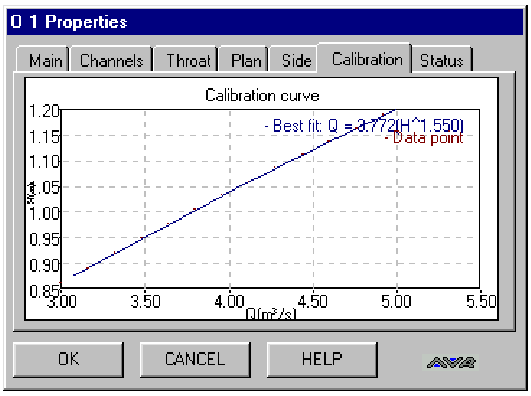


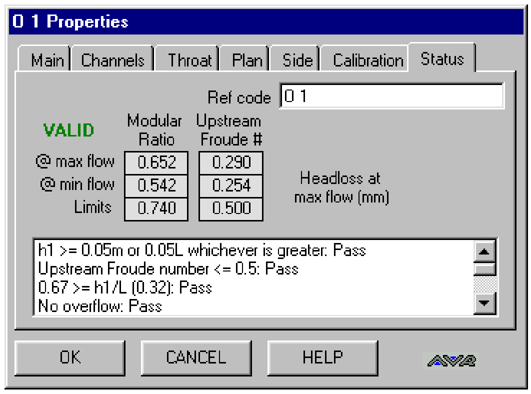
4 Edit the **Plan** page:



Example 11 Designing a flume (contd)

5 Check the **Calibration** page and the **Status** page to ensure a valid design:





Hydraulic design of weirs

ARTS caters for a range of weirs, including broad-crested weirs and thin plate weirs; the latter category includes proportional flow weirs, rectangular notch and V-notch weirs.

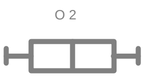
Procedure:

- Draw a weir on the design sheet.
- Edit the various properties, starting at **Main**, then **Channels**, then **Section**, then **Side** and **Plan**.
- Click on the **Status** page to check that the design is valid.

Example 12 Designing a weir

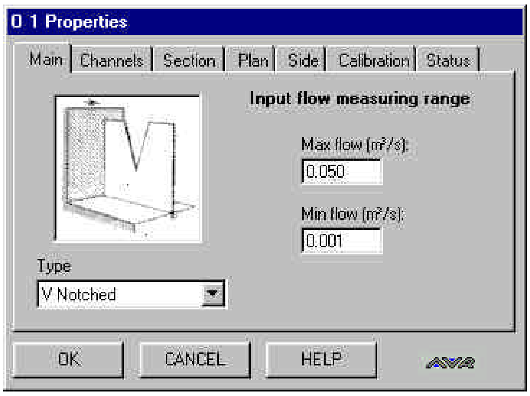
Design a V notch weir to measure the flows from a small stream to a proposed trout farm. The fish tanks require a minimum flow of 86.4m^3/day.

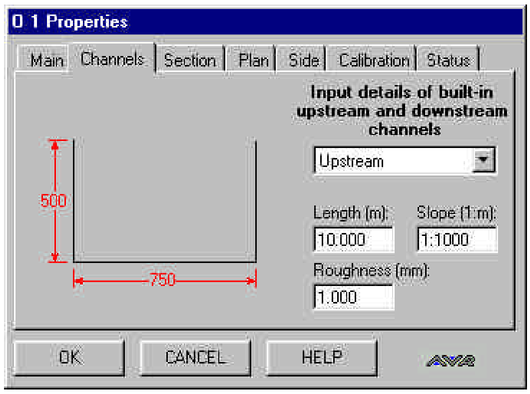
1 Place a weir on the design sheet.



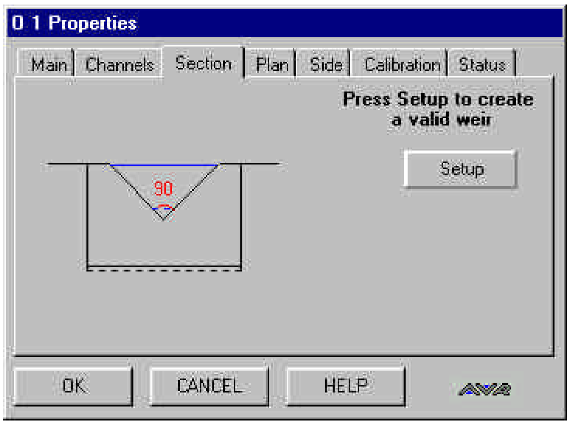
Example 12 Designing a weir (contd)

2 Edit the **Main** and **Channels** pages:

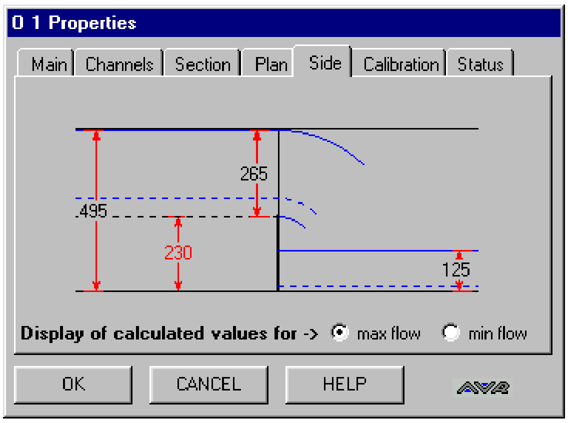




3 Press **Setup** and edit the **Section** page

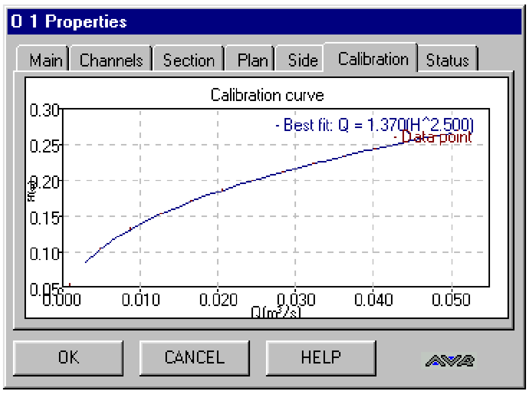


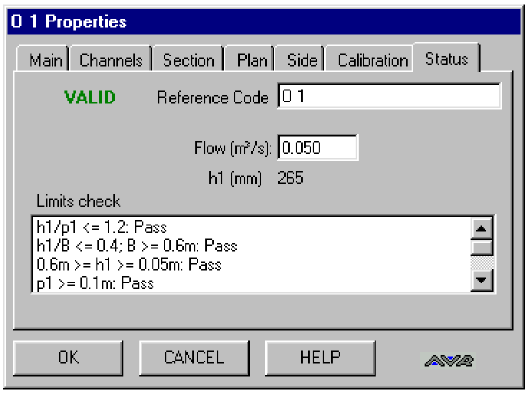
4 Edit the **Side** page:



Example 12 Designing a weir (contd)

5 Check the **Calibration** and **Status** Pages:





HYDRAULIC ANALYSIS OF PUMP/RISING MAIN SYSTEMS

ARTS treats pump/rising main systems as sub-sets of pipe networks and hence can analyse complex rising mains as well as multiple pumps and variable pump speed.

Example 13 Rising main pump duty point

Check the duty point of the pump Model PU45 when used to pump from a low level reservoir at 23.4mOD to 43.6mOD through a 2km, 250mm ID rising main. The manufacturer's data sheet for the pump is illustrated. The pump is connected to the rising main by a 5m long, 200mm ID pipe (with1 x 90o elbow, 1 x NRV, 1 x taper transition 200/250), and connected to the sump by a 4m long, 250mm ID pipe (with 1 x 90o elbow).

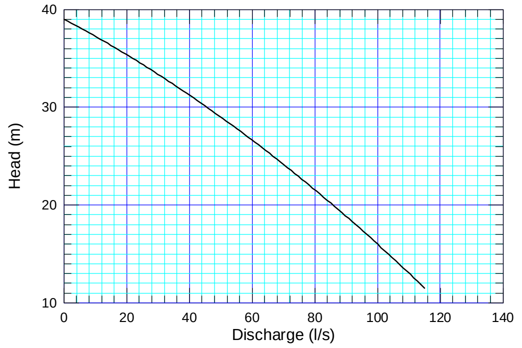
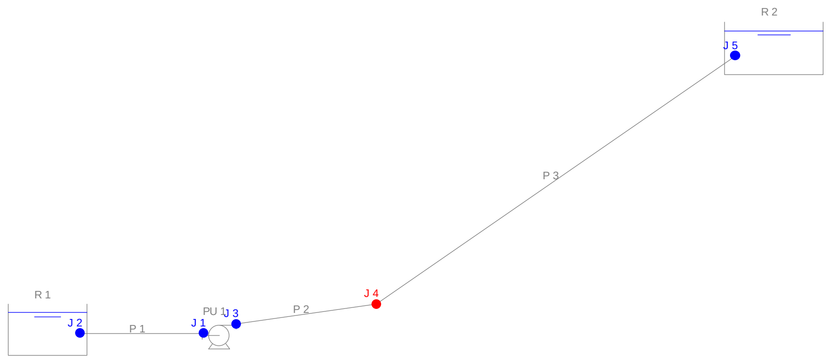


Figure 12 HQ curve for PU45 (@ 1490rpm)

1 Draw the system on the design sheet.



2 Edit the properties as follows:

Pipes

Ref	Diameter (mm)	Length (m)	k (mm)	Total K	No. Fittings
P 1	250	4.00	0.010	0.000	0
P 2	200	5.00	0.010	2.850	2
P 3	250	2000.00	0.010	0.000	0

Example 13 Rising main pump duty point (contd)

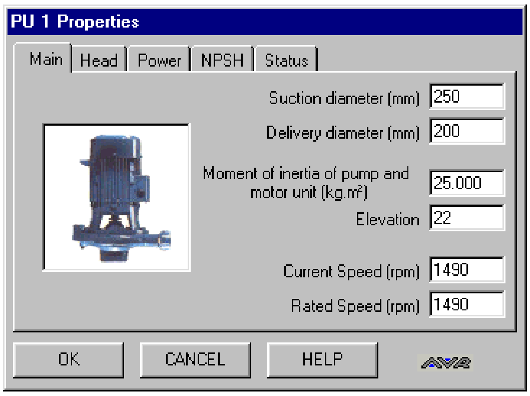
Nodes

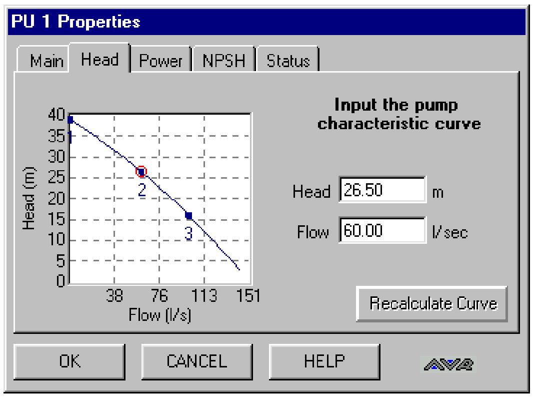
Ref	Elevation (mOD)
J 1	22.000
J 2	23.400
J 3	22.000
J 4	22.000
J 5	43.600

Reservoirs

Ref	Surface Level(m)
R 1	23.4000
R 2	43.6000

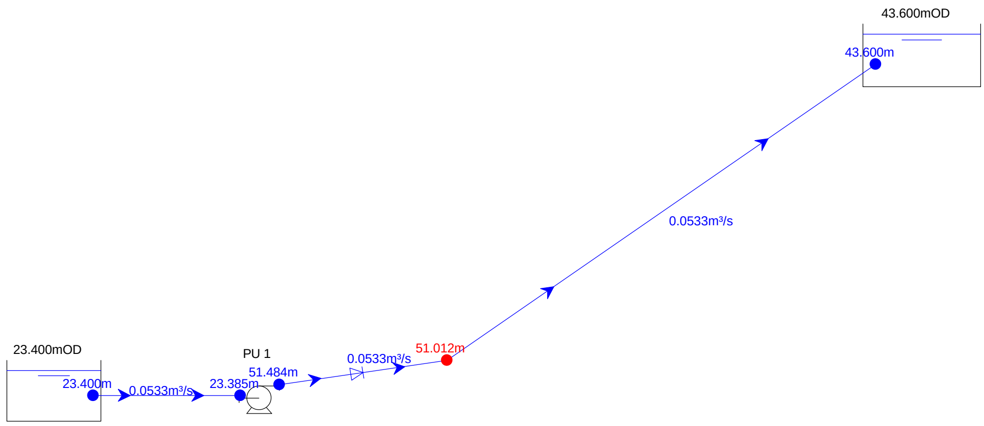
3 Edit the pump properties on the **Main**, **Head** and **Power** property pages, using data supplied.





__Note:__ information on the pump moment of inertia is not required for steady flow analysis, hence, it is not necessary to edit the value for this parameter.

4 Select the **Steady Pipe Flow** command from the **Analysis** menu; ARTS prints the flow and potential head values on the design sheet graphic, as shown.



Solution: The duty point flow is **0.0533m³/s**.

Multiple pump systems, variable speed pumps

Analysis of systems with multiple pumps or systems with variable speed pumps is done in a similar manner to plain pump/rising main systems.

Procedure:

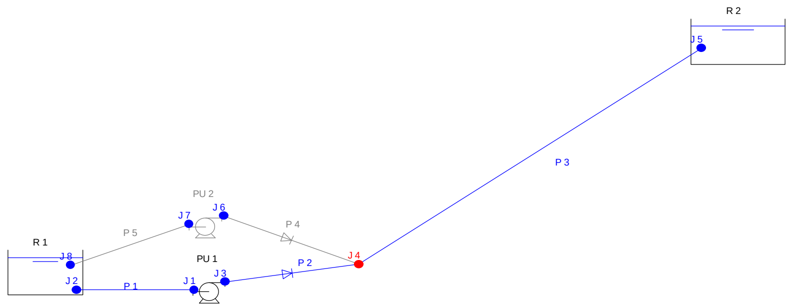
- Draw the system on the design sheet.
- Edit the relevant properties
- Select the **Steady pipe Flow** from the **Analysis** menu.

Example 14 Multiple pumps

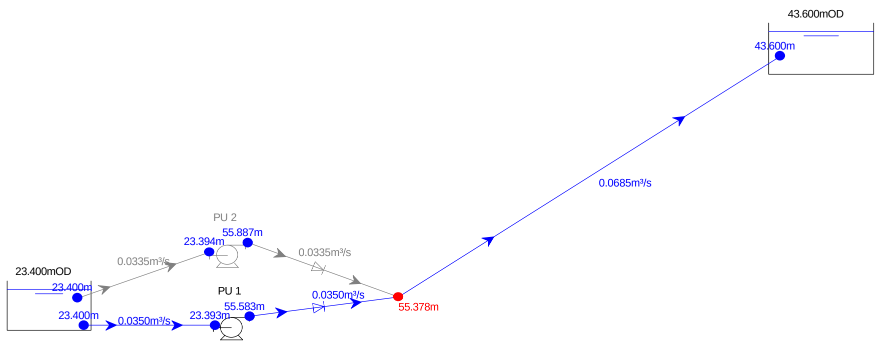
Determine the flow in the previous example if a second pump is added to the system in parallel.

1 Copy the pump on the design sheet from the previous example, and paste the copy onto the sheet. Do the same with the suction pipe and the delivery pipe.

2 Move the elements around to get the system below:



3 Select the **Steady Pipe Flow** command from the **Analysis** menu; ARTS prints the flow and potential head values on the design sheet graphic, as illustrated.



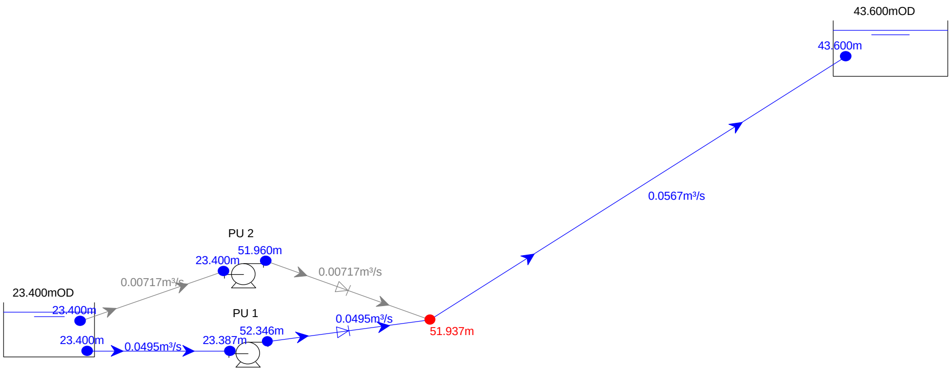
Solution: The duty point flow for two pumps is **0.0685m^3/s**.

Example 15 Variable speed pumps

Determine the pump output in the previous example if one of the pumps is operated at a reduced speed of 1300rpm.

1 Using the design sheet from the previous example, edit the **Current speed** of one of the pumps.

2 Select **Steady Pipe Flow** from the **Analysis** menu.



Solution: The combined pump output with one pump at 1300rpm is **0.0567m^3/s**.

WASTEWATER TREATMENT SYSTEMS

ARTS can compute WWTP TWLs, starting from a downstream elevation or TWL for single or multi-stream WWTP. Graphs of hydraulic profiles can be plotted for single stream WWTPs. Analysis can also be carried out on individual units, isolated from a system.

Hydraulic design of individual process units

In ARTS, the property pages for the individual treatment unit objects enable the user to carry out an internal hydraulic design of the treatment unit, for example, the sequence of property pages for the sedimentation object allow the user to select the sedimentation tank shape and plan dimensions, select the type of peripheral overflow weir and compute its dimensions, design the external peripheral collector channel and compute the head loss across the treatment unit

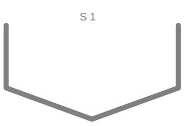
Procedure:

- Draw a unit on the design sheet.
- Edit the relevant properties
- Select the **Status** page

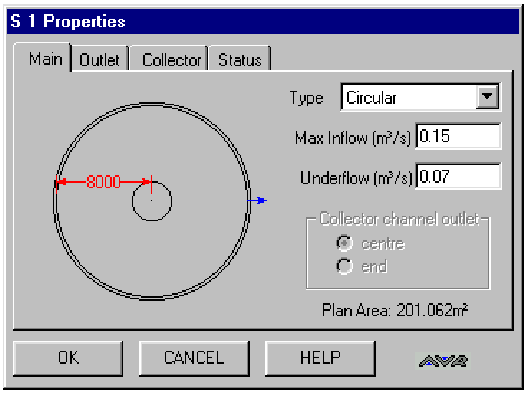
Example 16 Hydraulic design of a Sedimentation unit

Design a secondary sedimentation unit to cater for a maximum wastewater inflow of 0.15m^3/s and a recycle flow of 0.7m^3/s. The tank is to have a rectangular plan shape, with outflow over a weir spanning the full tank width. The weir overflow should discharge into a collector channel with a central outlet.

1 Draw a sedimentation unit on the design sheet.

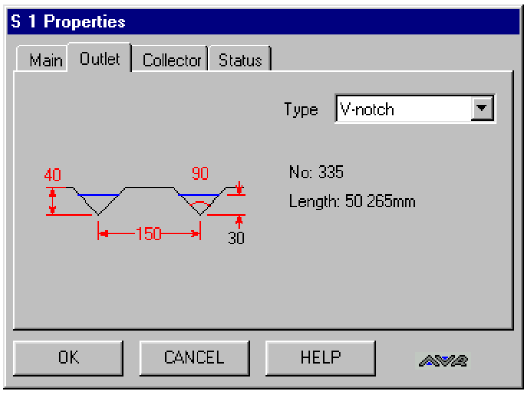


2 Edit the properties on the **Main** page:

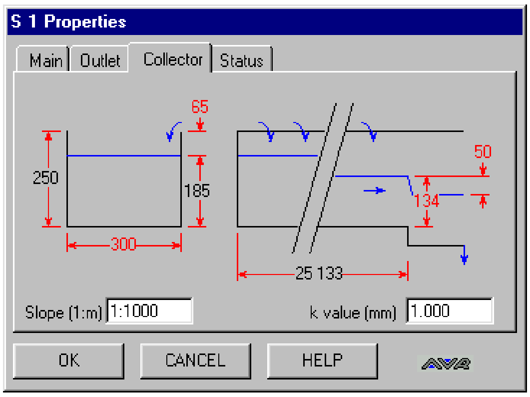


Example 16 Hydraulic design of a Sedimentation unit(contd)

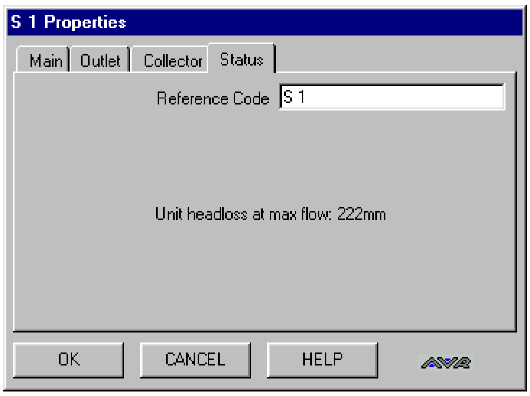
3 Edit the properties on the **Outlet** page:



4 Edit the properties on the **Collector** page:



5 Click on the **Status** page to check the headloss through the unit at maximum flow:



The **Analysis** menu has an **Hydraulic Profile** sub-menu that has been designed for the computation of hydraulic profiles across WWTPs, enabling the user to:

- Carry out a detailed hydraulic analysis/design of the components of a wastewater treatment system, including the process units and the inter-connecting links.
- Set the relative elevations of the treatment process units that comprise the treatment system, to permit **gravity** flow through the system, at all flows up to a specified maximum design flow
- Compute the hydraulic profile for flow through the system at any flow rate between the specified maximum and minimum flow rates.

Provision is made for the sub-division of flow into parallel streams, using the Flow-divider tool, and also for the re-combination of flows into a single stream. “Drops” may be incorporated into the treatment system layout to cater for varying site topography

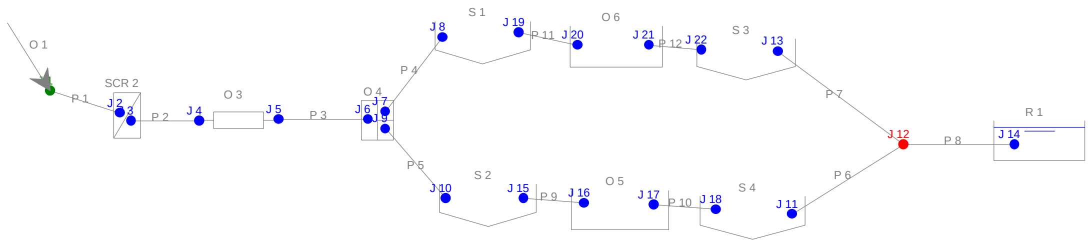
Procedure:

- Draw a process system on the design sheet.
- Edit the relevant unit and link properties
- Select **Hydraulic profile at max flow**
- Select **Hydraulic profile at min flow**

Example 17 Computation of an hydraulic profile for a WWTP

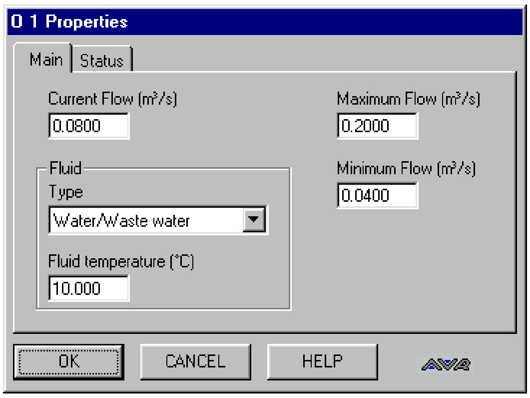
A municipal WWTP, having a design capacity of 30,000PE, incorporates the following processes: screening, flow measurement, primary sedimentation, stream extended aeration, secondary sedimentation. The wastewater is pumped to the WWTP inflow chamber; the effluent is discharged to a receiving water having a maximum TWL of 12.60 mOD. It is required to determine the design TWL for the WWTP inflow chamber. The process flow is to be split into two stream downstream of the flow measurement device.

1 Draw a system on the design sheet, using a flow divider to split the flow.



Example 17 Hydraulic profile for a WWTP (contd)

2 Set the properties of the Inflow:



3 Set the **Recycle flows** in each of the activated sludge units to $0.04m^3/s$ and the **Underflow** in each of the sedimentation units to $0.04m^3/s$.

4 Select **Auto design** from the **Analysis** > **Hydraulic Profile** menu

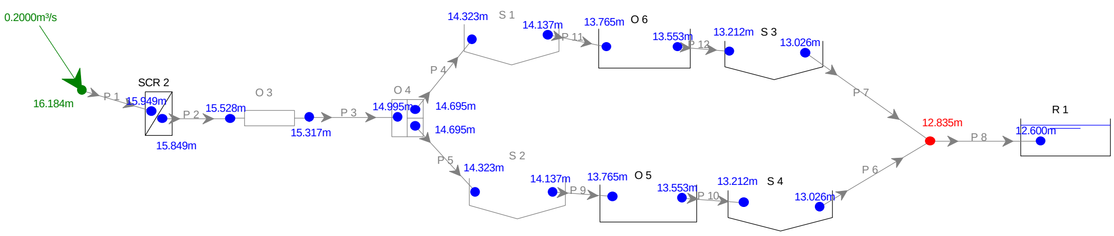
This command sizes units and links to approximately correct values, creating an initial design, which you could then edit.

5 Edit the **TWL** of the downstream reservoir to 12.60mOD. This simulates a receiving water.

This TWL determines the elevations and TWLs of all upstream objects.

6 Select **Hydraulic profile @ Max Flow**

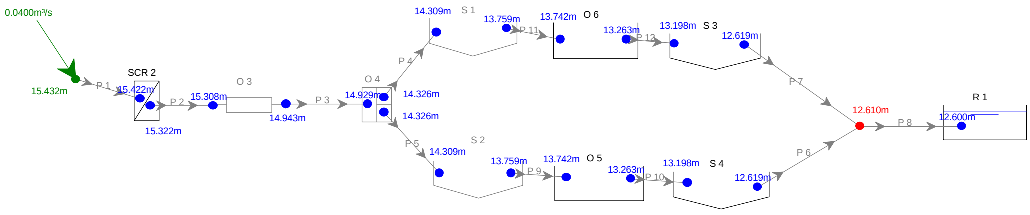
This command calculates the required elevations and TWLs relative to the specified downstream receiving water TWL and displays the results on screen.



Example 17 Hydraulic profile for a WWTP (contd)

7 Select **Hydraulic profile @ Min Flow**

This command calculates TWLs starting from the downstream node, checks that pipes are fully submerged and displays the results on screen.



8 Examine the text output using the **Text output** command on the **View** menu

Dividers

```
                Width  Length   No. Crest Level
Ref              (mm)    (mm)   Divs      (mOD)
O 4              1793    3587     2      14.895
```

Nodes

```
                Elevation                   Elevation
Ref               (mOD)        Ref            (mOD)
J 1              15.060        J 12          12.091
J 2              15.050        J 13          12.359
J 3              14.950        J 14          12.228
J 4              14.936        J 15          13.499
J 5              14.570        J 16          13.482
J 6              14.557        J 17          12.953
J 7              14.066        J 18          12.888
J 8              14.050        J 19          13.499
J 9              14.066        J 20          13.482
J 10             14.050        J 21          12.953
J 11             12.359        J 22          12.888
```

Flumes

```
  Ref:                                 O 3
  Discharge Equation: Q = 1.167(H^1.750)
  Invert level:                     15.162 mOD
```

Sedimentation Units

```
  Ref:                                 S 1
  Max TWL:                          14.323 mOD
  Min TWL:                          14.309 mOD
  Weir/orifice level:               14.302 mOD
  Max Sump TWL:                     14.137 mOD
  Min Sump TWL:                     13.759 mOD

  Ref:                                 S 2
  Max TWL:                          14.323 mOD
  Min TWL:                          14.309 mOD
  Weir/orifice level:               14.302 mOD
  Max Sump TWL:                     14.137 mOD
  Min Sump TWL:                     13.759 mOD

  Ref:                                 S 3
  Max TWL:                          13.212 mOD
  Min TWL:                          13.198 mOD
  Weir/orifice level:               13.191 mOD
  Max Sump TWL:                     13.026 mOD
  Min Sump TWL:                     12.619 mOD
```

Sedimentation Units

```
Ref:                              S 4
Max TWL:                       13.212 mOD
Min TWL:                       13.198 mOD
Weir/orifice level:            13.191 mOD
Max Sump TWL:                  13.026 mOD
Min Sump TWL:                  12.619 mOD
```

Activated Sludge Units

```
Ref:                              O 5
Max TWL:                       13.765 mOD
Min TWL:                       13.742 mOD
Weir/orifice level:            13.712 mOD
Max Sump TWL:                  13.553 mOD
Min Sump TWL:                  13.263 mOD

Ref:                              O 6
Max TWL:                       13.765 mOD
Min TWL:                       13.742 mOD
Weir/orifice level:            13.712 mOD
Max Sump TWL:                  13.553 mOD
Min Sump TWL:                  13.263 mOD
```

Solution: The computed TWL for the WWTP inflow chamber at max flow is **14.976mOD**,

Hydraulic profile plot

ARTS can create a plot of the hydraulic profile through a group of units.

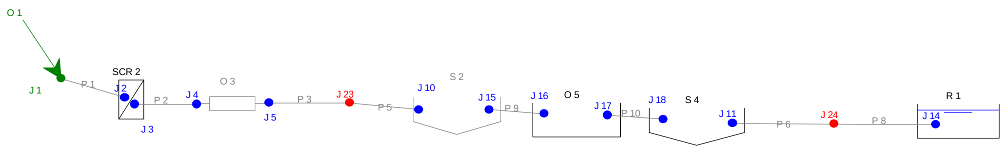
Procedure:

- Draw a process system on the design sheet.
- Edit the relevant unit and link properties
- Select **Hydraulic profile @ max flow**
- Select **Hydraulic profile @ min flow**
- Select **Hydraulic profile > Plot linear profile**

Example 18 Plotting of hydraulic profile for a WWTP

Modify the previous example to a single stream system and plot the hydraulic profile of the previous example at max and min flows of 0.1m³/s and 0.02m³/s.

1 With the previous example design sheet, delete one of the activated sludge streams:

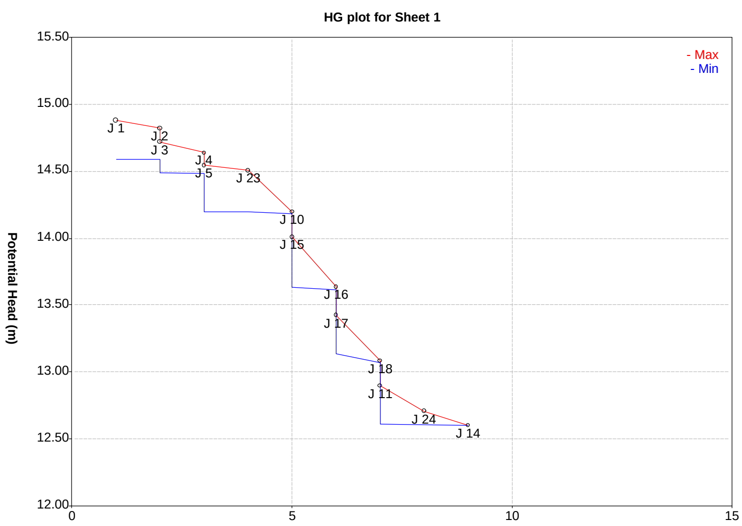


2 Set the max and min flows of the flow object, and adjust the min flow value of the flume.

3 Select **Hydraulic Profile** > **@ max flow**

4 Select **Hydraulic Profile** > **@ min flow**

5 Select **Hydraulic Profile** > **Plot linear profile**



WATERHAMMER ANALYSIS

ARTS incorporates an analytical capability for the computation of the transient pressure fluctuation in rising mains caused by sudden pump trip-out. Rising mains may include waterhammer control devices such as air vessels and/or air valves. Where waterhammer protection is required, it is commonly provided by the installation of an air vessel, connected to the rising main at its upstream end.

ANALYSIS AND CONTROL OF WATERHAMMER PRESSURE TRANSIENTS

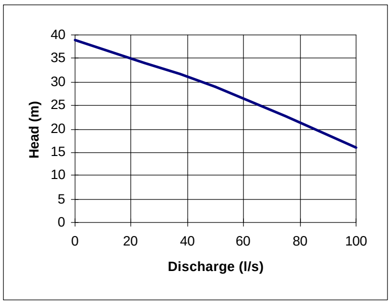
Procedure:

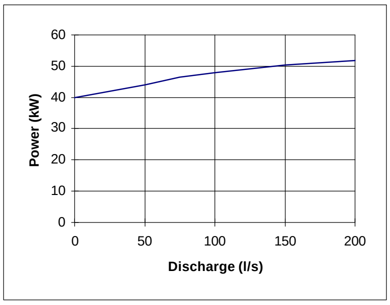
- Draw the system the design sheet.
- Edit the relevant properties
- Select **Unsteady Pipe Flow** from the **Analysis** menu

Example 19 Waterhammer example

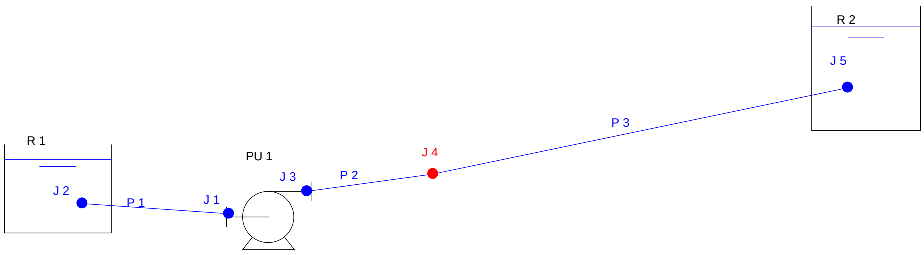
A pump is required to lift sewage from a pump sump, TWL -2.5 mOD to the inlet chamber of a WWTP at TWL 13.00 mOD. The ductile iron rising main is 1502m long, has an ID of 300mm and a wall thickness of 7.2mm. It is required to compute the pressure transients resulting from sudden pump trip-out. The profile of the main is as follows:

Chainage (m)	*Elevation (mOD)*
165	*0.00*
700	*2.00*
750	*1.80*
1200	*3.50*
1501	*12.00*





1 Draw the system on the design sheet



Example 19 Waterhammer example (contd)

2 Edit the properties as indicated below

Pipes

Ref	Diameter (mm)	Length (m)	k (mm)	Total K
P 1	250	10.00	0.010	0.500
P 2	250	6.00	0.010	9.600
P 3	300	1502.00	0.100	4.000

Nodes

Ref	Elevation (mOD)
J 4	-1.000

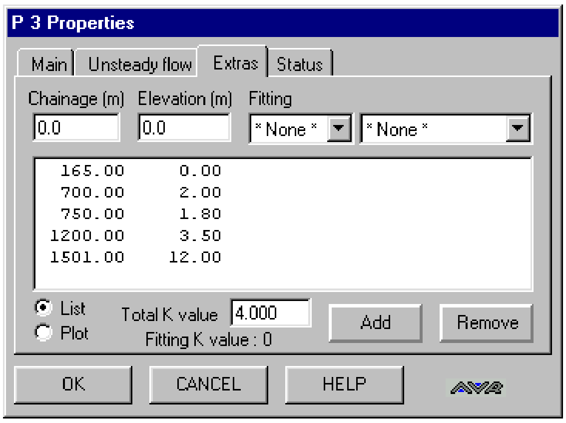
Reservoirs

Ref	Surface Level(m)
R 1	-2.5000
R 2	13.0000

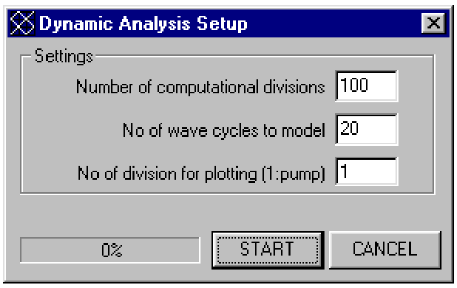
Pumps

Ref	Elevation (mOD)	Speed (rpm)	Moment of Inertia (kgm²)
PU 1	-2.000	1490	0.550

3 Edit the **Extras** page of the rising main to include the profile:

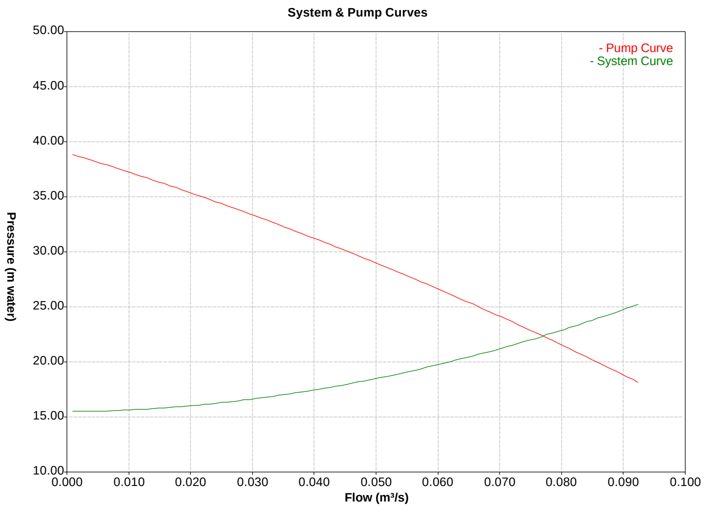


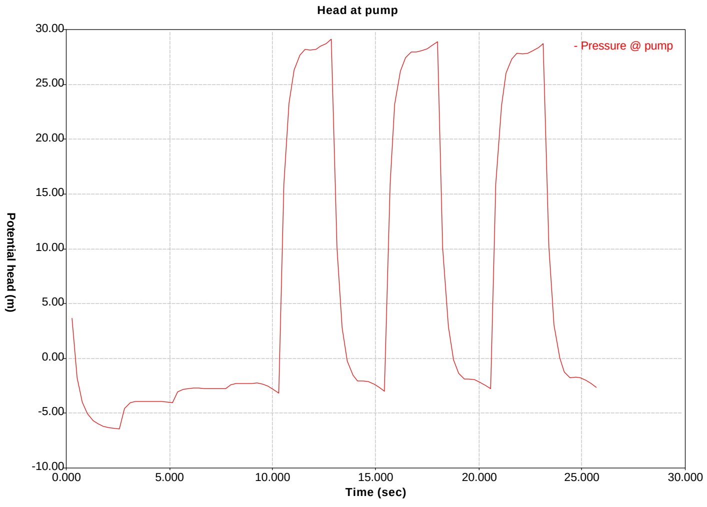
4 Select **Unsteady Pipe Flow** from the **Analysis** menu and edit the dialog:

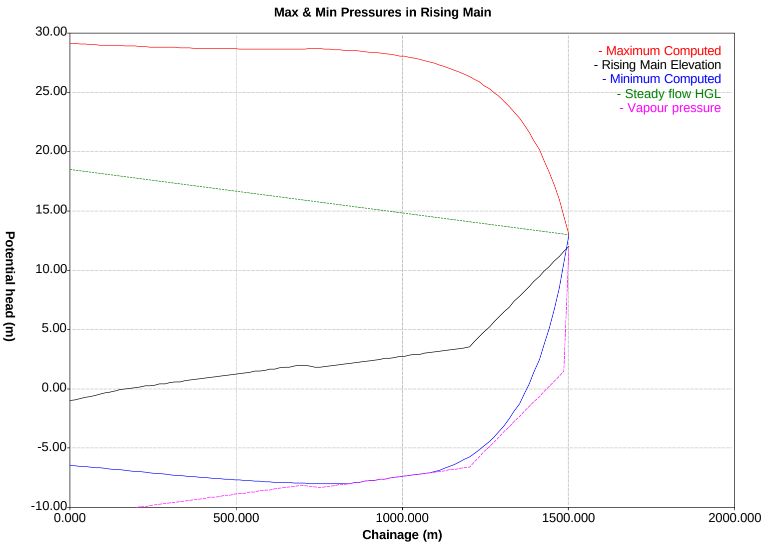


Example 19 Waterhammer example (contd)

5 The computed results are summarised by three graphical outputs and one textual summary as illustrated:







Example 19 Waterhammer example (contd)

Unsteady Flow Analysis Summary
Maximum gauge pressure of 30.12 m occurs at pump.
Check recommended design limits for maximum allowable gauge pressures and maximum allowable pressure amplitude fluctuation in selected pipes.
Note: Rising main experiences cavitation, waterhammer protection required.

Boundary conditions:

Mean sump water level:	-2.500 m
Rising main delivery level:	13.000 m
=> Static Lift:	15.500 m

Pump data:

Number of pumps:	1
Standard pump speed:	1490 rpm
Pump duty point head:	22.355 m
Pump duty point discharge:	277.17 m^3/h
Moment of inertia of pump set:	0.550 $kg.m^2$
Pump elevation:	-1.000 m

Rising main:

Length:	1502.000 m
Internal diameter:	300.0 mm
Wall thickness:	7.2 mm
Wall roughness:	0.100 mm
total k-value:	4.000
Youngs' modulus:	1.50E+11 N/m^2

Pumphouse pipework:

Suction

Pipe Ref.:	P 1
internal diameter:	250.0 mm
length:	10.000 m
wall roughness:	0.010 mm
total k-value:	0.5

Delivery

Pipe Ref.:	P 2
internal diameter:	250.0 mm
length:	6.000 m
wall roughness:	0.010 mm
total k-value:	9.6

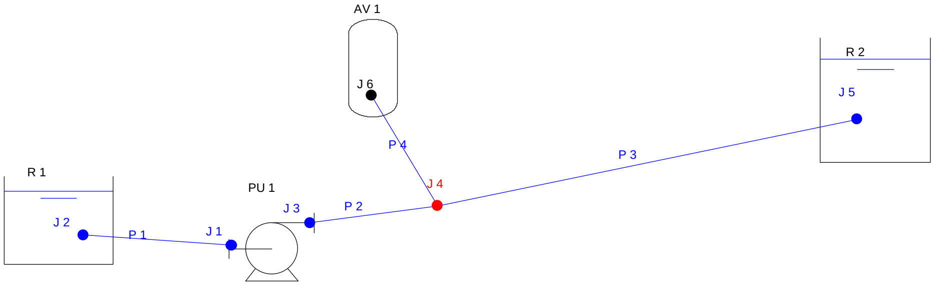
Computational details:

No iterations:	2000
No divisions:	100

Example 20 Waterhammer example, incorporating an air vessel

It is required to examine the waterhammer control effect, on the pump/rising main system in example 19, of using a 2m3 air vessel.

1 Add an air vessel and connecting pipe to the system on the design sheet



Example 20 Waterhammer example, incl air vessel (contd)

2 Edit the properties of the new objects as follows

Pipes

Ref	Diameter (mm)	Length (m)	k (mm)	Total K	No. Fittings
P 4	100	10.00	0.010	0.100	0

Air Vessels

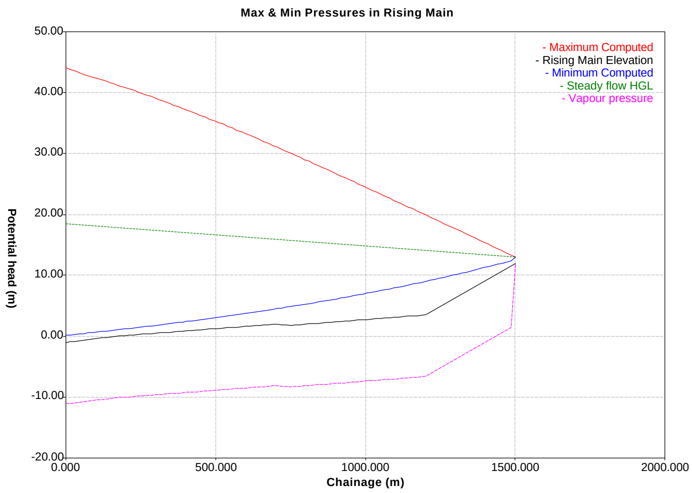
Ref	Diameter (mm)	Height (mm)	Total Vol(m³)	Air Vol(m³)	Water Hgt (mm)
AV 1	1366	1366	2.000	0.389	1100

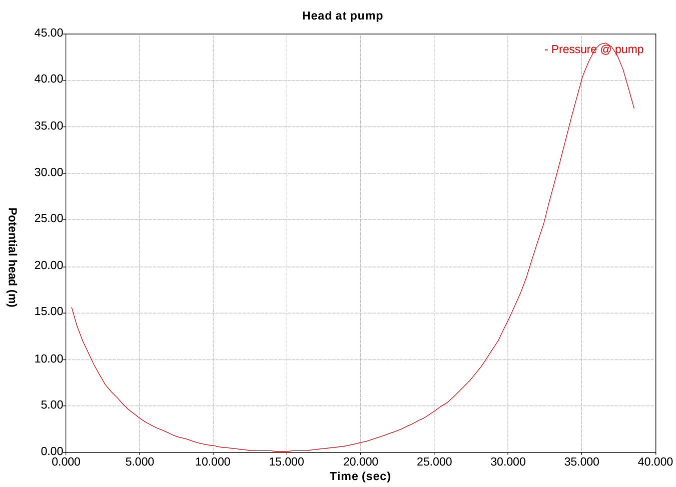
Nodes

Ref	Elevation (mOD)
J 6	1.000

3 Select **Unsteady Pipe Flow** from the **Analysis** menu

4 Check the various graphs produced





5 Check the text output

Unsteady Flow Analysis Summary

Maximum gauge pressure of 45.09 m occurs at pump.
Check recommended design limits for maximum allowable gauge pressures and maximum allowable pressure amplitude fluctuation in selected pipes.

Boundary conditions:
```
  Mean sump water level:                    -2.500 m
  Rising main delivery level:               13.000 m
  => Static Lift:                           15.500 m
```

Air vessel installed:
```
  Throttle pipe diameter:                      100 mm
  Throttle pipe total k-value:                 0.1
  Total volume:                              2.000 m³
  Air volume at steady flow:                 0.389 m³
  Max. expanded air volume:                  1.008 m³
```

Pump data:
```
  Number of pumps:                               1
  Standard pump speed:                        1490 rpm
  Pump duty point head:                     22.355 m
  Pump duty point discharge:                277.17 m³/h
  Moment of inertia of pump set:             0.550 kg.m²
  Pump elevation:                           -1.000 m
```

Rising main:
```
  Length:                                 1502.000 m
  Internal diameter:                         300.0 mm
  Wall thickness:                              7.2 mm
  Wall roughness:                            0.100 mm
  total k-value:                             4.000
  Youngs' modulus:                        1.50E+11 N/m²
```

Pumphouse pipework:
```
Suction
  Pipe Ref.:                                   P 1
  internal diameter:                         250.0 mm
  length:                                   10.000 m
  wall roughness:                            0.010 mm
  total k-value:                               0.5

Delivery
  Pipe Ref.:                                   P 2
  internal diameter:                         250.0 mm
  length:                                    6.000 m
  wall roughness:                            0.010 mm
  total k-value:                               9.6
```

Computational details:
```
  No iterations:                              3000
  No divisions:                                100
```

End

Example 21 Generating a custom report in other applications

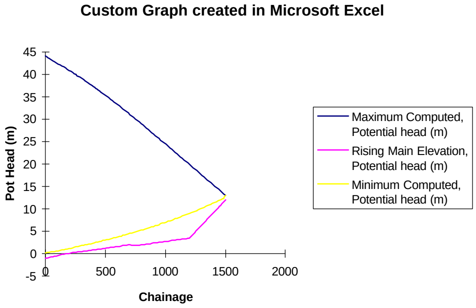
Customise the graphs produced in the previous example and create a document in a word processing package.

1 Select the design sheet

- With nothing on the design sheet selected, select **Edit** > **Copy**
- Paste into a word processing program

2 Select the **Max & Min pressures in the rising main** graph

- Select **Copy** > **Data** from the **Edit** menu
- Start a spreadsheet package, such as Microsoft Excel
- In the spreadsheet package, select Edit > Paste
- Create a graph of Max Pressure, Min Pressure and Main Elevation
- Copy the graph to the Windows Clipboard
- Paste into a word processing program



3 Select the Waterhammer results window

- Select **Edit** > **Copy**
- Paste into a word processing program, below the graph
- Edit the text to suit