MIKE
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WEST

Getting Started

Tutorial

The expert in **WATER ENVIRONMENTS**

MIKE 2020

PLEASE NOTE

WEST GETTING STARTED

1 Introduction

WEST offers a user-friendly platform for dynamic modelling and simulation of water quality systems (such as wastewater treatment plants, rivers, sewers and urban catchments) and uses mathematical models as a reliable representation of real-world systems.

The layout of a plant is set up in a graphical way, by selecting the relevant blocks (unit processes) from a library. Control strategies can be implemented very easily, by adding sensor and controller units on the layout, with no additional code required.

Standard TAB-separated text files as well as MS-Excel spreadsheets can be used as input files for the simulations. The plot environment offers full flexibility in creating visually appealing plots to represent the results of a simulation.

WEST has an extensive library of models and an open structure that allows for implementing new models and modifying existing ones, by using a set of integrated *tools*:

- The Model Editor, consisting of a Code Editor and a (graphical) Gujer Matrix Editor, allows for editing the models;
- The Block Editor allows for managing icon libraries, i.e. the collection of icons that can be used to represent blocks in a WEST layout;
- The Unit Editor allows for managing the unit table of WEST, i.e. editing the units and the respective conversion factors;
- The Data Editor allows for managing data, e.g. input files;
- The Designer allows for dimensioning a treatment plant based on conventional design rules.

WEST has an open structure that allows for integration with supervisory systems (SCADA) and data management systems on the WWTP. Using this approach one can implement a Decision Support System to assist the operator in plant management, while saving on operational costs and ensuring the required effluent quality.

The main features of WEST are:

- Possibility of setting up complex plant layouts and models in a short time.
- Extensive model library, including all standard wastewater treatment plant process units and process control blocks.
- Influent fractionation and data evaluation.
- Dynamic and interactive display of simulation output during simulation.

- Advanced experiment types for efficient model calibration, i.e. local and global sensitivity analysis, automatic parameter estimation, scenario analysis and uncertainty analysis.
- Completely open modelling environment for the implementation of customised models through a Model Editor (Gujer Matrix and Code Editor) and a Block Editor.
- Automatic generation of optimised model code, resulting in unparalleled simulation speed.
- The possibility for integration of modelling and simulation in custom applications.

Typical categories of users and applications of WEST are summarised in Table 1.1.

Table 1.1 Types of WEST users

User type	Application
Researcher	Research tool, to investigate the dynamics of the process in details
Design consultant	Tool to evaluate design options and operating scenarios
Process consultant	Fast dynamic simulator that allows for process optimisation
Automation engineer	Fast dynamic simulator to predict process behaviour and optimise process control
Plant operator	Training tool, to learn how the plant operates
Authority (policy maker)	Decision support tool, to evaluate policy alternatives

2 WEST Release 2020

WEST products of the new generation are named after the year in which they are released, rather than labelled with a number. The last release that was labelled according to the old scheme was WEST 3.7.6 (April 2009).

New generation products that have been released since then are:

- WEST 2011
- WEST 2012
- WEST 2014
- WEST 2016
- WEST 2017

2.1 The Concept

The main driver for a new generation, hence completely new concept, of the WEST simulation tool is to make it more user-oriented. In this light, the main changes to WEST may be summarised as follows:

- The product suite: WEST has dropped the modular format (e.g. Configuration, C; Simulation, S; etc.), each module corresponding to a specific set of functionalities. The focus is shifted to the practical application that a certain product is intended for: e.g. WESTforDESIGN is especially suited for (pre)design modelling.
- The graphical user interface: following the same concept, the applications that WEST used to consist of, i.e. the Configuration Builder and Experimentation Environment, are merged into one single application.
- The influent/effluent tool: this tool enables to import influent data and compose the influent file directly from within WEST, as well as to generate an influent file based on some average characteristics and typical patterns. The tool also enables to graphically set up the fractionation of the influent and to maintain a database of average influent data.

2.2 The Product Suite

WEST comprises four products that address the requirements of a specific target group of users (Table 2.1).

Table 2.1 The WEST Products

Product	Description
WEST Basic	Construction of plant models using a limited number of standard blocks, simulation and output visualisation
WEST Player	Simulation, output visualisation, and computation of user-specified objective functions on the basis of a fixed executable plant model, previously prepared by WEST or WEST+
WEST	Construction of plant models using standard blocks, simulation, output visualisation, and computation of user-specified objective functions
WEST+	Construction of plant models using standard and custom blocks, simulation, output visualisation, computation of user-specified objective functions, and advanced experiments
WEST SDK	Software Development Kit for the integration of the WEST engine in custom applications

2.2.1 WEST Basic

WEST Basic allows for the implementation and evaluation in dynamic conditions of simple plant layouts, consisting of a limited number and types of process units and simplified control strategies.

2.2.2 WEST

WEST allows for validation of design options and evaluation of different plant layouts in dynamic conditions. This is done by running scenarios (e.g. high vs. low load), and by evaluating the effect of complex control strategies.

2.2.3 WEST Player

WEST Player enables operators to perform short-term (e.g. storm events) and long-term (e.g. consistent nutrient removal) evaluations of their plant. The evaluations (e.g. bottle-neck identification) are carried out by running scenarios for specific influent and operational conditions and costs evaluation. The tool is also useful to improve understanding of the WWTP and hence for operator training.

WEST Player is a very flexible and customisable tool which allows a plant operator to use the model that a modelling engineer may have set up independently.

2.2.4 WEST+

WESTf+ enables consultants and engineers to optimise the wastewater treatment processes. With its flexibility and fully open model structure (one can change any model in the model library without limitations) in combination with specific tools for easy model calibration and plant performance evaluation (sensitivity analysis, parameter estimation, scenario analysis and uncertainty analysis) and for minimisation of objective functions (e.g. costs), WEST+ is the most powerful tool of the suite.

2.2.5 WEST SDK

WEST SDK allows for fast integration of modelling and simulation in custom applications by automation or software engineers. Different SDKs containing comprehensive and extensive documentation and sample sets, allow for linking WEST with SCADA systems or other modelling software (MATLAB, CFD, MIKE URBAN, etc.).

The following APIs are available: .NET (standard), MATLAB/MEX, C, C++, Java/JNI, OpenMI, COM and R.

2.3 The Features

The main features of WEST are briefly described below.

Note that some of the features may not be available for a certain type of licence.

- **Interactive Layout Editor**: graphical construction of plant/process models by placing blocks from a toolbox on a canvas and drawing connections.
  - Extended unit process block library
  - Extended drawing functionalities: e.g. resize, rotate, easy labelling of blocks, undo/redo option
  - Possibility to add illustrations (text boxes, rectangles…) to the layout
  - Possibility to add animations (line thickness and line colour), labels an alerts to the layout
  - Multiple layers (e.g. main, water line, sludge line, control)
  - Quick access to the most important data (Info Pane)
  - Automatic, conditional generation of the executable model
- **Influent Generator**: selection of influent data and creation of the influent fractionation model. Settings and data are made persistent.

  - Data import from multiple text files (.txt) and/or MS-Excel spreadsheets (.xls, .xlsx)
  - Graphical tool for influent fractionation
  - Automatic generation of steady-state input file

- **Executable Model Builder**: converts the plant layout to an efficient (fast) executable model, fit for simulation.

- **Steady-state Simulation**: simulation of the plant with constant influent, and appropriate integration solver settings.

- **Dynamic Simulation**: simulation of the plant with dynamic influent and/or dynamic control, and appropriate integration solver settings.

- **Objective Evaluation**: automated computation of aggregated / statistical data on the basis of simulation outputs (e.g. sum of squared errors between simulated and measured data).

- **Local Sensitivity Analysis**: evaluation of the sensitivity of a plant model to changes in selected parameters through the application of a finite difference approach around user-specified nominal parameter values.

- **Global Sensitivity Analysis**: evaluation of the sensitivity of a plant model to changes in selected parameters through Monte Carlo analysis based on Latin Hypercube Sampling over a user-specified, wide parameter range.

- **Parameter Estimation**: automated minimisation of a user-specified objective function (e.g. sum of squared errors between simulated and measured data).

- **Scenario Analysis**: execution of a batch of simulations using a set of parameter values generated with a wizard (linear or logarithmic spacing, random sampling or user-specified), followed by automated ranking of the results according to a user-specified objective function.

- **Uncertainty Analysis**: evaluation of the effects of input (parameter) uncertainty on the output uncertainty of a plant model, using Monte Carlo analysis based on Latin Hypercube Sampling.

- **Input and Output Controls**: can be used to interactively provide inputs to the plant model or visualise simulation outputs, respectively.
  - Easy generation of input and output items (e.g. sliders, fields, plots, tables and files) by dragging and dropping model parameters or variables
  - Extended set of widgets (radio-buttons, combo- and check-boxes) for the creation of dashboards

- **Project documentation**:

  - RTF annotations can be added to a project and contain formatted text, pictures and tables
  - Relevant pieces of information (e.g. project information, notes, lay-out, etc.) can be gathered into one document which can be further enhanced in terms of content and layout in a tool such as Word

- **Effluent Generator**: graphical creation of the effluent fractionation model. Settings and data are made persistent.

- **IUWS library**: suite of models for Integrated modelling of Urban Water Systems, i.e. catchment, sewer, treatment plant and river water quality.

- **Block Editor**: auxiliary application that allows defining the graphical appearance (icon) of blocks.
  - Possibility to edit icon and palette libraries, e.g. add/remove icons to/from an icon library; add/remove (reference to) icon libraries to/from a palette library
  - Graphical editor for icons

- **Model Editor**: auxiliary application that allows defining the behaviour (i.e. the model equations) of blocks in the MSL object-oriented modelling language.
  - Easy navigation through the WEST Model Library
  - Automatic generation of a Block Library from earlier versions of a WEST Model Library
  - Possibility to edit a Block Library (e.g. adding a new Model Library Instance)
  - Multiple Conversion Models per Category and multiple Categories per Instance are supported
  - Gujer Matrix Editor to edit a Model Category and automatic generation of the necessary code
  - MSL Code Editor with advanced editing support to directly edit MSL files

- **Unit Editor**: auxiliary application that allows specifying measurement units (metric, US) and automatic conversions between units.

- **Data Editor**: auxiliary application that allows manipulating data sets.

- **Designer**: auxiliary application that allows designing a WWTP according to a template layout and following a design protocol.

- **API**: Application Programming Interface that enables software developers to develop custom applications on top of the WEST engine.

Table 2.2 The WEST 2020 Feature Matrix

	WEST Basic	WEST Player	WEST	WEST+	WEST SDK
WEST Application	ü	ü	ü	ü	
Steady-state Simulation	ü	ü	ü	ü	
Dynamic Simulation	ü	ü	ü	ü	
Objective Evaluation		ü	ü	ü	
Custom Dashboards	ü	ü	ü	ü	
Layout Animation		ü	ü	ü	
Project Documentation	With limitations	ü	ü	ü	
Interactive Layout Editor	ü		ü	ü	
Influent / Effluent Tool	ü		ü	ü	
Executable Model Builder			ü	ü	
Local Sensitivity Analysis				ü	
Global Sensitivity Analysis				ü	
Parameter Estimation				ü	
Scenario Analysis				ü	
Uncertainty Analysis				ü	
IUWS library				ü	
Block Editor Application				ü	
Model Editor Application				ü	
Unit Editor Application		ü	ü	ü	
Data Editor Application		ü	ü	ü	
Designer Application			ü	ü	
API					ü

3 Quick Tour

1. Start up WEST.

2. (WESTforOPERATORS licence only) Open the desired Project: you may look at the Description and/or miniature snapshot of the Layout for reference. Then go to point 7.

3. In case your licence includes more than one product: select one of the products enabled in your licence (Figure 3.1).

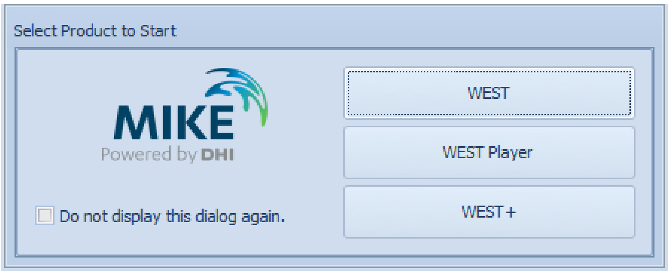


Figure 3.1 Product Selection at start-up

4. From the list of Templates, double-click on ‘Create Blank Project’. Or: choose “New” from the Application menu (top-left corner).

5. Enter a valid name for the New Project, e.g. ‘Project1’ and choose the appropriate Model Library ‘Instance’: ‘ASM1Temp’ for modelling Carbon and Nitrogen removal based on ASM1. You may also provide a description of the project that will help identifying it for future reference, e.g.: ‘TwoASU sample: MLE layout for Nitrification-Denitrification’ (Figure 3.2).

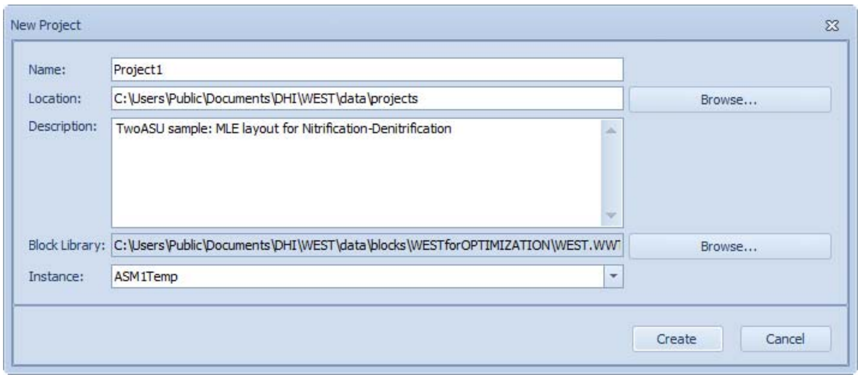


Figure 3.2 Create a New (blank) Project

6. Drag all the necessary Blocks from the Block Library to the Layout Sheet, i.e. an Input Block of type 'Municipal wastewater', a 3-way Flow Combiner, two Activated Sludge Units, two Pumps (2-way Flow Splitters), a Secondary Clarifier, a Controller of type 'PI controller', two Loop Breakers (optional), one Output Block of type 'Effluent' and one of type 'Waste' (Figure 3.3 and Table 3.1).
   - Rotate and resize the Blocks, if necessary.
   - Use the Properties pane, to rename Blocks and to hide labels, if wanted.
   - Establish the relevant connections.
   - Enter the relevant dimensions (use the Block Details- or the Block Summary pane), i.e. the volume of the anoxic and aerobic tanks (2000 and 4000 m^3 respectively), the internal recycle (55331 m^3/d), the sludge underflow in the clarifier (18831 m^3/d), the sludge wastage (385 m^3/d) and the DO set-point for the aeration controller (1.5 mg/l). See also Table 3.1.

The Loop Breaker blocks can be left out as long as the "InsertLoopBreaker" property of the Layout is set to True.

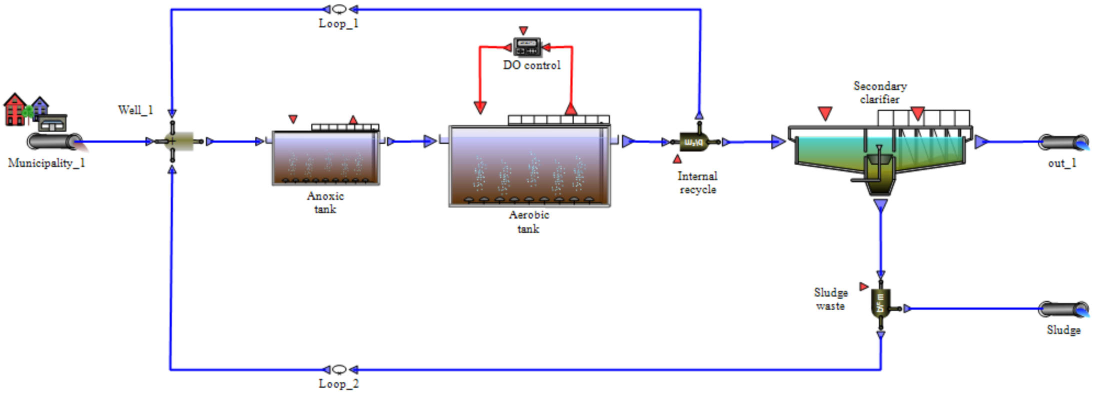


Figure 3.3 The plant layout for the TwoASU sample

Table 3.1 The blocks for the TwoASU sample

Name	Block	Palette	Parameters	Remarks
Municipality_1	Municipal wastewater	Input and Output	N.A.	Access the Influent Generator
Well_1	Three combiner	Flow	N.A.	Hide name
Anoxic tank	Activated sludge unit	Biological Treatment	Vol = 2000 m^3	Rename

Table 3.1 The blocks for the TwoASU sample

Name	Block	Palette	Parameters	Remarks
Aerobic tank	Activated sludge unit	Biological Treatment	Vol = 4000 m^3	Rename Resize
DO control	PI Controller	Controllers	y_S = 1.5 mg/l	Rename Flip horizontally
Internal recycle	Two flow splitter	Flow	Q_Out_2 = 55331 m^3/d	Rename Flip vertically
Loop_1 (optional)	Loop breaker	Other	Default	Flip horizontally Hide name
Secondary clarifier	Secondary clarifier	Separation	Q_Under = 18831 m^3/d	Resize
Sludge waste	Two flow splitter	Flow	Q_Out_2 = 385 m^3/d	Rename Rotate 90º Flip horizontally
Loop_2 (optional)	Loop breaker	Other	Default	Flip horizontally Hide name
out_Water	Effluent	Input and Output	N.A.	Rename Access the Effluent Generator
out_Sludge	Effluent	Input and Output	N.A.	Rename Access the Effluent Generator

7. Double-click on the Input Block (Municipality_1), to access the Influent Generator:
   - **General**: choose the option of Custom components and continue
   - **Data Import**: the default Time Policy, “Time Series In” is good; select the WEST.BODCOD.Month.Influent.txt file, as the source file for the influent characterisation; drag the filename to the Time Series Out box at the bottom
   - **Fractionation**: Load the WEST.ASM1.Input.Layout.xml Fractionation Layout (Figure 3.4)
   - **Build and Review**: click Build, to create the influent model and steady-state and dynamic files.

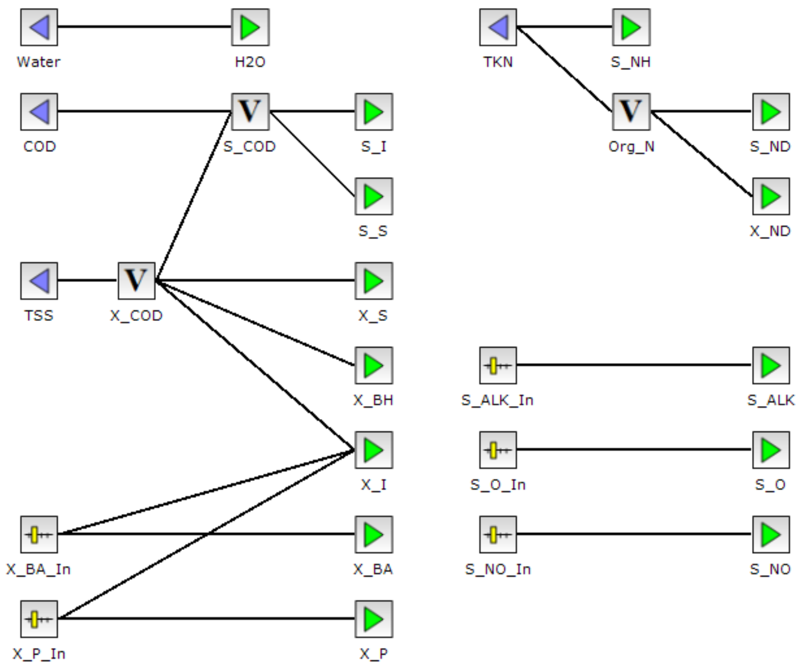


Figure 3.4 Default ASM1 fractionation layout

8. Double-click on the Output Block (out_1), to access the Effluent Generator:
   - **General**: choose the option of Custom components
   - **Defractionation**: load the WEST.ASM1.Output.Layout.xml fractionation layout (Figure 3.5)
   - **Build**: click Build, to create the effluent model.

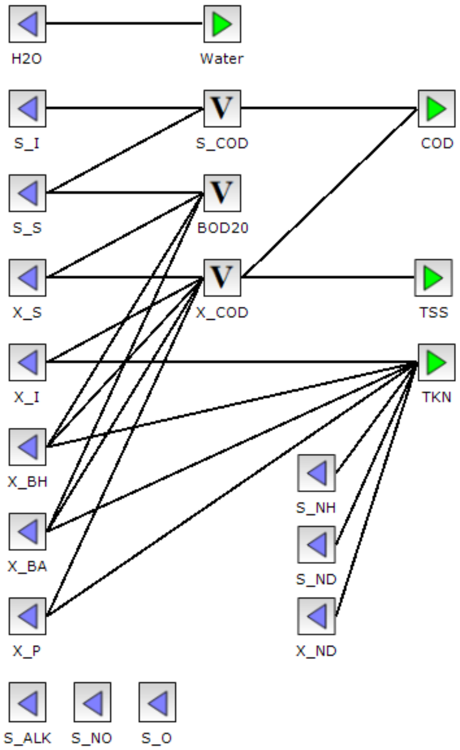


Figure 3.5 Default ASM1 de-fractionation layout

9. Create some Output objects to visualise the results of the simulation.
   - Add as many new Sheets as needed and add new Plot (Output, Field or Table) items to the Sheets, e.g. add four plots, ‘Anoxic unit’, ‘Aerobic unit’, ‘Oxygen concentration’ and a ‘Solids profile’.
   - Make sure the appropriate Block is selected in the Layout Sheet (or in the Model Explorer) and drag the relevant variables from the Block Details to the plot window.
   - For instance, for the plots ‘Anoxic unit’ and ‘Aerobic unit’, the soluble COD, nitrate and ammonium concentrations in the anoxic and aerobic units respectively; for the plot ‘Oxygen concentration’, the oxygen concentration from then anoxic and from the aerobic units; for the plot ‘Solids profile’, the mass of solids in each layer of the secondary clarifier (Table 3.2).

Table 3.2 Suggestion for the visualisation of the simulation output

Name	Quantity	Block	Tab	Category	Group
Plot 'Anoxic tank'					
Soluble COD	C(S_S)	Anoxic tank	Variables	Output Variable	Measurement data
Nitrate	C(S_NO)	Anoxic tank	Variables	Output Variable	Measurement data
Ammonium	C(S_NH)	Anoxic tank	Variables	Output Variable	Measurement data
Plot 'Aerobic tank'					
Soluble COD	C(S_S)	Aerobic tank	Variables	Output Variable	Measurement data
Nitrate	C(S_NO)	Aerobic tank	Variables	Output Variable	Measurement data
Ammonium	C(S_NH)	Aerobic tank	Variables	Output Variable	Measurement data
Plot 'Oxygen levels'					
Anoxic	C(S_O)	Anoxic tank	Variables	Output Variable	Measurement data
Aerobic	C(S_O)	Aerobic tank	Variables	Output Variable	Measurement data
Plot 'Solids profile'					
Solids	X_Layer(i)	Sec. clarifier	Variables	Derived State Variable	Concentration

10. Run the Steady-State simulation (to the end).

11. Run the Dynamic simulation.

12. Evaluate the results (Figure 3.6).

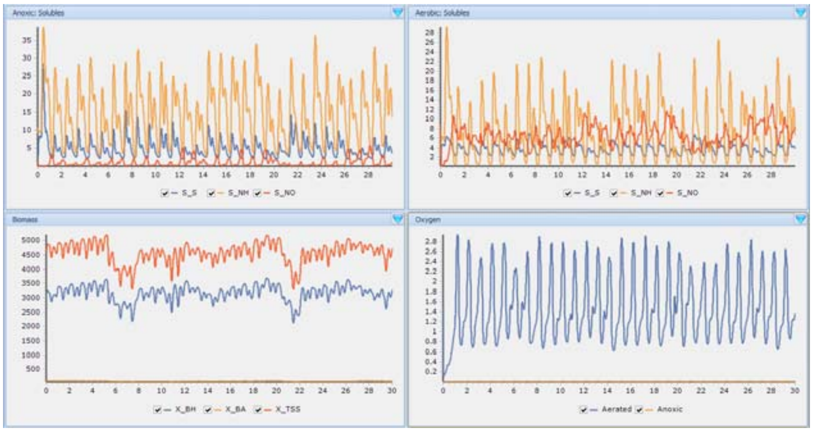


Figure 3.6 Results of the 30-day dynamic simulation of the TwoASU sample

For a more detailed illustration of how to set up a simulation experiment, please refer to the WEST Tutorial.

4 Technical Support

DHI believes that providing technical assistance to WEST users is essential.

For this reason, several channels have been activated to enhance the communication with the community of WEST users.

Website:

- MIKE Powered by DHI homepage: http://www.mikepoweredbydhi.com
- MIKE Forum: http://forum.mikebydhi.com/index.php
- Frequently Asked Questions: http://faq.dhigroup.com

Email:

- Technical questions can be sent to mike@dhigroup.com

Training courses:

- THE ACADEMY by DHI offers Calendar as well as Tailored WEST training courses, please refer to http://www.theacademybydhi.com

WEST TUTORIAL

5 Introduction

This Guide illustrates:

- the base experiment type, i.e. Objective Evaluation, which consists of a Steady-State and a Dynamic Simulation experiment
- the 5 advanced (virtual) experiment types (Scenario Analysis, Uncertainty Analysis, Global Sensitivity Analysis, Local Sensitivity Analysis and Parameter Estimation).

A very simple two-tank activated sludge plant layout (TwoASU) will be used throughout this Guide.

The preparatory work that is necessary to set up the basic plant layout, to initialise the model and to set up the relevant graphical outputs is described in details in Chapter 6.

The Objective Evaluation experiment is described in Chapter 7.

Chapters 8 to 12 are devoted to the advanced experiments that are created on top of one of the base experiments (either Steady-State or Dynamic).

Chapters 13 and 14 illustrate two examples, unrelated to the base TwoASU case. The first one is a UCT layout with anaerobic digestion of the activated sludge, that uses the “PWM_SA” plant-wide model. The second example is a hypothetical integrated urban system, consisting of a catchment, the sewer, an MLE plant layout and two river stretches.

6 The TwoASU Sample, Step-by-Step

This chapter will guide you through setting up the ‘TwoASU’ plant layout and running a standard 4-week dynamic simulation. This example is fully worked out as Sample in WEST and can be accessed through the ‘Getting Started’ panel.

The ‘TwoASU’ is a MLE process (Modified Ludzack and Ettinger) consisting of an activated sludge stage with two compartments, i.e. anoxic and aerated, followed by a secondary clarifier. To ensure sufficient denitrification, an internal recycle returns part of the effluent of the aerobic stage back to the anoxic stage upstream.

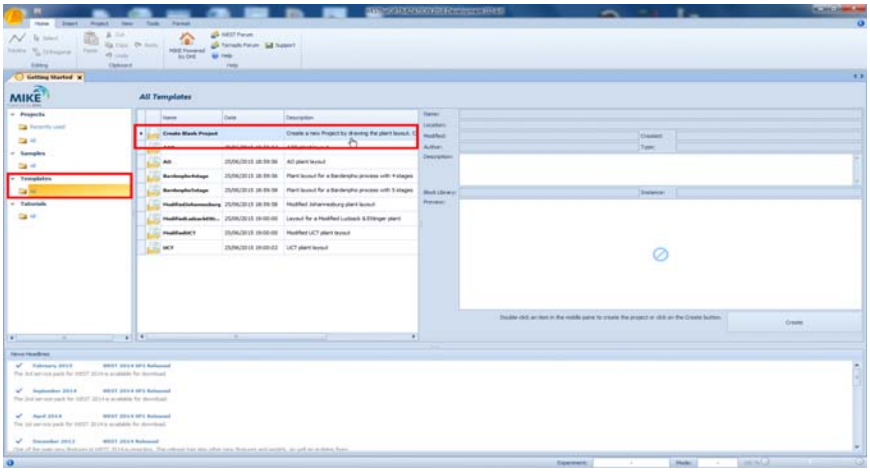


Figure 6.1 Getting Started: create a New (blank) Project

6.1 Start a New Project

From the ‘Templates’ category of the Getting Started panel, choose ‘All’ and the ‘Create blank Project’ item of this group (Figure 6.1).

Double-click on the *card*, or click on the “Create” button: the dialogue window shown in Figure 6.2 will be displayed:

- Rename the New Project ‘**TwoASU**’
- Fill in an appropriate Description

There is no need to modify the remaining items: Phosphorous is not going to be modelled in this exercise, so the ‘Instance’ ASM1Temp is appropriate; and you are going to use the default ‘Location’ and ‘Block Library’.

Confirm, by clicking on the “OK” button.

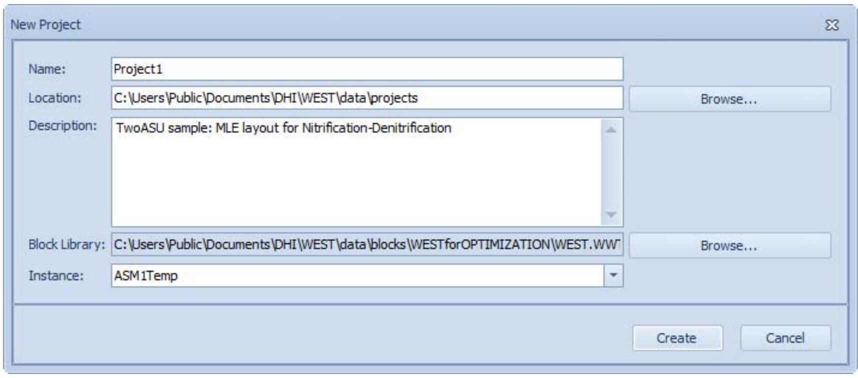


Figure 6.2 Input the preliminary information and settings for the New Project

6.2 Set Up the Plant Layout

Choosing the option of starting up a new (blank) Project will open the WEST Environment (REF TO FIG 6.3). The following elements can be identified:

- The Layout Sheet, where the Blocks are to be dropped to compose the plant layout.
- The Block Library, a collection (Palette) of Blocks grouped in categories, e.g. ‘Biological treatment’, ‘Flow’, etc.
- The Properties and the Model Explorer Panes which are initially empty but are going to show the Properties of the current *object* on the Layout Sheet and the tree view of the overall model as it gets composed on the Layout Sheet, respectively.
- The Block Summary Pane which provides a quick access to the key parameters and variables of the Block that is currently active on the Layout Sheet.

In order to increase the visibility of the information that is going to be displayed, it may be convenient to dock the Model Explorer pane on top of the Overview pane and move the combined pane below the Block Details/Properties pane; to dock the Block Details pane on top of the Properties pane; to move the Info pane on top of the Layout Sheet (as it is only to be examined in case of error messages); and to leave the Control Center floating atop (Figure 6.3).

Most of the panes (termed “System Windows”) are associated with a shortcut; and all can be activated via Windows | System of the View menu.

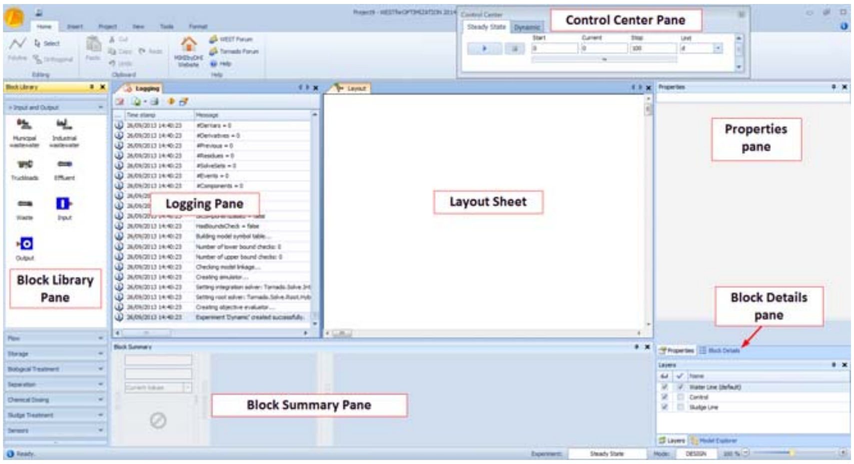


Figure 6.3 The customised WEST environment

Select the following Blocks, from the Block Library, and drop them on the Layout Sheet, following the logical disposition of the units (i.e. Influent, Anoxic tank, Aerobic tank, Clarifier and Effluent: Figure 6.4) to facilitate connection of the nodes in the final plant layout:

Table 6.1 Block units for the plant layout of the TwoASU sample

Block	Group	Quantity
Municipal wastewater	Input and output	1
Effluent	Input and output	2
Three combiner	Flow	1
Activated sludge unit	Biological treatment	2
Two flow splitter	Flow	2
Secondary clarifier	Separation	1
PI controller (*)	Controllers	1
Loop breaker (**)	Other	2

(*) You may want to assign the Control Block to the Control Layer

(**) Optional as of release 2016 - provided the InsertLoopBreakers property of the Layout be set to True

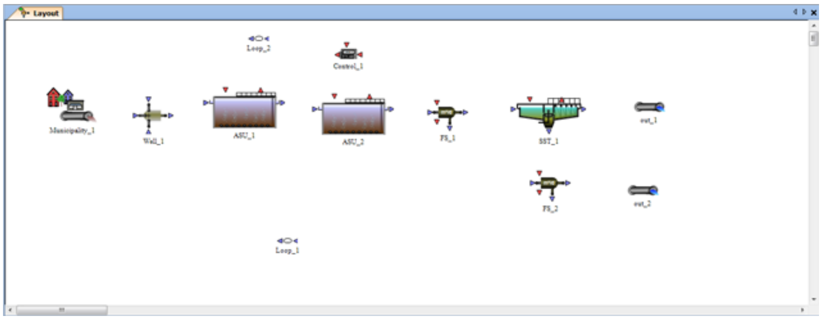


Figure 6.4 First step in setting up a TwoASU plant layout

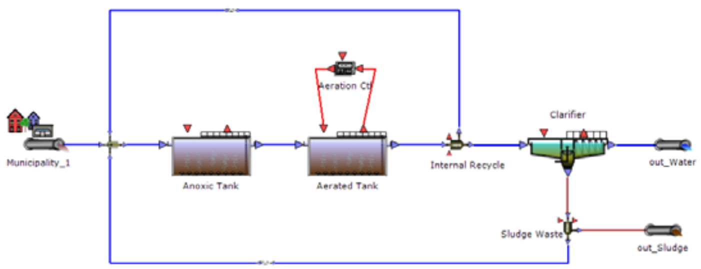


Figure 6.5 Final plant layout for the TwoASU sample

You may want to resize some Blocks, to mimic their relative importance in the layout or their actual size on the plant; it may also be convenient to rotate some Blocks to ensure a neater layout at the end (cf. 'Resize a Block', 'Rotate a Block' and 'Flip a Block' in the WEST User Guide).

As a suggestion, proceed as follows:

- Make the ASU_1 unit (Anoxic Tank) smaller and the ASU_2 block (Aerobic Tank) and the Clarifier bigger.
- Make the two flow splitters and the flow combiner smaller.
- Mirror the two loop breakers and the control block horizontally.
- Rotate the FS_2 block by 90° and further mirror it horizontally, so that the red control terminal points to the effluent node out_2.
- Mirror the FS_1 block vertically, so that the *red* control terminal points upwards.

Further, you may want to rename some Blocks to more appropriate identifiers (cf. 'Rename a Block' in the WEST User Guide).

Finally, connect the Blocks (cf. 'Connect two Blocks' in the WEST User Guide) on the Layout Sheet in the appropriate manner. The final result is shown in Figure 6.5.

6.3 Create an Input File

An input file containing the characteristics of the influent wastewater is to be generated through the Influent Generator (cf. 'The Influent Generator' in the WEST User Guide).

General

Double-click on the Input Block Municipality_1, to start up the Influent Generator: a new Sheet will be associated to the Block and can be subsequently accessed (and revised) at any time (Figure 6.6).

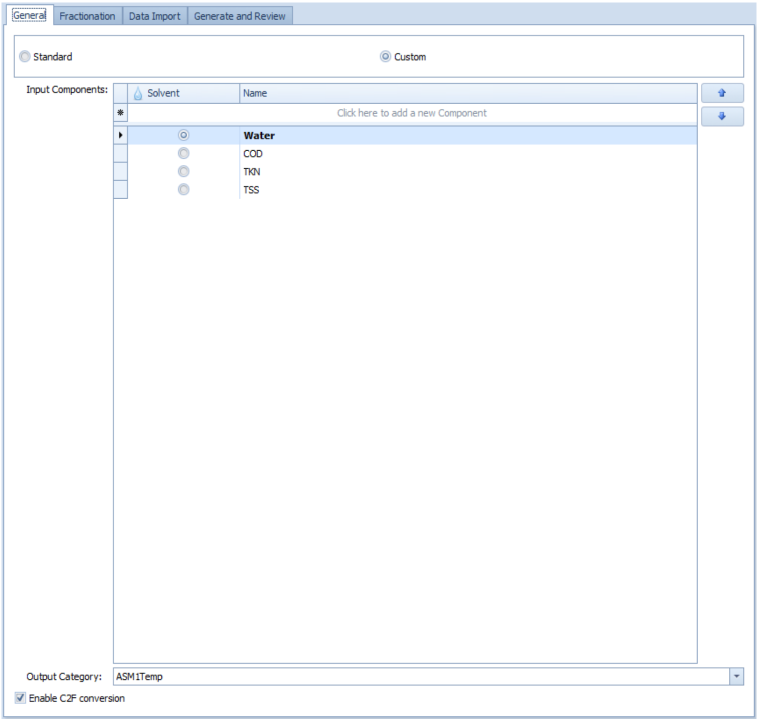


Figure 6.6 General page of the Influent Generator

The default settings are good for this example:

- The influent characteristics will be specified in Custom units.
- The Input Components will be water (flow rate) and COD, TKN and TSS (concentration)
- The Output Category is to be ASM1Temp

- The conversion “C to F” is necessary.

Fractionation

The Fractionation page will initially show:

- the list of components indicated in the General page as incoming variables of the Fractionation Model (blue arrows)
- the list of model components for the selected Model Category as outgoing variables of the Fractionation Model (green arrows)

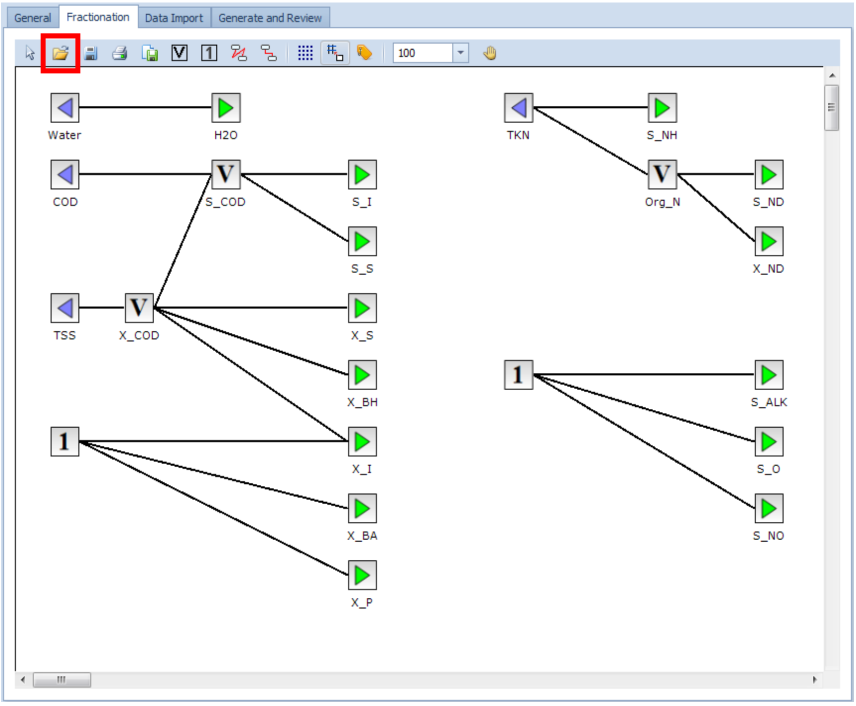
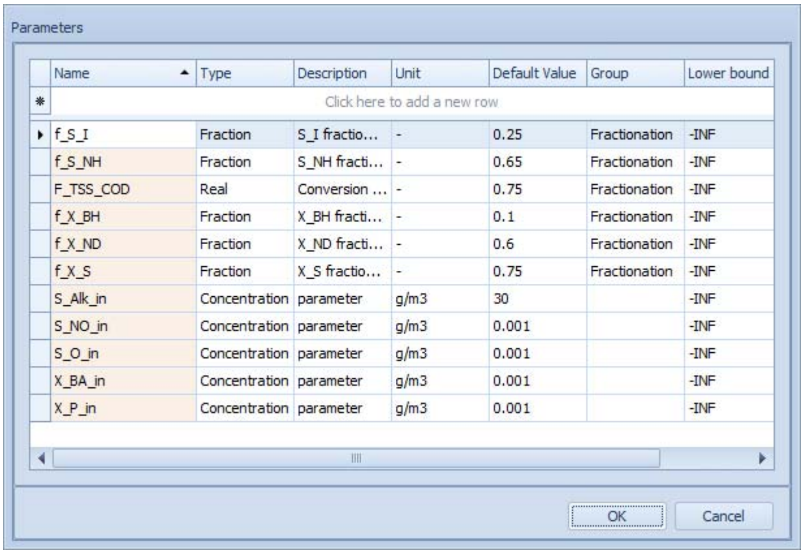


Figure 6.7 Default ASM1(Temp) fractionation model

For this example, we are not going to create a layout from scratch, but simply use the standard ASM1 fractionation, shipped with WEST: click on the “Open” button of the toolbar (Figure 6.7) and select the WEST.ASM1.Input.Layout.xml (located in the WEST\data\misc\InputOutput folder).

The parameters of the model can be viewed (and e.g. their default values may be changed) through the “Parameters ...” item in the context menu (Figure 6.8). When a connection between two blocks is selected, the corresponding weight is displayed in the Properties pane.


Parameters

Name	Type	Description	Unit	Default Value	Group	Lower bound
f_S_I	Fraction	S_I fractio...	-	0.25	Fractionation	-INF
f_S_NH	Fraction	S_NH fracti...	-	0.65	Fractionation	-INF
F_TSS_COD	Real	Conversion ...	-	0.75	Fractionation	-INF
f_X_BH	Fraction	X_BH fracti...	-	0.1	Fractionation	-INF
f_X_ND	Fraction	X_ND fracti...	-	0.6	Fractionation	-INF
f_X_S	Fraction	X_S fractio...	-	0.75	Fractionation	-INF
S_Alk_in	Concentration	parameter	g/m3	30		-INF
S_NO_in	Concentration	parameter	g/m3	0.001		-INF
S_O_in	Concentration	parameter	g/m3	0.001		-INF
X_BA_in	Concentration	parameter	g/m3	0.001		-INF
X_P_in	Concentration	parameter	g/m3	0.001		-INF

Figure 6.8 Parameters for the standard ASM1 Fractionation Model

Data Import

Next you are to select the file(s) that contain the data for the influent characterisation. Text files and/or MS-Excel spreadsheets can be used, provided that:

- the first line/row contains the headers
- the second line/row contains the units
- the first column contains the time scale

If the headers of the variables in the input file(s) match the name of the variable in the model library, the association between the 'Header' and the 'Component' ("Time Series Out" block) will be set automatically.

The default settings are fine for this example, in particular: the Time Policy ("Time Series In") and no interpolation ("Simulation Input Interpolation" off).

Click on the "Add" button in the left hand pane of the "Time Series In" blcok (Figure 6.9), to add the relevant files to the list. In this example, the predefined 'WEST.BODCOD.Month.Influent.txt' file is sufficient, as it contains all the relevant data sets.

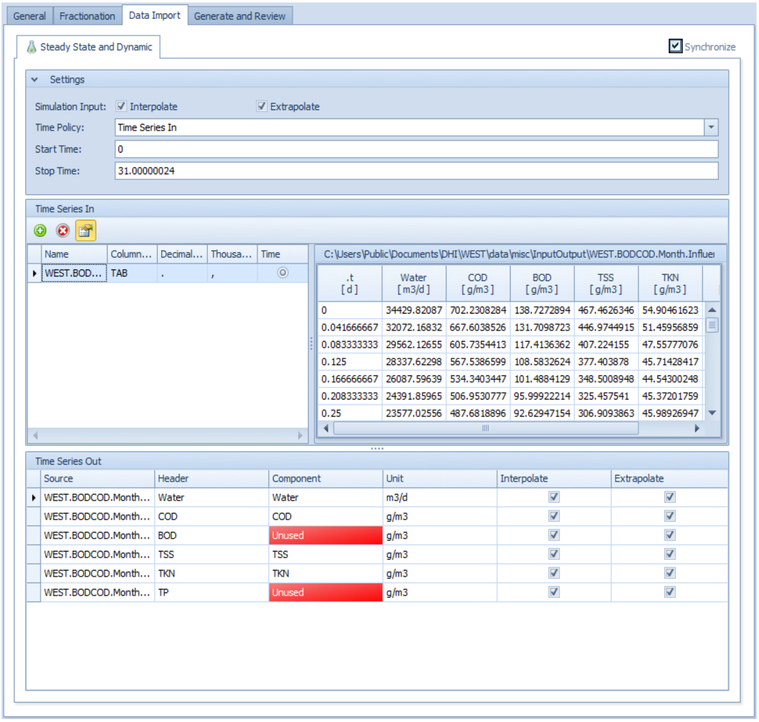


Figure 6.9 Import data (custom dataset) for the characterisation of the ASM1 influent

Once the file is loaded, its content will be displayed in the grid next to it. Columns can be selected individually or multi-selected, and dragged to the “Time Series Out” block.

For this example, since all the data are contained in one file, you can use a shortcut and drag the filename which is equivalent to dragging all its individual columns.

The only requisite at this stage is that all the “Input Components”, specified in the “General” tab page, are matched to a corresponding data source (column in the input file).

Generate and Review

Once data are loaded (Data Import) and the Fractionation Layout assembled (Fractionation), the final stage of the Influent Generator is the effective creation of the **influent fractionation** (to convert the custom- to the category data set used to characterise the influent), the steady-state and the dynamic **influent files** (used for the steady-state and for the dynamic simulations respectively).

To do this, click on the “Generate” button (Figure 6.10).

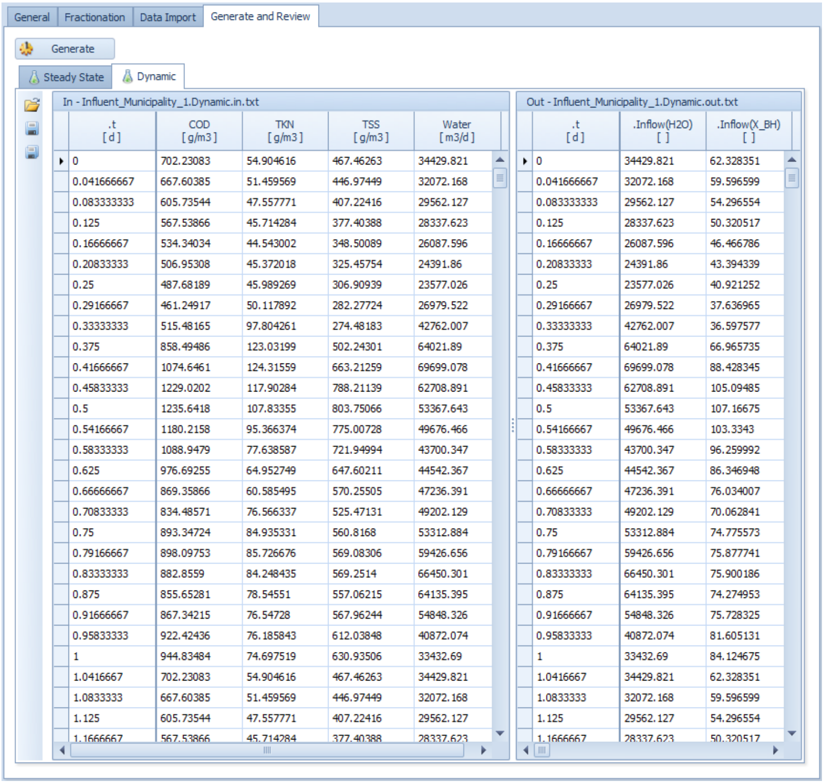


Figure 6.10 In (custom) and Out (ASM1) influent files are generated

6.4 Initialise the Model

Prior to executing the simulation, the model is to be initialised, i.e.: the model parameters are to be set and the derived state variables are to be assigned initial values (cf. 'Initialise the Models' in the WEST User Guide).

In first approximation, most default values that are preset for the model parameters will be acceptable; the user will have to set the process-specific parameters, typically the size of the units, the flow rates, etc.

For this example, set the parameter values shown in Table 6.2:

Table 6.2 Parameter values

Block	Parameter	Value	Units
Anoxic unit	Vol	2,000	m^3
Aerobic unit	Vol	4,000	m^3
Anoxic unit	Temp	20	°C

Table 6.2 Parameter values

Block	Parameter	Value	Units
Aerobic unit	Temp	20	°C
Aeration	y_S	1.5	mg/l
Secondary clarifier	Q_Under	18,831	m^3/d
Internal recycle	Q_Out2	55,338	m^3/d
Wastage	Q_Out2	385	m^3/d

To set model parameters:

- select a specific Block on the Layout Sheet (or the corresponding element in the Model Explorer pane)
- go to the Parameters tab page of the Block Details pane
- type in the desired value for the parameter.

A parameter that is common to more than one Block can be set simultaneously by multi-selecting the relevant Blocks (by drawing a selection window around them on the Layout Sheet or by selecting the corresponding elements in the Model Explorer pane, while holding the Ctrl key down) and following the same procedure outlined above.

For most models included in the WEST model library, the derived state variables are initialised automatically – and this is the case of all process units included in this Tutorial (except the secondary clarifier – but this is not essential).

As a general rule, however, initial values of derived state variables should be set to non-zero values.

6.5 Set Up the Effluent Model

If not otherwise indicated, the effluent characterisation will be specified in ASM units that is: in terms of model components (and as loads, i.e. mass per unit time). This is in most cases not convenient, as the effluent quality is to be compared against environmental Standards for specific components expressed in concentration units.

An effluent file containing the characteristics of the effluent wastewater can be generated through the Effluent Generator (cf. ‘The Effluent Generator’ in the WEST User Guide).

General

Double-click on the Output Block out_Water, to start up the Effluent Generator: a new Sheet will be associated to the Block and can be subsequently accessed (and revised) at any time (Figure 6.11).

Most of the default settings are fine for this example:

- The effluent characteristics will be specified as Custom units.
- The Input Category is ASM1Temp
- Next to Water, COD, TKN and TSS, add one component to the Output Components: “BOD”
- The conversion “F to C” is necessary.

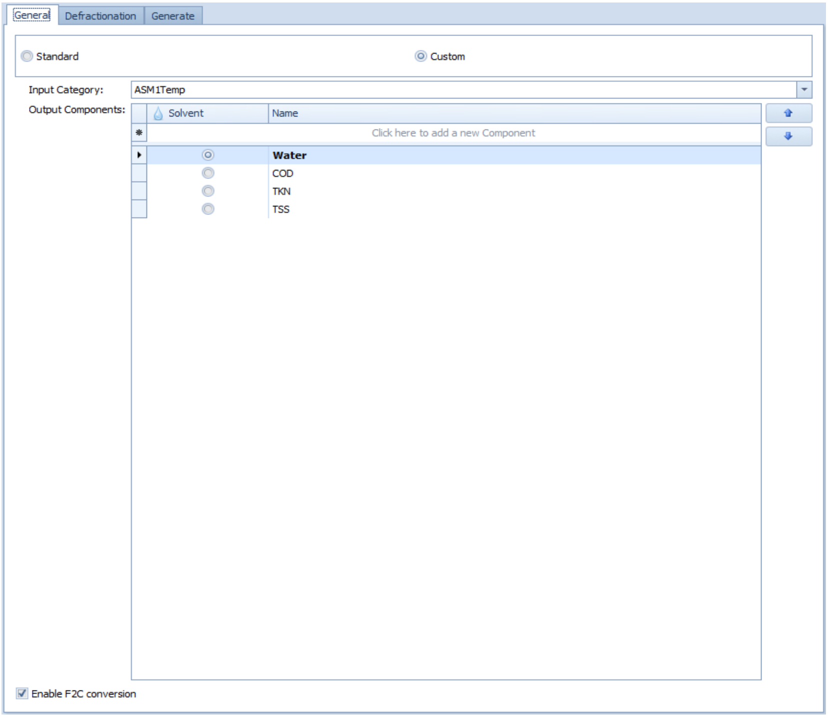


Figure 6.11 Start-up page of the Effluent Generator

Defractionation

The Defractionation page will initially show:

- the list of model components for the selected Model Category as incoming variables of the Defractionation Model (blue arrows)
- the list of components indicated in the General page as outcoing variables of the Fractionation Model (green arrows)

For this example, we are not going to create a layout from scratch, but simply use the standard ASM1 defractionation, shipped with WEST: click on the “Open” button of the toolbar (Figure 6.12) and select the WEST.ASM1.Output.Layout.xml (located in the WEST\data\misc\InputOutput folder).

The parameters of the model can be viewed (and e.g. their default values may be changed) through the “Parameters ...” item in the context menu (Figure 6.9). When a connection between two blocks is selected, the corresponding weight is displayed in the Properties pane.

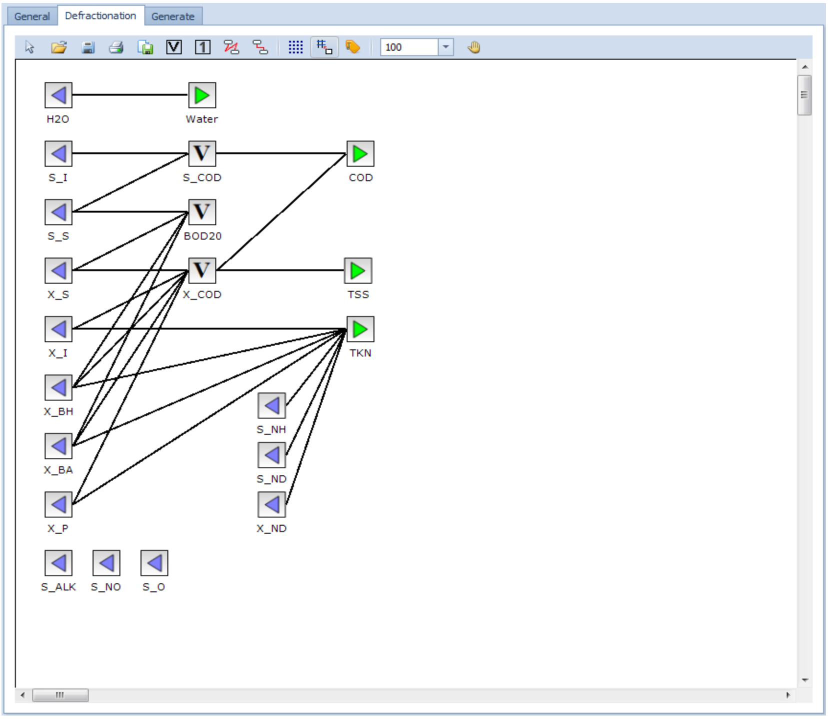


Figure 6.12 Default ASM1 De-fractionation Model

Generate

The final stage of the Effluent Generator is the effective creation of the Effluent De-fractionation Model that converts the category- to the custom data set used to characterise the effluent.

To do this, click on the “Generate” button.

6.6 Prepare the Output

There are 4 categories of graphical output in WEST (under the ‘Insert’ menu), i.e. Plots, Tables, Fields and Gauges (cf. ‘Input/Output Sheets’ in the WEST User Guide). In this example, you are going to set up a few plots and a table.

Proceed as follows.

- Create a new ‘Sheet’: click the “Add” button in the menu Insert | Sheets and name it ‘ASU Tanks’ (Figure 6.13).
- In the middle of the ‘Sheet’ area, two groups of buttons will be displayed: the first line shows Slider, Field, Radiobuttons, Comboboxes and Check-boxes *input* items; the second line, Plot, Field, Table and Gauges *output* items (the same objects are accessible through the Insert | Input and Insert | Output menu items respectively; Figure 6.13).
- Click on the “Plot” button to create a new “Plot”: the default options, i.e. ‘Time Series X(t)’ for the data set and ‘Fast Line’ for the series type are fine. Name the plot ‘Anoxic: Solubles’.
- Create three more ‘Plot’ items (by clicking on the “Plot” button of the Insert | Output menu’) and name them ‘Aerobic: Solubles’, ‘Biomass’ and ‘Oxygen’, respectively.
- Now create a second ‘Sheet’ and name it ‘Effluent and Sludge’.
- Add the following *output* items:
  - A Times Series X(t), Line type plots, named ‘Effluent: ASM specs’
  - A Current Value, Bar type plot, named ‘Sludge profile’
  - A Table, named ‘Effluent quality’: Source Type is the “Experiment” and Source Name is “Simul”
- By default, objects are simply stacked on a ‘Sheet’ (Figure 6.14). You may want to re-arrange them:
  - click on the “Design Mode” button in the View | Sheets menu (move the ‘Customisation’ dialogue window out of the way, if necessary)
  - in the Sheet ‘ASU Tanks’, drag the ‘Aerobic: Solubles’ plot window next to the ‘Anoxic: Solubles’ plot window
  - do the same, for the ‘Oxygen’ and ‘Biomass’ plot windows
  - in the Sheet ‘Effluent and Sludge’, move the ‘Sludge profile’ to the left and the Table to the right of the “Effluent: ASM specs” plot
  - you may want to resize the plot windows by moving their borders
  - the final layouts should look like Figure 6.15 and Figure 6.16
  - exit from the ‘Design Mode’ by clicking the close button of the ‘Customisation’ dialogue
- Now, you need to add the quantities that are to be plotted, to the respective output objects. To do so, proceed as follows:
  - In the ‘Model Explorer’, select the ‘Anoxic Tank’ Block (Figure 6.17)
  - Switch to the ‘Block Details’ pane and further to the ‘Variables’ tab page
  - Select the S_S, S_NO and S_NH concentrations (multi-select by holding down the Ctrl key), drag and drop them onto the ‘Anoxic: Solubles’ plot window (Figure 6.18)

– Set up the remaining plot windows as outlined in Table 6.3

Table 6.3 Variables for the plot and table outputs of the TwoASU sample

Object	Blocks	Variables
Plot ‘Anoxic: Solubles’	‘Anoxic’	C(S_S), C(S_NO), C(S_NH)
Plot ‘Aerated: Solubles’	‘Aerated’	C(S_S), C(S_NO), C(S_NH)
Plot ‘Biomass’	‘Aerated’	C(X_BA), C(X_BH), X_TSS
Plot ‘Oxygen’	‘Anoxic’ + ‘Aerated’	C(S_O)
Plot ‘Sludge profile’	‘Clarifier’	X_Layer(1) to X_Layer(10)
Plot ‘Effluent: ASM specs’	‘out_Water’	Outflow(S_S), Outflow(S_NO), Outflow(S_NH)
Table ‘Effluent quality’	‘out_Water’	BOD, COD, TKN, TSS

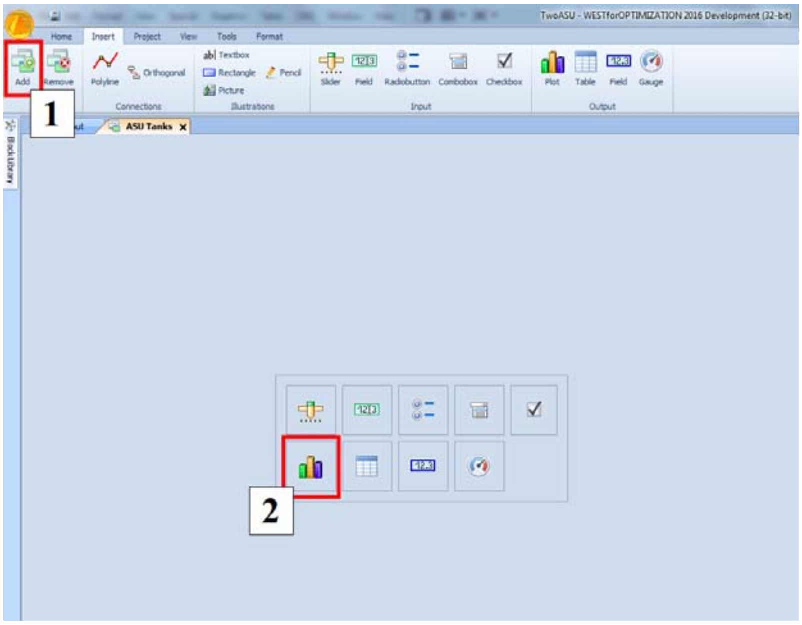


Figure 6.13 Create a new ‘Sheet’ that will contain plot and table items

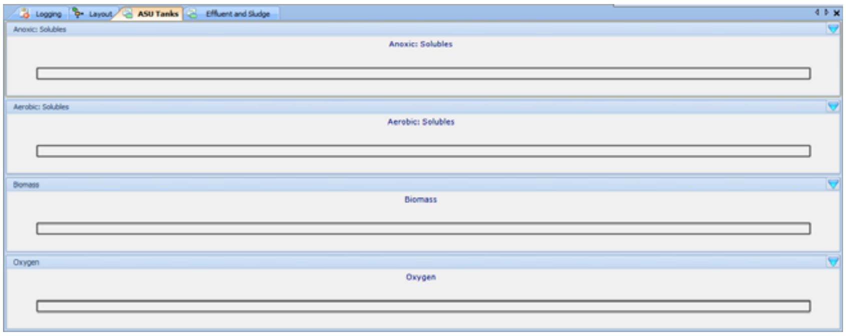


Figure 6.14 New plot items, stacked on a new Sheet

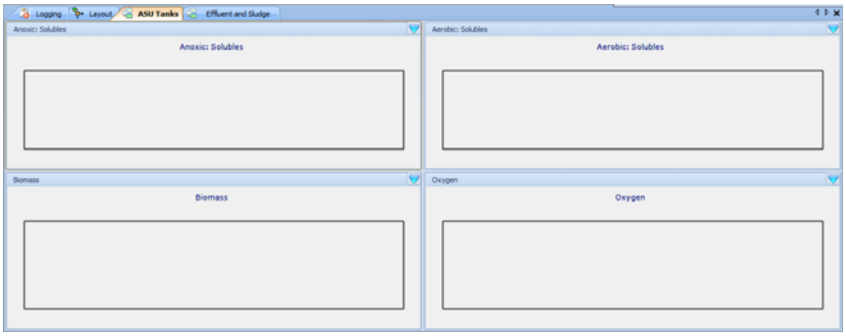


Figure 6.15 New plot items, re-arranged on the Sheet 'ASU tanks'

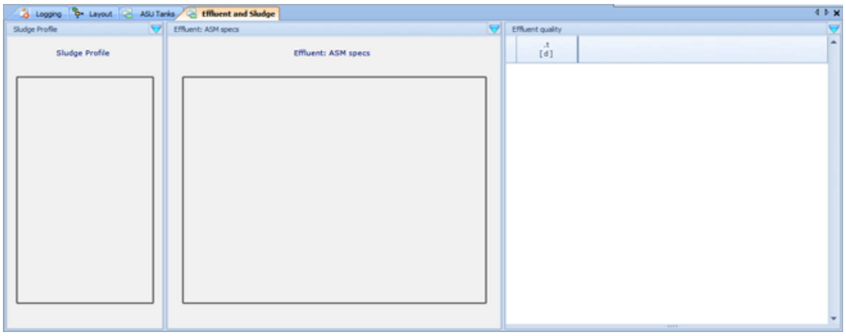


Figure 6.16 New plot items, re-arranged on the Sheet 'Effluent and Sludge'

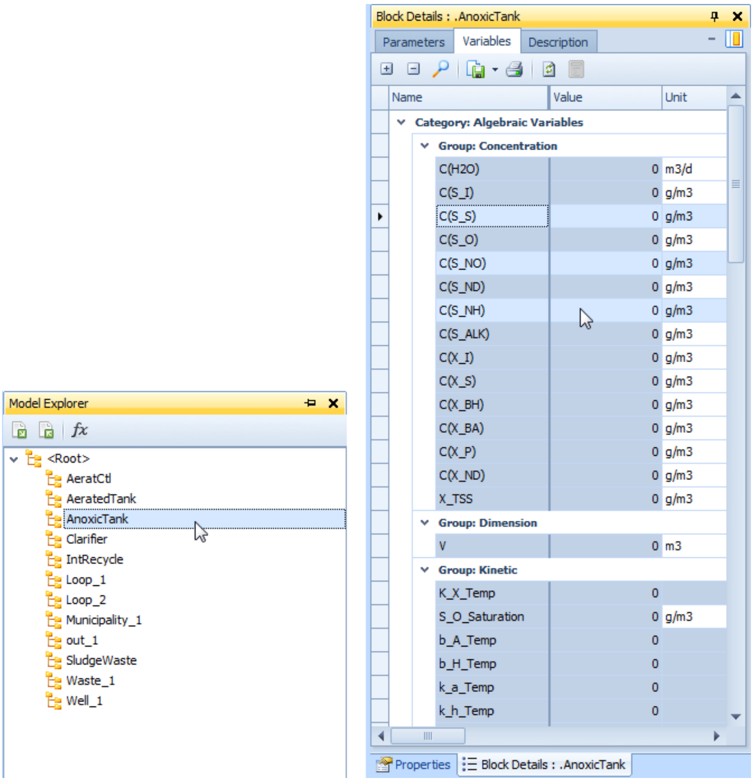


Figure 6.17 Model Explorer (left) and Block Details panes (right), to select variables that are to be added to output objects

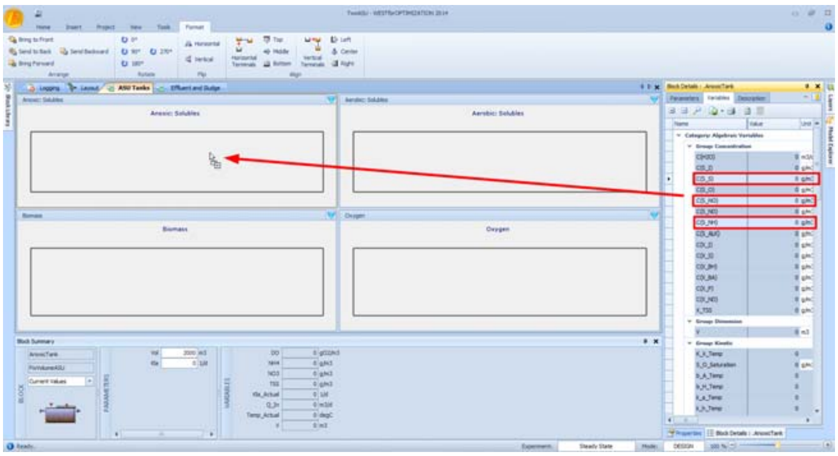


Figure 6.18 Multi-select, drag and drop variables that are to be added to a plot window

7 Dynamic Simulation Experiment

The two 'base' Experiment Types are the Steady-State and the Dynamic simulation, wrapped as an Objective Evaluation experiment (Chapter 5).

It is common practice to first run a relatively long steady-state simulation, starting at non-zero initial conditions and use the end-state as realistic initial conditions for the actual dynamic simulation (cf. 'Initialise the Models' in the WEST User Guide).

This is carried out automatically by WEST: as a dynamic simulation is launched, the derived state variables are reset to the end-state of the steady-state simulation, i.e. the model re-initialised (Section 6.4).

To switch off this automatic re-initialisation and rather proceed manually, deselect the corresponding check-box in the Options | Popular of the Application menu.

Remark that the length of the two simulations is pre-set to 100 (usually it takes about 5 times the SRT of the system to reach steady state) and 7 days respectively.

For this example, proceed as follows:

- In the 'Steady-state' tab page of the Control Center Pane, click on the button "Start".
- Wait until the simulation ends.
- In the 'Dynamic' tab page of the Control Center Pane, reset the length of the simulation to 30 days; then click on the button "Start".

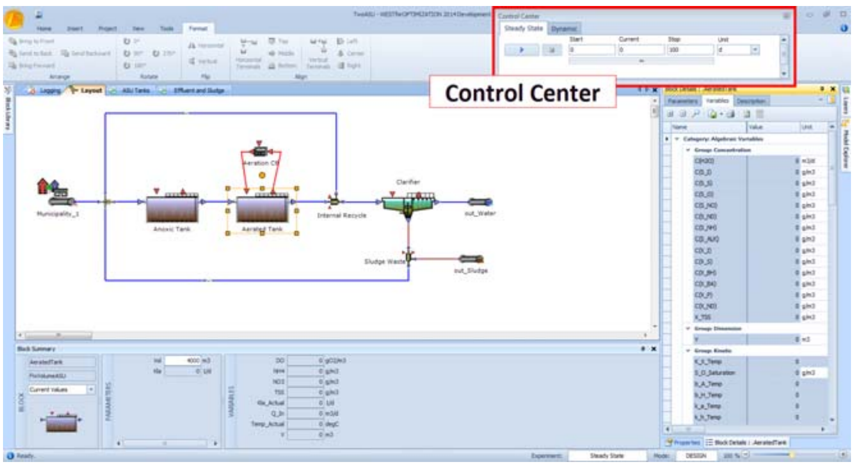


Figure 7.1 TwoASU sample: use the Control Center pane to run a Simulation

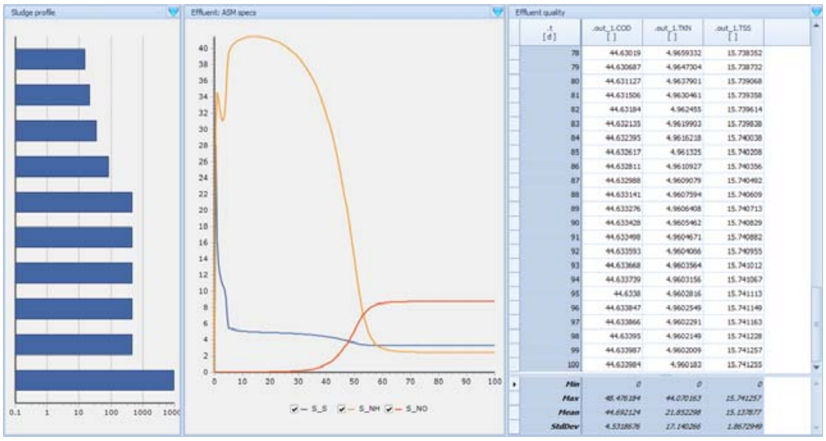


Figure 7.2 Results of the steady-state simulation for the TwoASU sample

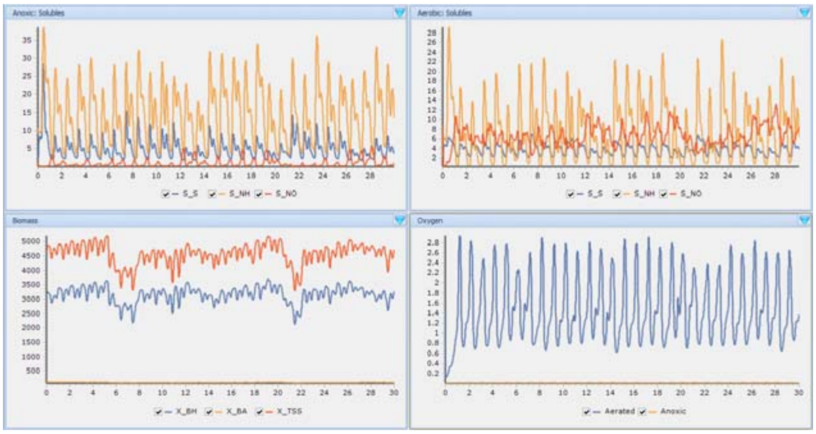


Figure 7.3 Results of the dynamic simulation for the TwoASU sample (1)

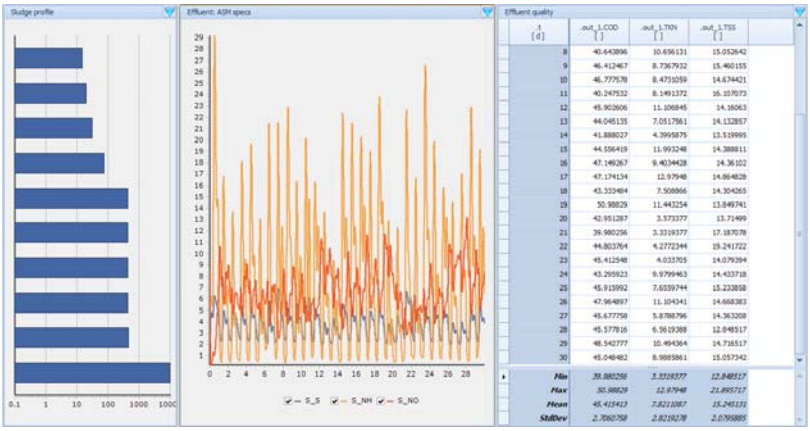


Figure 7.4 Results of the dynamic simulation for the TwoASU sample (2)

7.1 Adjust the Appearance of a Plot Window

The appearance of a plot window can be modified through the Properties pane, by:

- choosing the relevant plot item from the Plot menu (blue arrow at the top-right corner)
- modifying the relevant properties in the Properties pane.

In this example, you may want to maximise the space allocated to the actual data series on the plot (by renaming the data series and hiding the unnecessary plot header) and to improve the way numbers are diplayed on the axes.

- Hide the plot header:
  - select Plot Properties in the Plot menu
  - go to Titles | Header in the Properties pane
  - set the “Visible” property to False
- Rename the data series:
  - select the Series Properties in the Plot menu and then the relevant data series
  - go to the General | Name in the Properties pane
  - change the name, e.g. delete the prefix “.<BlockName>.”
  - repeat for all the data series of the plot

The “Sludge Profile” plot can be improved by inverting the order of the bars on the y-axis (so that the bottom layer, #10, sits at the bottom), by using a logarithmic scale for the x-axis and by hiding the legend (unnecessary in this case):

- select Axes Properties in the Plot menu

- go to the Left and set the “Inverted” propery to True
- go to the Bottom and set the “Logarithmic” property to True
- select the Legend Properties in the Plot menu
- set the “Visible” property to False

7.2 Select the Appropriate Integrator

One needs to be aware of the characteristics of each integrator offered in WEST (cf. Solver Tab page in the ‘Steady-State and Dynamic Experiment’ section of the WEST User Guide) in order to select the most appropriate for every case. Often, it is a trial-and-error process whereby the integrator settings can be tuned so as to achieve a trade-off between simulation accuracy and speed.

For the present example, you can try and change the integrator from the default ‘RK4ASC’ to ‘VODE’:

- Select the experiment, in the Control Center pane.
- Click on “Simulation” in the Project | Properties menu, to access the dialogue window shown in Figure 7.5.
- Select ‘VODE’ from the [Integrator] drop-down.
- Re-run the simulation(s): the steady-state and dynamic simulations should now be remarkably faster (3-4 times).

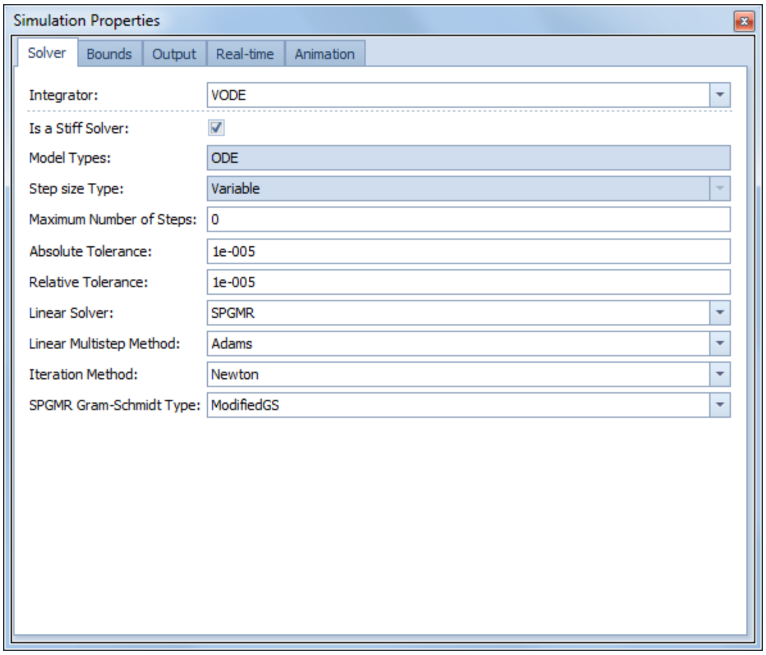


Figure 7.5 Simulation Properties dialogue window

7.3 Add Some Objectives To Be Evaluated

It may be interesting to evaluate some overall objectives that could give a quantitative indication of the performance of this plant. For instance, one may want to compute some statistics of the common effluent quality parameters that are to be compared against the legal limits.

Proceed as follows:

- In the Control Center pane, select the dynamic experiment
- In the Project | Properties menu, click on the “Analysis” button.
- In the Layout or in the Model Explorer, select the effluent Block.
- In the Block Details pane, select the variables COD, TKN, TSS, Outflow(S_NO) and Outflow(S_NH); drag and drop the selection to the Analysis Properties dialogue (Figure 7.6).
- In the Time series Criteria tab page, for each variable, select the criteria that are to be computed (Figure 7.7) and their properties:
  – Select Mean, Lower and Upper Percentiles for all variables; remark that the lower and upper percentiles are set to 5% and 95% respectively

  - Select the Percentage of Time in Violation of Upper bound for ammonia; set 5 (mg/l) as the Upper Bound in the Properties below
  - Do the same for nitrate; and set 10 (mg/l) as the Upper Bound

- Re-run the simulation to the end and examine the results.
  - the individual sub-objectives (e.g. the Upper Percentile of the COD concentration in the effluent) are shown in the Time series Criteria page
  - the composite objective for each variable and the overall objective for the simulation are shown in the Runs tab page (Figure 7.8)

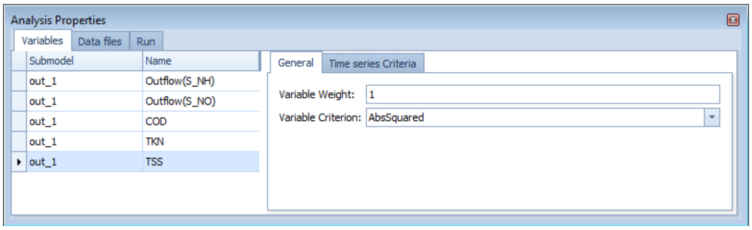


Figure 7.6 Analysis Properties dialogue and objective variables to be evaluated

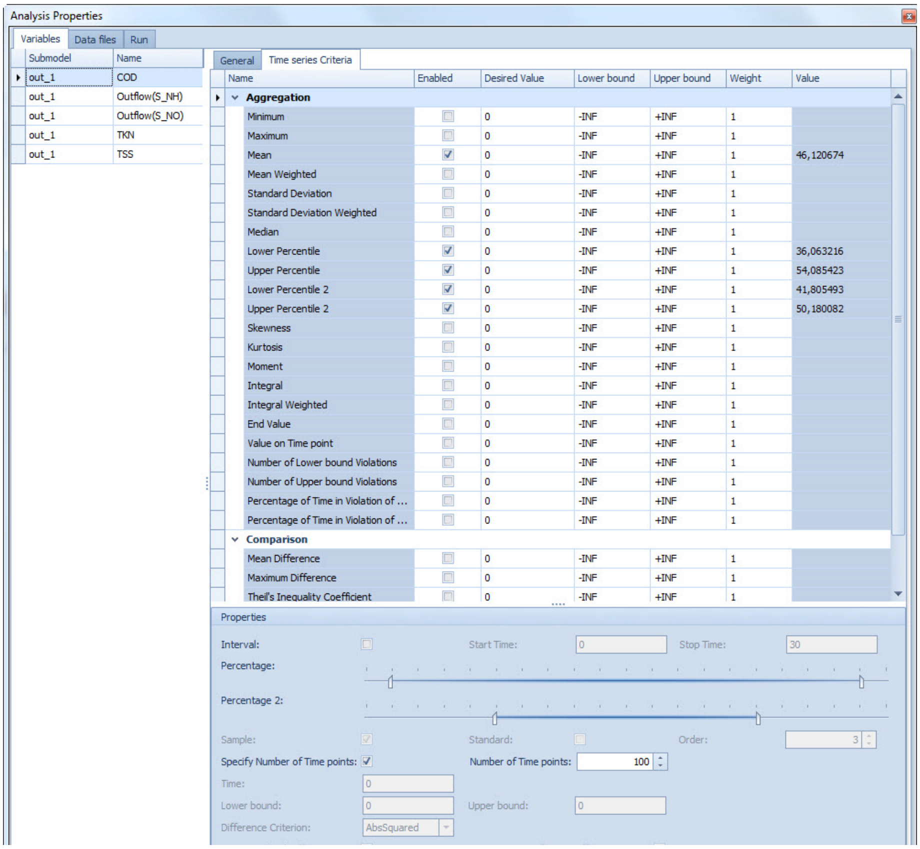
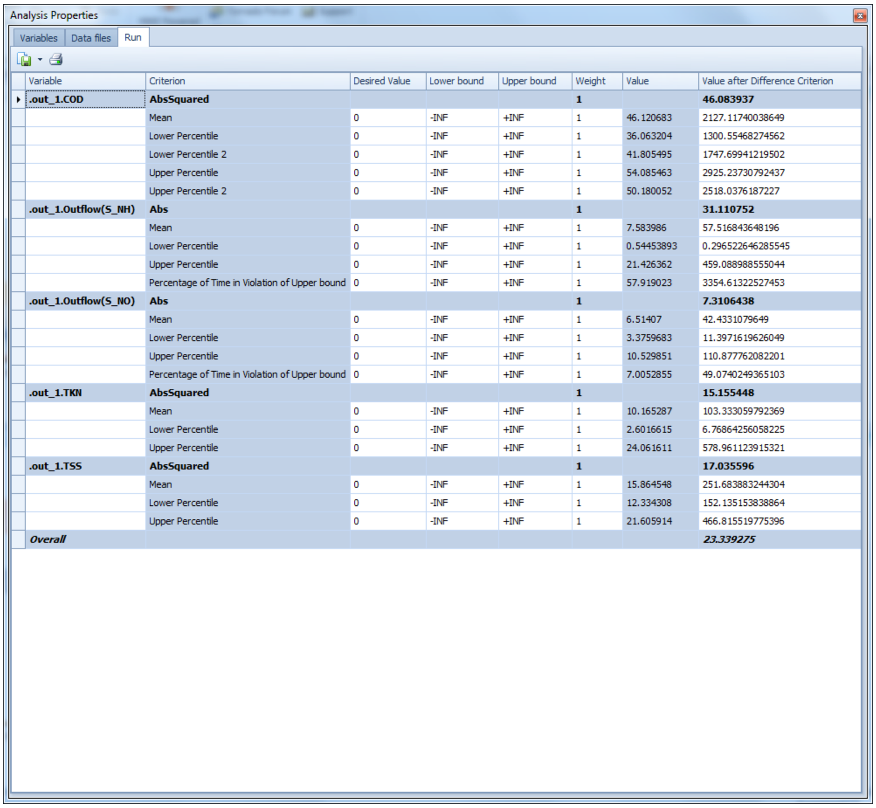


Figure 7.7 Analysis Properties dialogue and Time series Criteria for each objective



Variable	Criterion	Desired Value	Lower bound	Upper bound	Weight	Value	Value after Difference Criterion
.out_1.COD	**AbsSquared**				**1**		**46.083937**
	Mean	0	-INF	+INF	1	46.120683	2127.11740038649
	Lower Percentile	0	-INF	+INF	1	36.063204	1300.55468274562
	Lower Percentile 2	0	-INF	+INF	1	41.805495	1747.69941219502
	Upper Percentile	0	-INF	+INF	1	54.085463	2925.23730792437
	Upper Percentile 2	0	-INF	+INF	1	50.180052	2518.0376187227
.out_1.Outflow(S_NH)	**Abs**				**1**		**31.110752**
	Mean	0	-INF	+INF	1	7.583986	57.516843648196
	Lower Percentile	0	-INF	+INF	1	0.54453893	0.296522646285545
	Upper Percentile	0	-INF	+INF	1	21.426362	459.088988555044
	Percentage of Time in Violation of Upper bound	0	-INF	+INF	1	57.919023	3354.61322527453
.out_1.Outflow(S_NO)	**Abs**				**1**		**7.3106438**
	Mean	0	-INF	+INF	1	6.51407	42.4331079649
	Lower Percentile	0	-INF	+INF	1	3.3759683	11.3971619626049
	Upper Percentile	0	-INF	+INF	1	10.529851	110.877762082201
	Percentage of Time in Violation of Upper bound	0	-INF	+INF	1	7.0052855	49.0740249365103
.out_1.TKN	**AbsSquared**				**1**		**15.155448**
	Mean	0	-INF	+INF	1	10.165287	103.333059792369
	Lower Percentile	0	-INF	+INF	1	2.6016615	6.76864256058225
	Upper Percentile	0	-INF	+INF	1	24.061611	578.961123915321
.out_1.TSS	**AbsSquared**				**1**		**17.035596**
	Mean	0	-INF	+INF	1	15.864548	251.683883244304
	Lower Percentile	0	-INF	+INF	1	12.334308	152.135153838864
	Upper Percentile	0	-INF	+INF	1	21.605914	466.815519775396
Overall							***23.339275***

Figure 7.8 Computed objective values for the dynamic simulation]

Table 7.1 Criteria for the simulation

Variable	Mean+/.StDev (mg/l)	5% - 95%-ile (mg/l)	Compliance (%)	Limit (mg/l)
COD	46.1 +/- 5.8	36.1 - 54.1	-	-
NHx	7.6 +/- 6.3	0.5 - 21.4	42.1	5
NOx	6.5 +/- 2.1	3.4 - 10.5	93.0	10
TKN	10.2 +/- 6.5	2.6 - 24.1	-	-
TSS	15.9 +/- 3.0	12.3 - 21.6	-	-

7.4 Add Some Calculator Variables

One may also need to evaluate quantities that are not immediately available in any particular model, but that can easily be implemented as expressions, i.e. combinations of existing model variables (and parameters). These *Calculator Variables* (cf. 'Calculator Variables' in the WEST User Guide) will be assigned to the overall plant model.

Proceed as follows:

- Select the top-most node of the Model Explorer (Project) or click anywhere in the Layout, not on a Block or a link.
- In the Block Details pane, select the Variables tab page and click on the “Calculator Variables” button. Or:
- Right-click anywhere in the layout and select the “Calculator Variables” item in the Context menu
- In the Calculator Variables dialogue window, add a new row and fill in the relevant information (Figure 7.9):
  - Name: ‘Removal_COD’ (remark: the ‘.’ prefix in the Figure is prepended automatically, once the row is confirmed)
  - Expression: type in ‘(.Municipality_1.COD-.out_water.COD)/(.Municipality_1.COD)’
  - Description (optional): ‘COD removal’
  - Unit (optional): ‘-’
  - Group (optional): ‘Evaluation’
- Upon confirmation, the new variable will be added to the list of top-level variables in the Block Details pane (Figure 7.10).

The new variable will be treated as any other model variable, e.g. can be plotted (Figure 7.11) or used as an objective.

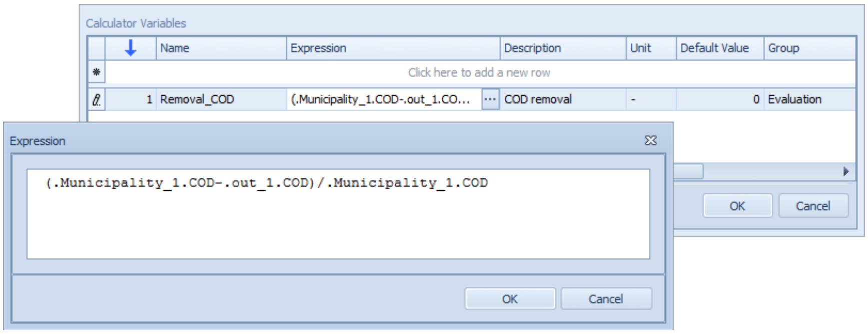


Figure 7.9 Add calculator variable dialogue window

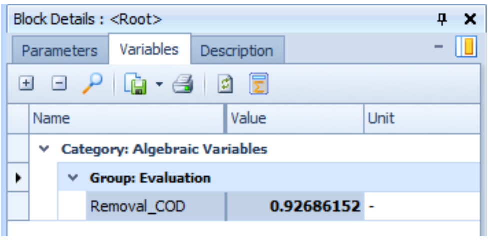


Figure 7.10 New calculator variable, at the Project level

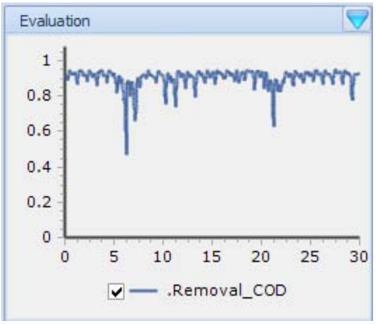


Figure 7.11 Plot for a Calculator Variable

7.5 Options to Control Model Parameters

Two distinct classes of model parameters are used in WEST:

- True parameters
- Input variables

Objects of the first class are defined as *parameters* in the model code; objects of the second class, as *interface variables* (and flagged as “manipulated”).

This distinction translates in a substantial difference as to how the two types of model parameters can be altered by the user.

- True parameters can only be changed prior to launching a simulation (and are constant during the simulation)
- Manipulated variables can be altered during a simulation, in one of the following ways:
  - Through a graphical input widget, i.e. Slider, Field, Radiobutton, Combobox or Checkbox
  - Through a control model
  - Through a time series input

See also ‘How to Manage Simulation Inputs’ in the WEST User Guide.

7.5.1 Use of a Slider to Vary a Model Parameter

A manipulated variable can be linked to a slider (cf. ‘Input/Output Sheets’ in the WEST User Guide) by:

- Dragging the model parameter from the Block Details pane onto a Slider
- Adjusting the Max and Min values
- Adjusting the Frequency and the Large- and Small change values through the Properties pane (optional)
- Moving the slider while the Simulation is running

Figure 7.12 Movement of the slider for the manipulated variable y_S (top) and its effect on the actual aeration via kLa (bottom)

7.5.2 Use of a Control Model to Vary a Model Parameter

A manipulated variable can be controlled by establishing a ‘control loop’, as follows (see also ‘How to Set Up a Controller’ in the WEST User Guide):

- Connect a sensor output to the data input of a Control Block. The sensor can be the data output terminal of the Block or a Sensor Block (if the variable that is to be measured is not available as sensor from the Block)
- In the Interface Link dialogue, establish the link from the measured variable to the control input (generally **y_m**)
- Connect the data output of the Control Block to the data input of the Block
- In the Interface Link dialogue, establish the link from the control signal (generally **u**) to the manipulated variable that is to be controlled

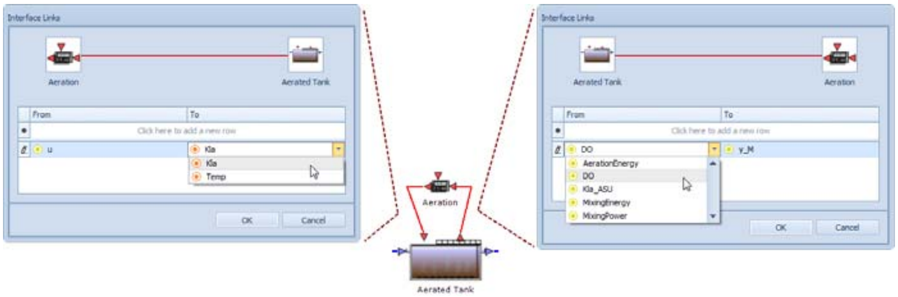


Figure 7.13 Aeration control loop: DO is measured in the tank and used by the Control model to control the Manipulated Variable kLa

7.5.3 Use of a Data Input to Vary a Model Parameter

A manipulated variable can take up data coming from an input file (cf. 'Generic Input Data' in the WEST User Guide) as follows:

- Drop a (data) Input Block on the Layout
- Define a new Top-level Interface Variable:
  - right-click in the Layout and select the relevant item in the Context menu
  - in the Top-level Interface Variable dialogue (Figure 7.14), add a new row and fill in the relevant information:
    a. Name: Temperature
    b. Causality: Input (set by default)
    c. Type: CelsiusTemperature
    d. Description: Measured temperature
    e. Unit: degC
    f. Group: Data Input
- Associate the Input Block with the new Top-level Interface Variable:
  - double-click on the Block
  - select the variable from the list of available variables in the General tab page of the Input Generator

– complete the Generator, as explained in User Guide

- Draw a connection between the Input Block and the data input terminal of the Anoxic- and Aerated Tank Blocks
- In the Interface Link dialogue, establish the link from the input variable to the manipulated variable that is to be controlled

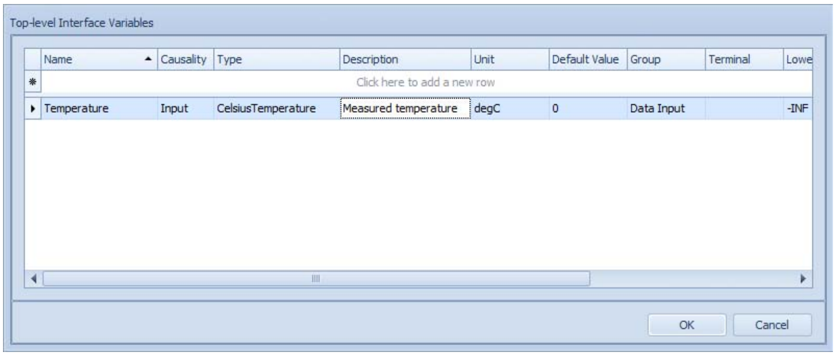


Figure 7.14 Create a top-level Interface Variable

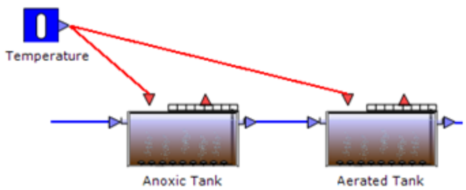


Figure 7.15 The Temperature data input Block controlling the manipulated interface variable “Temperature” of the two activated sludge tanks

7.6 Generate a Report

A Report can be created and printed, or saved (e.g. in RTF format) and finalised outside of WEST. Proceed as follows:

- Click on the “Reports” button of the Project | Miscellaneous menu
- A new, empty report, named “Report 1” is created
- Add the relevant objects to the report, by flagging the corresponding check-box (Figure 7.16). For instance:
  – General | Information
  – Layout

- Plots: “Anoxic: Solubles”, “Aerobic: Solubles”, “Biomass”, Oxygen”, “Effluent : ASM specs”
- Input files: the steady-state input file

- Do not just flag the top-most check-box “Report” (to include everything) as this may take an extremely long time
- Preview the report in the Preview tab
- Print or Save

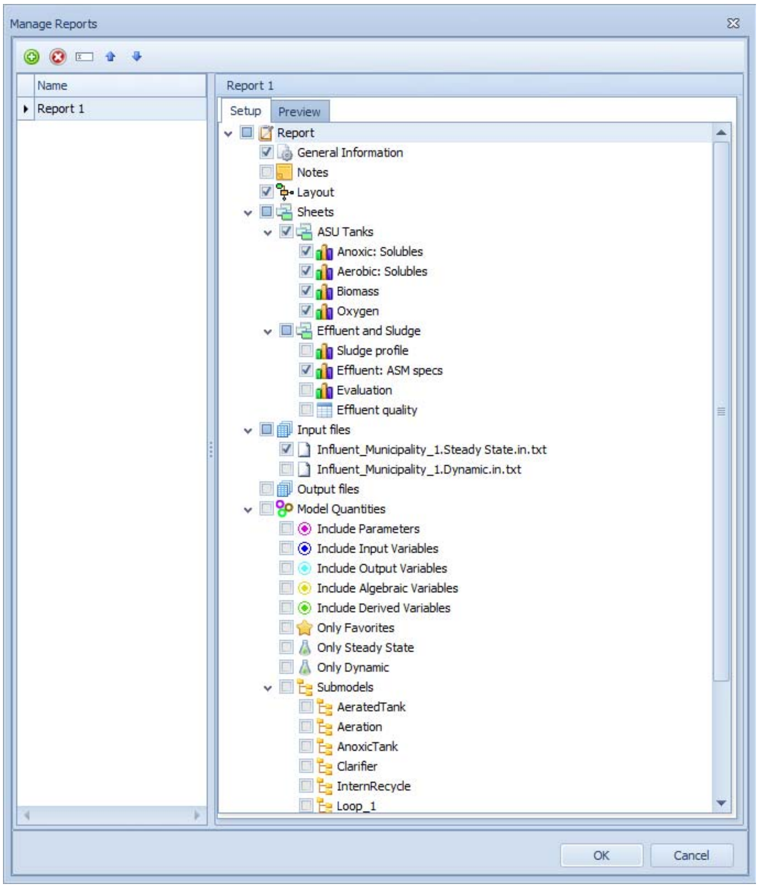


Figure 7.16 Select the individual elements of the Project to create a Report

8 Local Sensitivity Analysis Experiment

A Local Sensitivity Analysis (LSA) experiment computes (a numerical approximation of) the local sensitivity of state variables, worker variables or output variables with respect to parameters, input variables and/or initial conditions.

In this chapter, we will look at the effect of aeration (DO set-point), sludge settling properties (rP and v0), internal recycle and sludge wastage on the quality of the effluent (TSS and nitrate concentration)

Proceed as follows:

- Re-open the ‘TwoASU’ Project that was built in Chapter 6 ‘The TwoASU Sample, Step-by-Step’, which we are going to use as starting point.
  – Delete the Sheet “Aeration”, to release the manipulated variable “y_”S” of the aeration control block (that was controlled by a slider in the base example)
- Save it as a new Project:
  – Click the “Save as” button in the Application Menu
  – Provide a name and a description for the new Project (Figure 8.1)

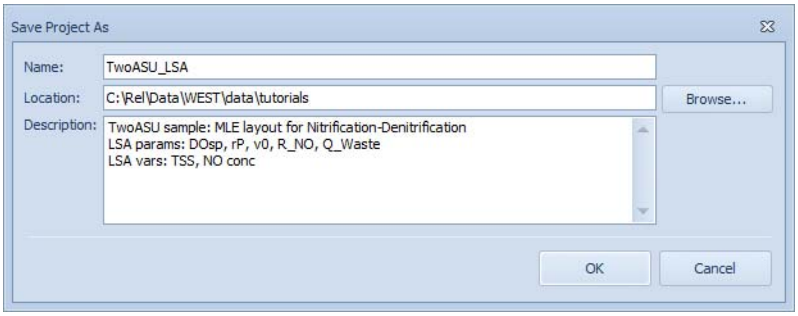


Figure 8.1 Save As dialogue, to use the TwoASU sample as the starting point for the Local Sensitivity Analysis example

- In the Project | Virtual Experiments menu, click on the “Local Sensitivity Analysis” button and select the Dynamic simulation as the base experiment that the advanced experiment is to be added to:
  – You will remark that all other advanced experiments have become unavailable and the “Remove” button is enabled: this is because only one advanced experiment per Project is allowed (cf. ‘Experiment Types’ in the WEST User Guide). Should you need a different advanced experiment, you will first have to remove the current one (Chapter 12)
- Open the Analysis Properties dialogue.

- Drag and drop the relevant parameters and variables on the “Parameters and Variables” tab page (Figure 8.4). The default settings are fine.
- Make sure that the Communication Interval be not zero, in the Simulation Output tab page (e.g. 0.014).
- The sensitivity functions for each of the runs (i.e. parameter/variable combination) will be computed and the values displayed in the Runs tab page.
- Set up some graphical outputs:
  - Add a new Sheet: “CRS” (Central Relative Sensitivity)
  - Add two Time Series X(t) Line plots: “Effluent TSS” and “Effluent S_NO”
  - In the plot sub- menu (Figure 8.2), choose “Add Series”, to access the dialogue shown in Figure 8.3:

    a) For the TSS plot, choose the following sensitivity functions (*SensFunc*) as Sources: “.Aeration.y_S”, “.Clarifier.r_P”, “.Clarifier.v0” and “.InternRecycle.Q_Out2” in combination with “.out_1.TSS”

    b) Choose “.t” and “CRS” for the X- and Y- items respectively, for every data series

    c) Prior to confirm each series, provide an informative Name (e.g. “y_S”, “r_P”, etc.

    d) Repeat, for the second plot, using the corresponding sensitivity function pairs (i.e. in combination with “.out_1.Outflow(S_NO)”

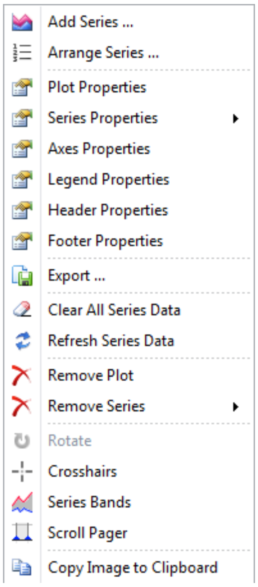


Figure 8.2 Plot sub-menu

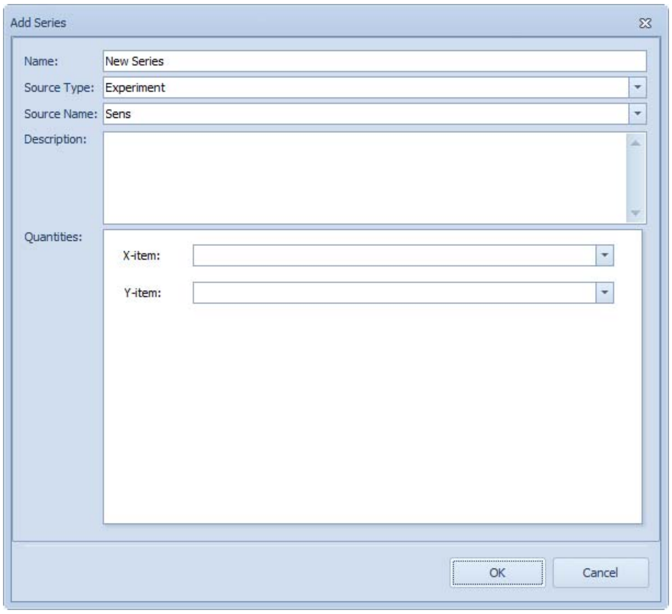


Figure 8.3 Add Series dialogue window

- Execute
- The output of the LSA experiment is shown in Figure 8.5 and Figure 8.6

- By clicking on the “Copy Values” button, the parameter values of the selected run (typically one would choose the best run, but not necessarily) can be copied to the simulation

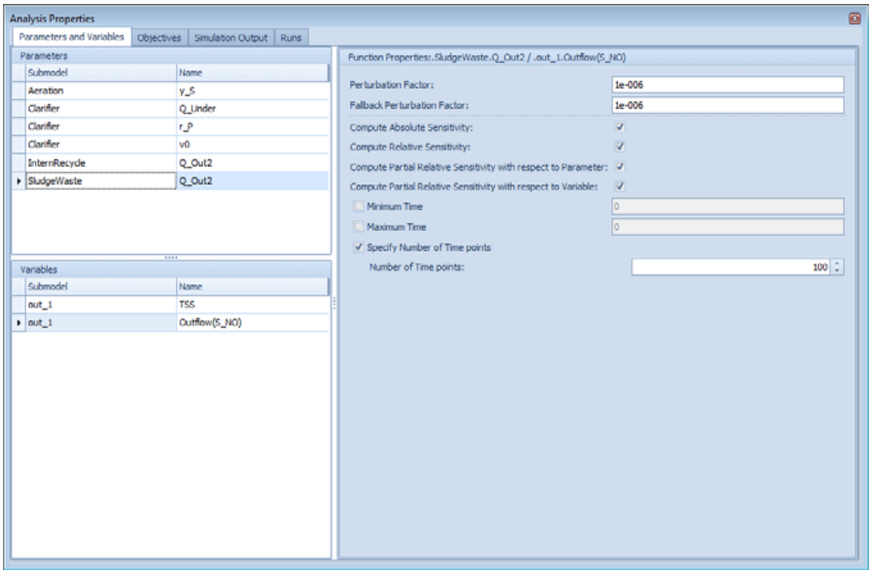
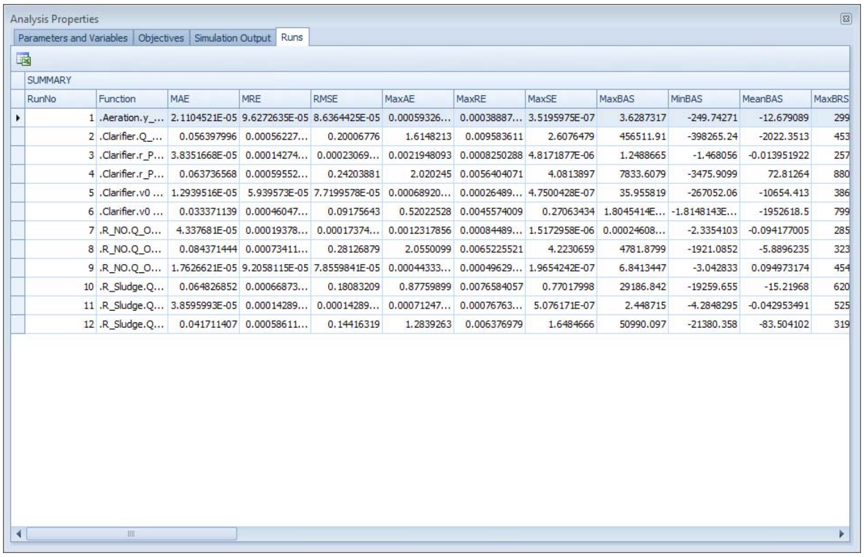


Figure 8.4 Parameters and Variables tab page for the Local Sensitivity Analysis experiment



RunNo	Function	MAE	MRE	RMSE	MaxAE	MaxRE	MaxSE	MaxBAS	MinBAS	MeanBAS	MaxBRS
1	.Aeration.y_...	2.1104521E-05	9.6272635E-05	8.6364425E-05	0.00059326...	0.00038887...	3.5195975E-07	3.6287317	-249.74271	-12.679089	299
2	.Clarifier.Q_...	0.056397996	0.00056227...	0.20006776	1.6148213	0.009583611	2.6076479	456511.91	-398265.24	-2022.3513	453
3	.Clarifier.r_P...	3.8351668E-05	0.00014274...	0.00023069...	0.0021948093	0.0008250288	4.8171877E-06	1.2488665	-1.468056	-0.013951922	257
4	.Clarifier.r_P...	0.063736568	0.00059552...	0.24203881	2.020245	0.0056404071	4.0813897	7833.6079	-3475.9099	72.81264	880
5	.Clarifier.v0 ...	1.2939516E-05	5.939573E-05	7.7199578E-05	0.00068920...	0.00026489...	4.7500428E-07	35.955819	-267052.06	-10654.413	386
6	.Clarifier.v0 ...	0.033371139	0.00046047...	0.09175643	0.52022528	0.0045574009	0.27063434	1.8045414E...	-1.8148143E...	-1952618.5	799
7	.R_NO.Q_O...	4.337681E-05	0.00019378...	0.00017374...	0.0012317856	0.00084489...	1.5172958E-06	0.00024608...	-2.3354103	-0.094177005	285
8	.R_NO.Q_O...	0.084371444	0.00073411...	0.28126879	2.0550099	0.0065225521	4.2230659	4781.8799	-1921.0852	-5.8896235	323
9	.R_NO.Q_O...	1.7626621E-05	9.2058115E-05	7.8559841E-05	0.00044333...	0.00049629...	1.9654242E-07	6.8413447	-3.042833	0.094973174	454
10	.R_Sludge.Q...	0.064826852	0.00066873...	0.18083209	0.87759899	0.0076584057	0.77017998	29186.842	-19259.655	-15.21968	620
11	.R_Sludge.Q...	3.8595993E-05	0.00014289...	0.00014289...	0.00071247...	0.00076763...	5.076171E-07	2.448715	-4.2848295	-0.042953491	525
12	.R_Sludge.Q...	0.041711407	0.00058611...	0.14416319	1.2839263	0.006376979	1.6484666	50990.097	-21380.358	-83.504102	319

Figure 8.5 Runs tab page and results for the Local Sensitivity Analysis experiment

Figure 8.6 Example of plot output for the Local Sensitivity Analysis experiment: Central Relative Sensitivity (CRS) for TSS (top) and Nitrate concentration (bottom) in the effluent

8.1 Results Interpretation

The solid concentration (TSS) in the effluent appears to be more sensitive to the sludge characteristics (r_P and v0) and occasionally to the internal recycle; whereas, the nitrate concentration (S_NO), mostly to the internal recycle but also to the sludge characteristics (v0).

The interpretation of these local sensitivity plots however is complicated by the presence of the variable “time” and therefore by the interference of specific events (e.g. high flow rate or load) that may occur at given points in time.

9 Global Sensitivity Analysis Experiment

A Global Sensitivity Analysis (GSA) experiment allows for the evaluation of the sensitivity of a set of variables to a set of 'parameters'

In this chapter, we will examine the effect of aeration (DO set-point), sludge settling properties (rP and v0), sludge extraction from the clarifier, internal recycle and sludge wastage, on the quality of the effluent.

Proceed as follows:

- Re-open the 'TwoASU' Project that was built in Chapter 6 'The TwoASU Sample, Step-by-Step', which we are going to use as starting point.
  - Delete the Sheet "Aeration", to release the manipulated variable "y_"S" of the aeration control block (that was controlled by a slider in the base example)
- Save it as a new Project:
  - Click the "Save as" button in the Application Menu
  - Provide a name and a description for the new Project (Figure 9.1)

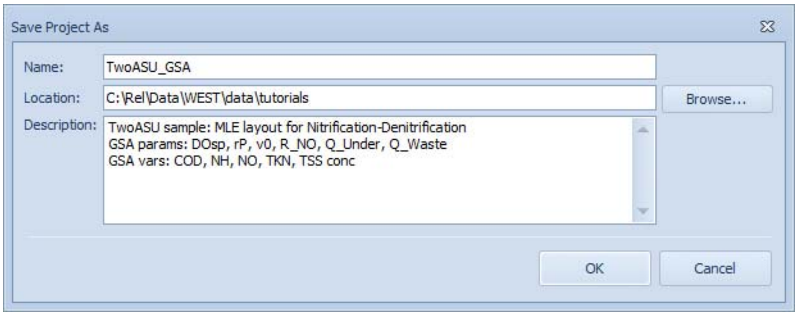


Figure 9.1 Save As dialogue, to use the TwoASU sample as the starting point for the Global Sensitivity Analysis example

- In the Project | Virtual Experiments menu, click on the "Global Sensitivity Analysis" button and select the Dynamic simulation as the base experiment.
  - Run a slave Steady-State simulation prior to the Dynamic simulation
- Open the Analysis Properties dialogue: remark that the variables (and their settings) that were used to define objectives for the dynamic simulation are still available. One can however add/remove variables and their settings, in the Variables tab page. For this example, we are not going to modify the variables list.

- Drag and drop the relevant parameters on the “Parameters” tab page (refer to Table 9.1).
- In the “Variables” tab page, we will be looking at the sensitivity of the COD, Nitrate (NO) and solids (TSS) concentration in the effluent (make sure the usual Time series Criteria are selected for these variables).
- In the Solver tab page, set the Number of Shots to 50.
- In the Runs tab page, the list of runs and the respective parameter values should be automatically filled in; if not, click on the “Generate” button (this can be done to regenerate the series).
- Make sure that the Communication Interval be not zero, in the “Simulation Output” tab page (e.g. 0.014).
- Execute
- The outputs of the GSA experiment are shown in Figure 9.2 to Figure 9.6:
  - The “Linear Regression | Scalars” tab page displays the aggregated values for the simulation objectives resulting from the Linear Regression process (cf. ‘Linear Regression’ in the ‘Global Sensitivity Analysis Experiment’ section of the WEST User Guide).
  - The “Linear Regression | Vectors” tab page, displays several predefined regression Coefficients.
    To create a “Tornado plot”, select the objective of interest first (e.g. the Upper Percentile of TSS in the effluent), then click on the “Plot” button and choose the vector of interest (e.g. LCC).
  - The “Runs” tab page displays the objective values for each simulation run. The overall best run, i.e. which has the smallest overall ‘ObjValue’, is highlighted.
- By clicking on the “Copy Values” button, the parameter values of the selected run (typically one would choose the best run, but not necessarily) can be copied to the simulation.

Table 9.1 Objective variables for the Global Sensitivity Analysis experiment

Block	**Parameter**	**Method**	**Settings**
Aeration	y_S	Normal	Mean: 1.5 Standard Deviation: 0.05

Table 9.1 Objective variables for the Global Sensitivity Analysis experiment

Block	Parameter	Method	Settings
Clarifier	r_P	Normal	Mean: 0.00286 Standard Deviation: 0.0005
	v0	Normal	Mean: 474 Standard Deviation: 100
	Q_Under	Uniform	Lower bound: 10000 Upper bound: 30000
R_NO	Q_Out2	Uniform	Lower bound: 20000 Upper bound: 70000
R_Sludge	Q_Out2	Uniform	Lower bound: 100 Upper bound: 500

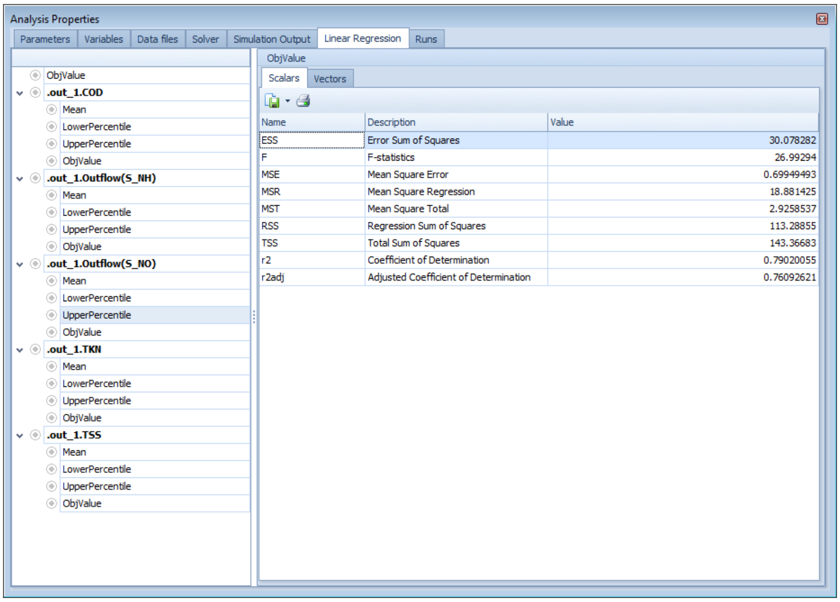
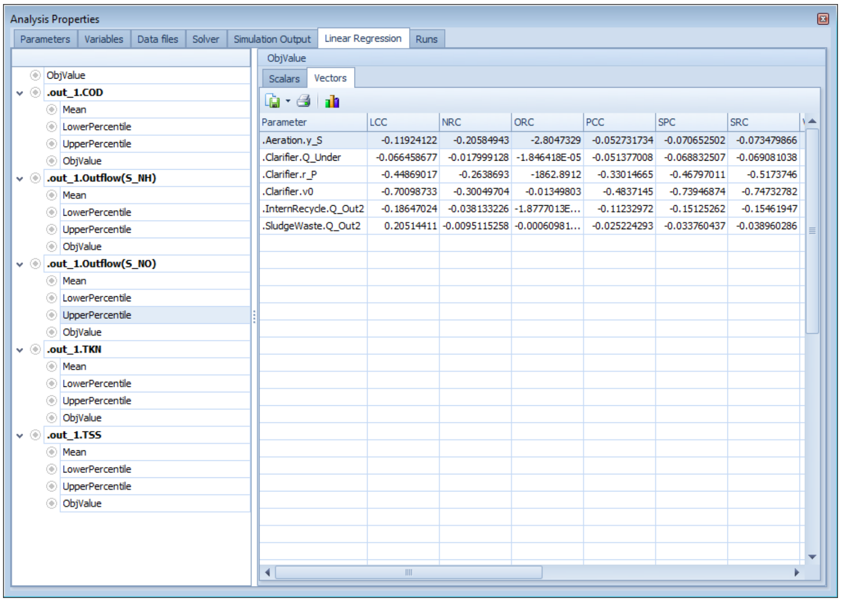
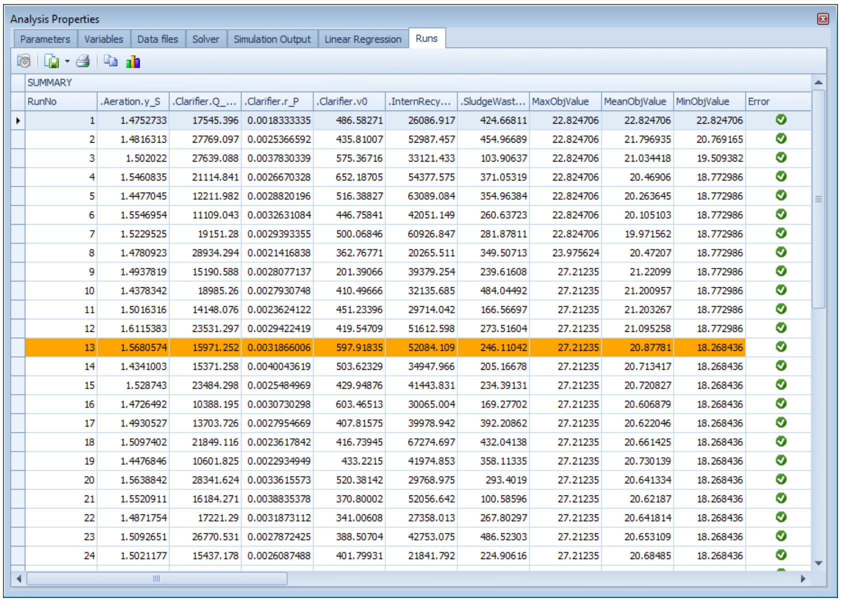


Figure 9.2 Example of Scalars values for one of the simulation objectives



Parameter	LCC	NRC	ORC	PCC	SPC	SRC
.Aeration.y_S	-0.11924122	-0.20584943	-2.8047329	-0.052731734	-0.070652502	-0.073479866
.Clarifier.Q_Under	-0.066458677	-0.017999128	-1.846418E-05	-0.051377008	-0.068832507	-0.069081038
.Clarifier.r_P	-0.44869017	-0.2638693	-1862.8912	-0.33014665	-0.46797011	-0.5173746
.Clarifier.v0	-0.70098733	-0.30049704	-0.01349803	-0.4837145	-0.73946874	-0.74732782
.InternRecycle.Q_Out2	-0.18647024	-0.038133226	-1.8777013E...	-0.11232972	-0.15125262	-0.15461947
.SludgeWaste.Q_Out2	0.20514411	-0.0095115258	-0.00060981...	-0.025224293	-0.033760437	-0.038960286

Figure 9.3 Example of Vectors values for one of the simulation objectives



RunNo	.Aeration.y_S	.Clarifier.Q_...	.Clarifier.r_P	.Clarifier.v0	.InternRecy...	.SludgeWast...	MaxObjValue	MeanObjValue	MinObjValue	Error
1	1.4752733	17545.396	0.0018333335	486.58271	26086.917	424.66811	22.824706	22.824706	22.824706	✓
2	1.4816313	27769.097	0.0025366592	435.81007	52987.457	454.96689	22.824706	21.796935	20.769165	✓
3	1.502022	27639.088	0.0037830339	575.36716	33121.433	103.90637	22.824706	21.034418	19.509382	✓
4	1.5460835	21114.841	0.0026670328	652.18705	54377.575	371.05319	22.824706	20.46906	18.772986	✓
5	1.4477045	12211.982	0.0028820196	516.38827	63089.084	354.96384	22.824706	20.263645	18.772986	✓
6	1.5546954	11109.043	0.0032631084	446.75841	42051.149	260.63723	22.824706	20.105103	18.772986	✓
7	1.5229525	19151.28	0.0029393355	500.06846	60926.847	281.87811	22.824706	19.971562	18.772986	✓
8	1.4780923	28934.294	0.0021416838	362.76771	20265.511	349.50713	23.975624	20.47207	18.772986	✓
9	1.4937819	15190.588	0.0028077137	201.39066	39379.254	239.61608	27.21235	21.22099	18.772986	✓
10	1.4378342	18985.26	0.0027930748	410.49666	32135.685	484.04492	27.21235	21.200957	18.772986	✓
11	1.5016316	14148.076	0.0023624122	451.23396	29714.042	166.56697	27.21235	21.203267	18.772986	✓
12	1.6115383	23531.297	0.0029422419	419.54709	51612.598	273.51604	27.21235	21.095258	18.772986	✓
13	1.5680574	15971.252	0.0031866006	597.91835	52084.109	246.11042	27.21235	20.87781	18.268436	✓
14	1.4341003	15371.258	0.0040043619	503.62329	34947.966	205.16678	27.21235	20.713417	18.268436	✓
15	1.528743	23484.298	0.0025484969	429.94876	41443.831	234.39131	27.21235	20.720827	18.268436	✓
16	1.4726492	10388.195	0.0030730298	603.46513	30065.004	169.27702	27.21235	20.606879	18.268436	✓
17	1.4930527	13703.726	0.0027954669	407.81575	39978.942	392.20862	27.21235	20.622046	18.268436	✓
18	1.5097402	21849.116	0.0023617842	416.73945	67274.697	432.04138	27.21235	20.661425	18.268436	✓
19	1.4476846	10601.825	0.0022934949	433.2215	41974.853	358.11335	27.21235	20.730139	18.268436	✓
20	1.5638842	28341.624	0.0033615573	520.38142	29768.975	293.4019	27.21235	20.641334	18.268436	✓
21	1.5520911	16184.271	0.0038835378	370.80002	52056.642	100.58596	27.21235	20.62187	18.268436	✓
22	1.4871754	17221.29	0.0031873112	341.00608	27358.013	267.80297	27.21235	20.641814	18.268436	✓
23	1.5092651	26770.531	0.0027872425	388.50704	42753.075	486.52303	27.21235	20.653109	18.268436	✓
24	1.5021177	15437.178	0.0026087488	401.79931	21841.792	224.90616	27.21235	20.68485	18.268436	✓

Figure 9.4 Runs tab page and best run for the Global Sensitivity Analysis experiment

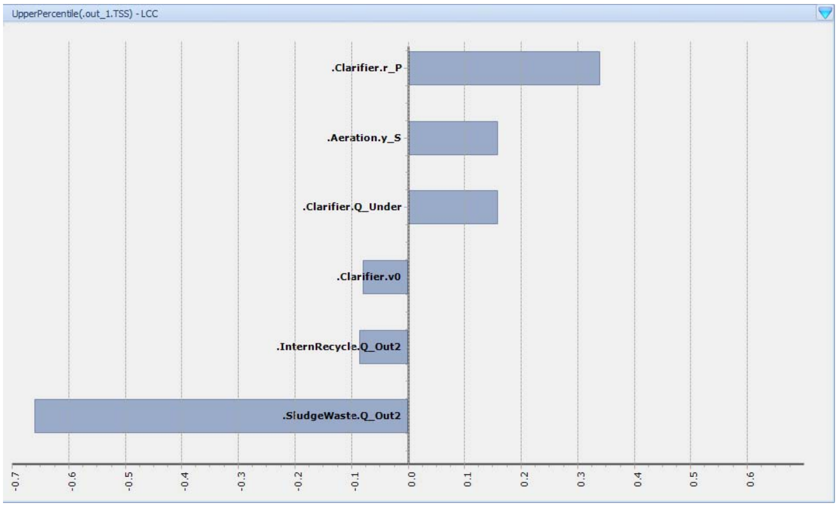


Figure 9.5 Linear Correlation Coefficient (LCC) for the Upper Percentile of the TSS concentration in the effluent

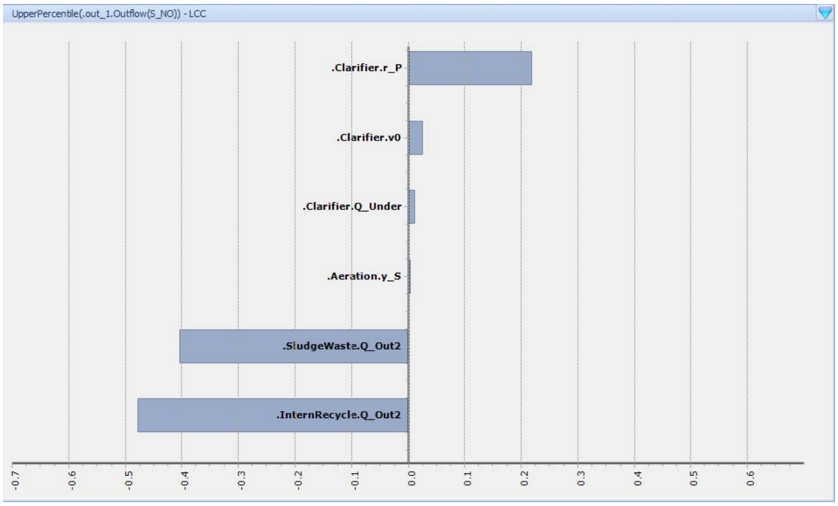


Figure 9.6 Linear Correlation Coefficient (LCC) for the Upper Percentile of nitrate concentration in the effluent

9.1 Results Interpretation

The following conclusions may be drawn:

- the sludge properties (rP and v0) have the greatest impact on the concentration of solids in the effluent (Figure 9.5);

- the aeration set-point and the internal recycle have the greatest impact on the concentration of nitrate in the effluent (Figure 9.6): the opposite sign indicates that the higher the internal recycle, the lower the nitrate concentration.

10 Parameter Estimation Experiment

A Parameter Estimation (PE) experiment runs a series of simulations on the basis of the same model, using automatically generated values for a selected set of ‘parameters’ for each simulation run, in order to minimise an objective function.

The objective function consists of a combination of individual sub-objectives (such as the mean, the upper percentile, etc.) of one or more variables; or one of the four special objectives (under the header “Comparison”), i.e. “Mean Difference”, “Maximum Difference”, “Theil’s Inequality Coefficient” and “End Value Difference”. In fact, a combination of both types of objectives is possible, but for clarity sake, we will treat the two groups separately.

In the latter case, the objective is defined *with reference to* an experimental data set and the Parameter Estimation experiment becomes a data fitting exercise, thus can be used for **model calibration**.

In the case the objective is defined as a combination of model variables alone, the Parameter Estimation experiment may be regarded as a true **optimisation** exercise, whereby the overall cost function is minimised.

10.1 Model Calibration

In this example, we will attempt to calibrate two parameters, i.e. K_NO (Nitrate half-saturation coefficient for denitrifying heterotrophs) and K_OA (Oxygen half-saturation coefficient for autotrophic biomass), by measuring the nitrate concentration in the anoxic tank.

Proceed as follows:

- Re-open the ‘TwoASU’ Project
  - Delete the Sheet “Aeration”, to release the manipulated variable “y_”S” of the aeration control block (that was controlled by a slider in the base example)
  - Make sure the set-point for the aeration controller (y_S) is set to 2 (mg/l)
- Save it as a new Project:
  - Click the “Save as” button in the Application Menu
  - Provide a name and a description for the new Project (Figure 10.5).

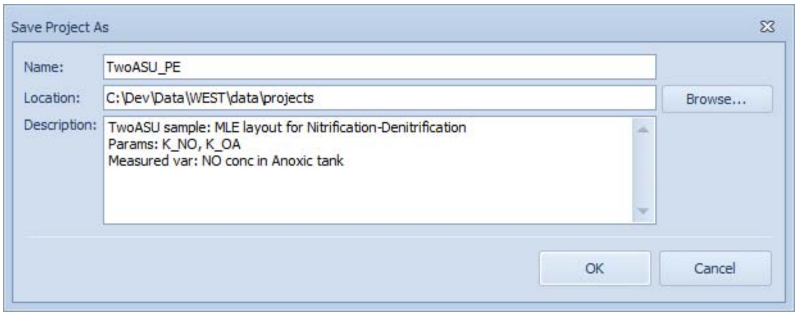


Figure 10.1 Save As dialogue, to use the TwoASU_PE sample as starting point for the Parameter Estimation example

- Create two top-level parameters (cf. 'Top Level Parameters' in the WEST User Guide) of the K_NO and K_OA in the anoxic and aerated tank.
- In the Project | Virtual Experiments menu, click on the "Parameter Estimation" button and select the Dynamic simulation as the base experiment.
  - Run a slave Steady-State simulation prior to the Dynamic simulation
- Open the Analysis Properties dialogue.
- Drag and drop the top-level parameters on the Parameters tab page and use the following settings for both:
  - Initial Value: 1
  - Lower Bound: 0.05
  - Upper Bound: 2
  - Step Size: 0.01
  - Scaling: Auto-scale
- In the Variables tab page, only keep the Nitrate (NO) concentration in the anoxic tank; and select the Mean Difference as Time series Criterion.
- In the Data Files tab page, read in an appropriate data file:
  - Click on the Add button
  - Browse and select the 'TwoASU.Anox.NO.txt' file in the WEST\data\misc\InputOutput folder. Please note that the synthetic measurement set was generated for a DO set-point of 1.5 mg/l.
- In the Solver tab page, choose the Simplex solver and Constrained Optimization.
- Make sure the Communication Interval be not zero, in the "Simulation Output" tab page (e.g. 0.014).
- Set up some graphical outputs:

- Add a new Sheet, ‘Model Calibration’
- Add three X(t) plots, two of type Line, named ‘Parameters’ and ‘Data Fit’ respectively; and one of type Column, named ‘Error’
- In the sub-menu of the “Parameters” plot, choose ‘Add Series’:

  1) select “RunNo” (X-item) and “.Anoxic.K_OA” (Y-item)

  2) Repeat for K_NO
- For the “Data Fit” plot:

  1) Drag and drop the C(S_NO) series from the Block Details pane of the Anoxic tank

  2) Add a second data series (the experimental dataset), by choosing ‘Add Series’ from the plot sub-menu:
  a) Choose ‘File’ as the Source Type
  b) Browse and select the ‘TwoASU.Anox.NO.txt’ file in the WEST\data\misc\InputOutput folder.
  c) For the X- and Y- items, choose ‘.t’ and the ‘.Anoxic.C(S_NO)’ respectively
- In the sub-menu of the “Error” plot, choose ‘Add Series’:

  1) select “RunNo” (X-item) and “MeanDiff(.Anoxic.C(SNO))” (Y-item)

- Execute
  If the stop criterion is reached (the “Desired Value” for the selected Time series Criteria in the Variables tab page[1]), the calibration procedure stops automatically; otherwise, one can interrupt it manually when the overall error (or equivalently: when the objective parameters) appear to have reached a *plateau*.
- The output of the PE experiment is shown in Figure 10.2 to Figure 10.4.
- By clicking on the “Copy Values” button, the parameter values of the selected run (typically one would choose the best run, but not necessarily) can be copied to the simulation.

1 by default, this is set to 0 – which may be unrealistic (as it translates into ‘perfect match’ between measured and simulated values)

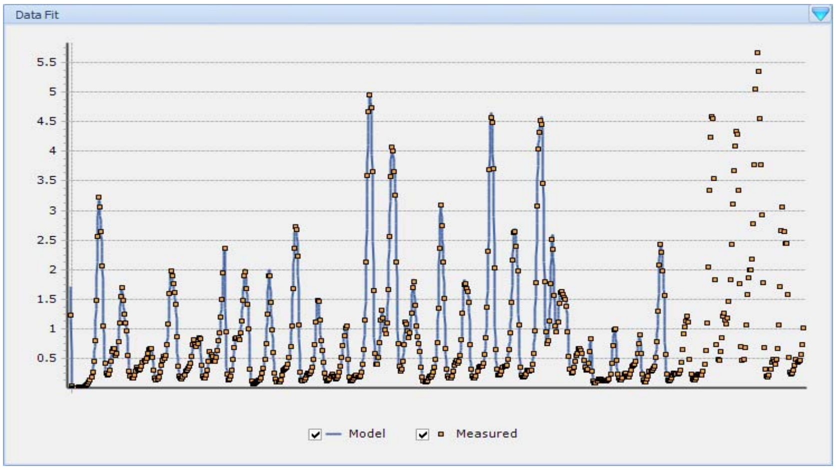


Figure 10.2 Data fit: measured data point vs. simulated values for nitrate concentration in the Anoxic tank

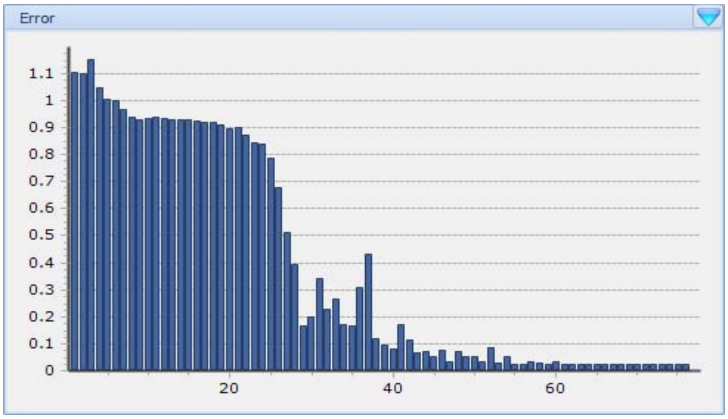


Figure 10.3 Progression of the overall error (mean difference between measured and simulated values) during the Parameter Estimation experiment

Figure 10.4 Progression of the estimated values for K_NO and K_OA during the Parameter Estimation experiment

10.1.1 Results Interpretation

After approximately 70 runs, the estimated values of K_NO and K_OA are stabilised around 0.50 and 0.40 respectively, which represent their *real* values (i.e. the default ASM1 values, in this example: Table 12.3).

By transferring the calibrated values of these two parameters back into the model, you would have obtained a calibrated model - at least, with respect to the two parameters.

Table 10.1 Comparison of the outcome of the Parameter Estimation exercise, between low and high frequency data

	K_NO	K_OA	Mean Difference
ASM1 default	0.5	0.4	---
Calibration	0.50	0.40	1.05 → 0.005

10.2 Optimisation

In this example, we will attempt to minimise the concentration of nitrogen in the effluent (NH4, NO3) by adjusting the aeration (DO set-point) and the dosage of external carbon for denitrification (NO set-point).

Proceed as follows:

- Re-open the 'TwoASU' Project
  - Delete the Sheet "Aeration", to release the manipulated variable "y_"S" of the aeration control block (that was controlled by a slider in the base example)

- Save it as a new Project:
  – Click the “Save as” button in the Application Menu
  – Provide a name and a description for the new Project (Figure 10.5).

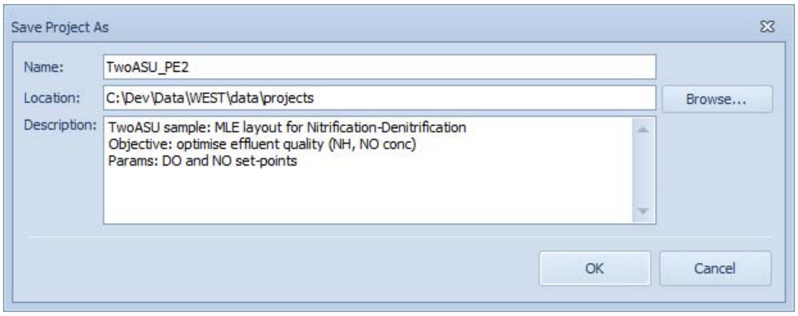


Figure 10.5 Save As dialogue, to use the TwoASU sample as the starting point for the Parameter Estimation example

- We want to make the following changes to the original layout:
  – Control the internal recycle, the sludge underflow and the sludge waste based on the influent flow rate
  – Dose external carbon into the anoxic tank to enhance denitrification
- The necessary blocks and their settings are listed in Table 10.2. You may want to assign the new controllers to the Control Layer, as it was done for the aeration in Chapter 6 ‘The TwoASU Sample, Step-by-Step’. The final layout is shown in Figure 10.6.
- Re-run the steady-state and the dynamic simulations.
- In the Project | Virtual Experiments menu, click on the “Parameter Estimation” button and select the Dynamic simulation as the base experiment
  – Run a slave Steady-State simulation prior to the Dynamic simulation

Table 10.2 New blocks that need to be added to the base TwoASU layout

Block	Model	Function	Settings
Sensor	Multiprobe	It is used to measure the influent flow rate.	---
Controller	Ratio	It sets the proportionality factor between the influent and the internal recycle flow rates.	ConstantRatio = 3

Table 10.2 New blocks that need to be added to the base TwoASU layout

Block	Model	Function	Settings
Controller	Ratio	It sets the proportionality factor between the influent and the sludge waste flow rates.	ConstantRatio = 0.01
Controller	Ratio	It sets the proportionality factor between the influent and the sludge underflow of the clarifier.	ConstantRatio = 1
Chemical Dosing	Acetate	It adds external carbon (acetate).	C_Dose = 10,000 g/m3 Q_Dose – controlled
Controller	P	It regulates the addition of acetate based on the con-centration of nitrate in the anoxic tank.	y_S = 1 g/m3 u_0 = 0 (m3/d) u_Min = 0 (m3/d) u_Max = 1000 (m3/d) K_P = -10,000
Two Combiner	---	It receives the acetate flow, upstream to the anoxic tank.	---

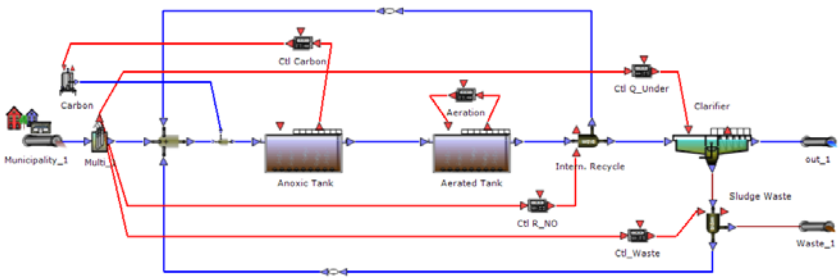


Figure 10.6 Final layout for the TwoASU_PE case

- Open the Analysis Properties dialogue.
- Drag and drop the relevant parameters on the Parameters tab page (refer to Table 10.3).
- In the Variables tab page, only keep the Nitrate (NO) and the Ammonia (NH) concentration in the effluent:
  - only set the Upper Percentile as Time series Criterion for both
  - set the weight of the NH variable to 10

- In the Solver tab page, choose the Simplex solver and Constrained Optimisation.
- Set up some graphical outputs:
  - Add a new Sheet, 'Process Optimisation'
  - Add two X(t) plots, one of type Line, named 'Objective variables'; and one of type Column, named 'Overall objective value'
  - In the 'Objective variables' plot sub- menu, choose 'Add Series':

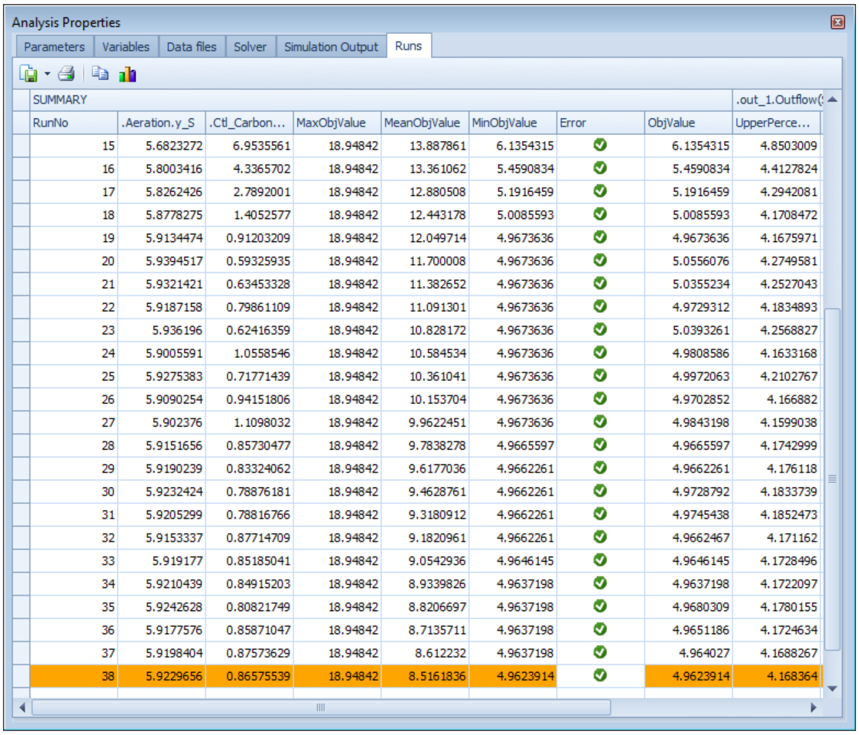
    1) For the X- and Y- items, choose 'RunNo' and the 'Upper Percentile' respectively, for the first variable (e.g. .out_1.Outflow(S_NH))

    2) Do the same for the second variable
  - In the 'Objective variables' plot sub- menu, choose 'Add Series':

    1) For the X- and Y- items, choose 'RunNo' and the 'ObjValue', respectively
- Execute
- The output of the PE experiment is shown in Figure 10.7 and Figure 10.8
- By clicking on the "Copy Values" button, the parameter values of the selected run (typically one would choose the best run, but not necessarily) can be copied to the simulation.

Table 10.3 Parameters settings for the Parameter Estimation experiment

Block	Parameter	Settings
Aeration	y_S	Initial value: 1 Lower bound: 0.5 Upper bound: 6 Step size: 0.05 Scale: *Auto-scale*
CtlAcetate	y_S	Initial value: 9 Lower bound: 0.1 Upper bound: 10 Step size: 0.05 Scale: *Auto-scale*



RunNo	.Aeration.y_S	.Ctl_Carbon...	MaxObjValue	MeanObjValue	MinObjValue	Error	ObjValue	UpperPerce...
15	5.6823272	6.9535561	18.94842	13.887861	6.1354315		6.1354315	4.8503009
16	5.8003416	4.3365702	18.94842	13.361062	5.4590834		5.4590834	4.4127824
17	5.8262426	2.7892001	18.94842	12.880508	5.1916459		5.1916459	4.2942081
18	5.8778275	1.4052577	18.94842	12.443178	5.0085593		5.0085593	4.1708472
19	5.9134474	0.91203209	18.94842	12.049714	4.9673636		4.9673636	4.1675971
20	5.9394517	0.59325935	18.94842	11.700008	4.9673636		5.0556076	4.2749581
21	5.9321421	0.63453328	18.94842	11.382652	4.9673636		5.0355234	4.2527043
22	5.9187158	0.79861109	18.94842	11.091301	4.9673636		4.9729312	4.1834893
23	5.936196	0.62416359	18.94842	10.828172	4.9673636		5.0393261	4.2568827
24	5.9005591	1.0558546	18.94842	10.584534	4.9673636		4.9808586	4.1633168
25	5.9275383	0.71771439	18.94842	10.361041	4.9673636		4.9972063	4.2102767
26	5.9090254	0.94151806	18.94842	10.153704	4.9673636		4.9702852	4.166882
27	5.902376	1.1098032	18.94842	9.9622451	4.9673636		4.9843198	4.1599038
28	5.9151656	0.85730477	18.94842	9.7838278	4.9665597		4.9665597	4.1742999
29	5.9190239	0.83324062	18.94842	9.6177036	4.9662261		4.9662261	4.176118
30	5.9232424	0.78876181	18.94842	9.4628761	4.9662261		4.9728792	4.1833739
31	5.9205299	0.78816766	18.94842	9.3180912	4.9662261		4.9745438	4.1852473
32	5.9153337	0.87714709	18.94842	9.1820961	4.9662261		4.9662467	4.171162
33	5.919177	0.85185041	18.94842	9.0542936	4.9646145		4.9646145	4.1728496
34	5.9210439	0.84915203	18.94842	8.9339826	4.9637198		4.9637198	4.1722097
35	5.9242628	0.80821749	18.94842	8.8206697	4.9637198		4.9680309	4.1780155
36	5.9177576	0.85871047	18.94842	8.7135711	4.9637198		4.9651186	4.1724634
37	5.9198404	0.87573629	18.94842	8.612232	4.9637198		4.964027	4.1688267
38	5.9229656	0.86575539	18.94842	8.5161836	4.9623914		4.9623914	4.168364

Figure 10.7 Runs tab page and results for the Parameter Estimation experiment

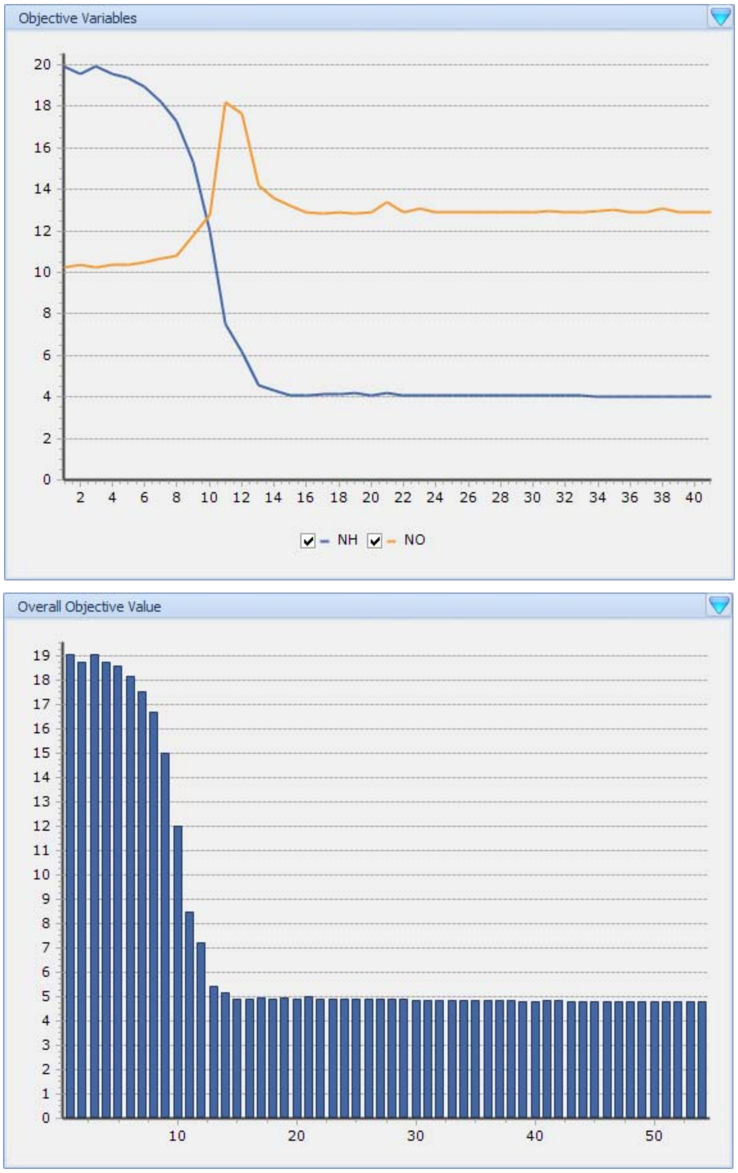


Figure 10.8 Plot outputs for the Parameter Estimation experiment, showing the evolution of the average NO3 and NH4 concentrations in the effluent (top) and of the objective value (bottom) as the selected parameters get optimised

10.2.1 Results Interpretation

After approximately 55-60 runs, the overall objective value appears to have reached its minimum value (from an initial value of approximately 19, down to 5). Correspondingly, the two objective variables (i.e. the 95%-ile of the ammonia and nitrate concentration in the effluent) level off, at 4 and 14 mg/l respectively.

The operating conditions that ensure this *optimised* conduction of the plant are a DO set-point of 5.9 mg/l and a nitrate set-point for the controller of the acetate dosage of 0.9 mg/l.

If the objective of the optimisation would include e.g. aeration costs (or with a different set of relative weights for the individual sub-objectives), the *optimal* operating conditions would most likely be different.

11 Scenario Analysis Experiment

A Scenario Analysis (SA) Experiment allows for the evaluation of the effect of a given set of parameter values on a set of objectives (variables), by performing a series of (dynamic) simulations.

In this chapter , we will look at the effect of aeration (through the DO set-point) and of the internal recycle on the quality of the effluent.

Proceed as follows:

- Re-open the 'TwoASU' Project.
  - Delete the Sheet "Aeration", to release the manipulated variable "y_"S" of the aeration control block (that was controlled by a slider in the base example)
- Save it as a new Project:
  - Click the "Save as" button in the Application Menu
  - Provide a name and a description for the new Project (Figure 11.1)

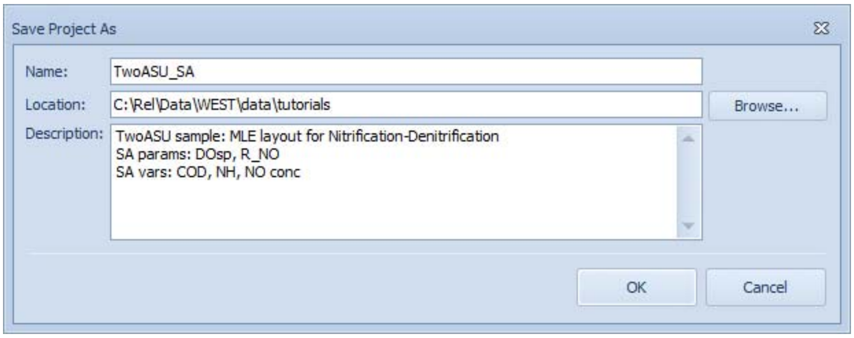


Figure 11.1 Save As dialogue, to use the TwoASU sample as the starting point for the Scenario Analysis experiment

- In the Project | Virtual Experiments menu, click on the "Scenario Analysis" button and select the Dynamic simulation as the base experiment.
  - Run a slave Steady-State simulation prior to the Dynamic simulation
- Drag and drop the relevant parameters on the Parameters tab page and input the relevant settings (see Table 11.1).
- The default for the Solver ("Sequential") is fine.
- Make sure the Communication Interval be not zero, in the "Simulation Output" tab page (e.g. 0.014).

- In the "Runs" tab page, the list of runs and the respective parameter values should be automatically filled in; if not, and to regenerate the series, click on the "Generate" button.
- For this example, there will be 8 (y_S values) times 10 (Q_Out2 values) = 80 runs (Figure 11.4).
- Set up the graphical output for the Scenario Analysis:
  - Add a new Sheet, 'Scenario Analysis (3D)'
  - Add a Z(X,Y), Surface type plot, "COD concentration" (Figure 11.2)
  - In the plot sub-menu, choose "Add Series" and add the two series Lower and Upper Percentile for the variable "out_water.COD" (Y-items); use the ".Aeration.y_S" and ".InternRecycle.Q_Out2" variables as X- and Z- items respectively.
- Add the same type of plot for the ".out_water.Outflow(S_NH)" and ".out_water.Outflow(S_NO)" variables
- Execute.
- The output of the SA experiment is shown in Figure 11.3 and Figure 11.4.
- By clicking on the "Copy Values" button, the parameter values of the selected run (typically one would choose the best run, but not necessarily) can be copied to the simulation.

Table 11.1 Parameter set and distribution methods for the Scenario Analysis experiment

Block	Parameter	Method	Settings
Aeration	y_S	Placement	Values: 0.25; 0.5; 1; 1.25; 1.5; 1.75; 2; 3
R_NO	Q_Out2	Spacing/Linear	Lower bound: 20000 Upper bound: 70000 (Specify Number of Values) Number of Values: 10

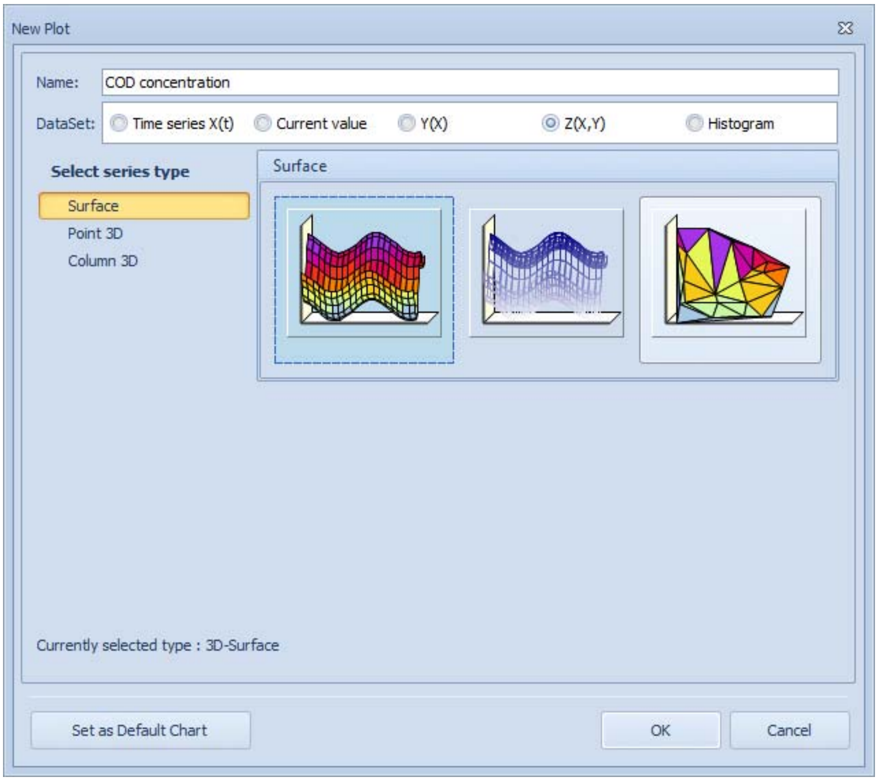


Figure 11.2 New plot dialogue: create a 3D Surface plot

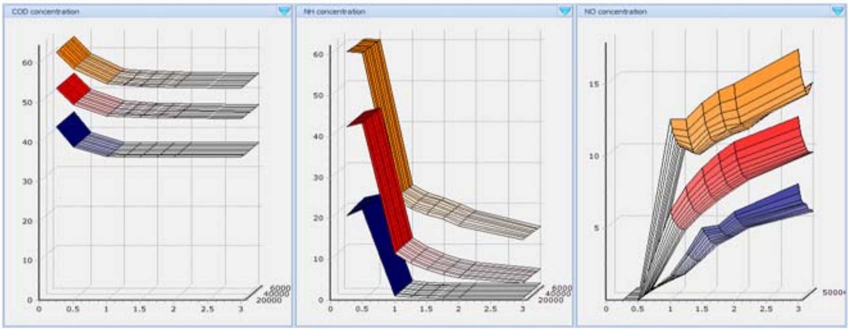


Figure 11.3 Results of the Scenario Analysis experiment

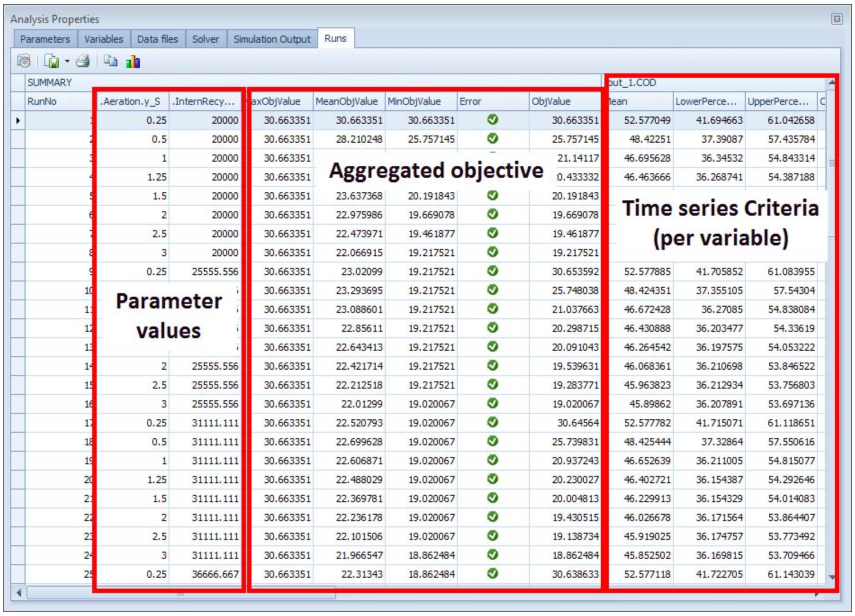


Figure 11.4 Runs tab page of the Analysis Properties dialogue, for a Scenario Analysis experiment

11.1 Results Interpretation

The outcome of this SA experiment suggests the following.

- Aeration has a major impact on ammonia concentration in the effluent: from 0.5 to 1 mg DO/l, the 95%-ile of ammonia gets reduced by almost 50%; from 1 to 2 mg DO/l, it gets further reduced by 30%
- Aeration has an adverse effect also on nitrate concentration in the effluent, i.e. the higher the DO set-point, the higher the nitrate.
- The internal recycle has an opposite effect, as it brings nitrate back to the anoxic tank where denitrification takes place. Beyond a certain limit though, the higher the recycle flow rate, the higher the oxygen that gets recirculated back to anoxic zone, which results in nitrate concentration in the effluent to rise.

12 Uncertainty Analysis Experiment

An Uncertainty Analysis (UA) experiment allows for the evaluation of how the uncertainty in a set of ‘parameters’ propagates to the (state and output) variables of the model, by executing a series of simulations – each using different values of the selected set of ‘parameters’.

In contrast to the SA experiment, parameter values are determined through a process that ensures equal spreading of the parameter vectors within the parameter space.

In this chapter, we will look at the effect of aeration (DO set-point) and of the internal recycle on the quality of the effluent.

Proceed as follows:

- Re-open the ‘TwoASU’ Project.
  - Delete the Sheet “Aeration”, to release the manipulated variable “y_”S” of the aeration control block (that was controlled by a slider in the base example)
- Save it as a new Project:
  - Click the “Save as” button in the Application Menu
  - Provide a name and a description for the new Project (Figure 12.1)

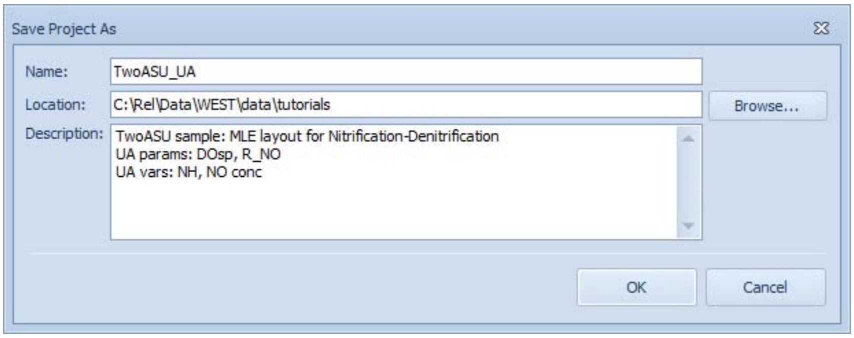


Figure 12.1 Save As dialogue, to use the TwoASU sample as the starting point for the Uncertainty Analysis experiment

- In the Project | Virtual Experiments menu, click on the “Uncertainty Analysis” button and select the Dynamic simulation as the base experiment.
  - Run a slave Steady-State simulation prior to the Dynamic simulation
- Open the Analysis Properties dialogue.
- Drag and drop the relevant parameters on the Parameters tab page and select the Distributions as shown in Table 12.1.

- In the Variables tab page, you will remark that the variables (and their settings) that were used to define objectives for the dynamic simulation are still available. We are not going to modify the variables list, nor the Time series Criteria, but we are going to specify Run and BVDF Criteria:
  - Run Criteria: for both COD and S_NO, select Minimum, Maximum, Median, Lower- and Upper Percentile
  - BVDF: by default, all Series are active; also, the same Criteria set for each Run will be active for BVDF; in addition, one could specify the Minimum and Maximum for the variables of interest and/or the Number of Values or the Intervals: a) COD: 25-60 (Interval 5) and b) S_NO: 0-20 (Number of Values 20)
  - Classification: do the same, as in BVDF

- In the Solver tab page, set the Number of Shots to 50.

- In the Runs tab page, the list of runs and the respective parameter values should be automatically filled in; if not, and to regenerate the series, click on the “Generate” button.

- Make sure that the Communication Interval be not zero, in the Simulation Output tab page (e.g. 0.014).

- Set up the graphical output for the Uncertainty Analysis:
  - An automatic way to set up some experiment-specific plots (related to lower and upper bounds violations), for the Time Series, for BVDF and for Classification, is available through the Runs tab page: click on the “Create Plot” button
  - In the Plot Creator dialogue window (Figure 12.2), it may be interesting to plot the following:
  - A BVDF plot of the “Percentage of Upper bound violations” (BVDF Type) for “.out_1.Outflow(S_NO)” (Quantity) over all runs (Specification: “1 Quantity - All Runs”)
  - The same for the quantity “.out_1.Outflow(S_NH)”
  - A BVDF “aggregated” plot (Specification: “Quantity Aggregation”) of the “Percentage of Upper bound violations” (BVDF Type) for “.out_1.Outflow(S_NO)” (Quantity)
  - The same for the quantity “.out_1.Outflow(S_NH)”
  - A Time series “aggregated” plot (Specification: “Quantity Aggregation”) for “.out_1.Outflow(S_NO)” (Quantity)

- To speed up the simulation, make sure to use VODE as integrator.

- Execute.

- The output of the UA experiment is shown in Figure 12.3 to Figure 12.5.

- By clicking on the “Copy Values” button, the parameter values of the selected run (typically one would choose the best run, but not necessarily) can be copied to the simulation.

Table 12.1 Parameter set and distribution methods for the Uncertainty Analysis experiment

Block	Parameter	Method	Settings
Aeration	y_S	Normal	Mean: 2 Standard Deviation: 0.25
InternRecycle	Q_Out2	Uniform	Lower bound: 20000 Upper bound: 70000

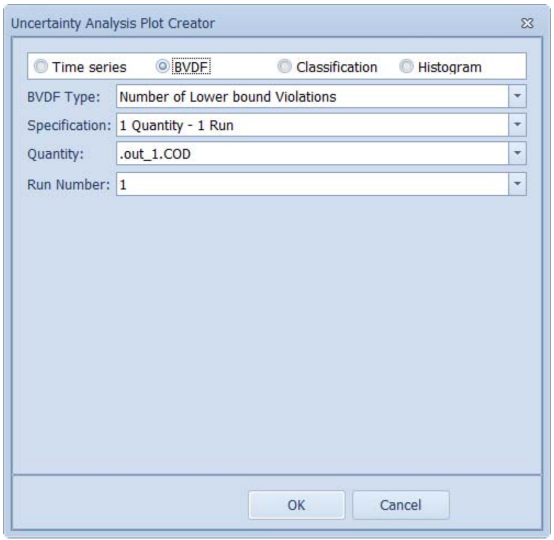


Figure 12.2 Dialogue for the automatic generation of ‘special’ plots for the Uncertainty Analysis experiment

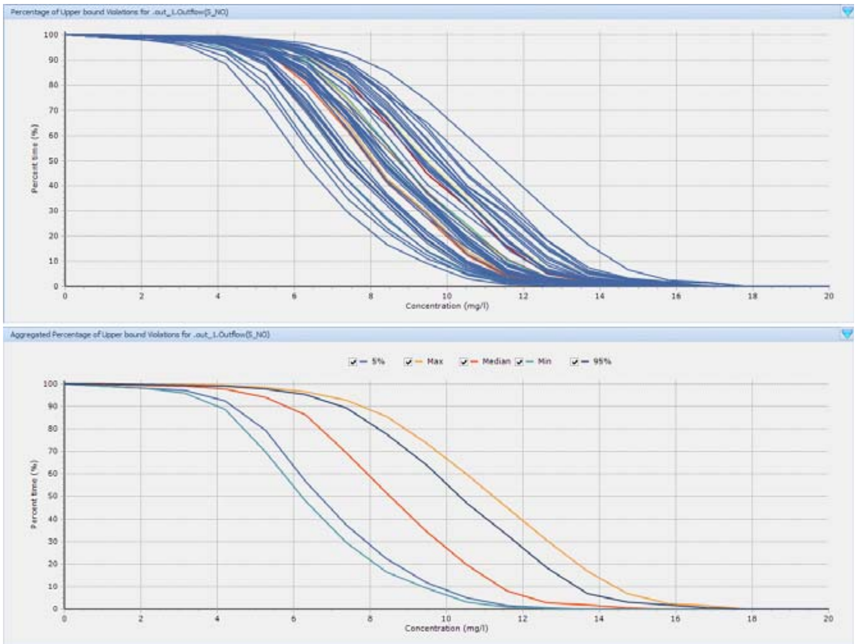


Figure 12.3 Results of the Uncertainty Analysis experiment: Percentage of Upper Bound Violation for Nitrate concentration in the effluent, all runs (top) and aggregated values (bottom)

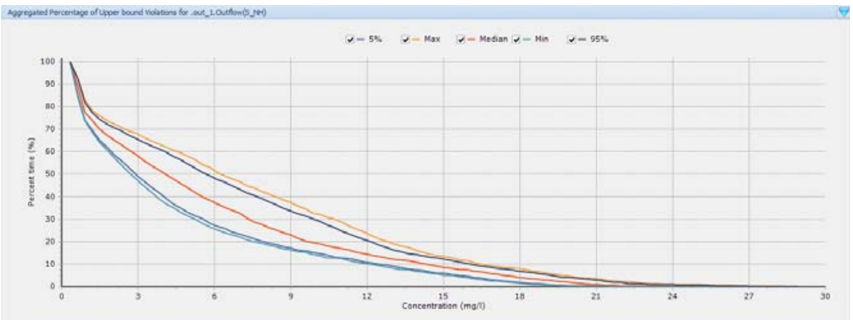


Figure 12.4 Percentage of Upper Bound Violation for Ammonia concentration in the effluent: aggregated values

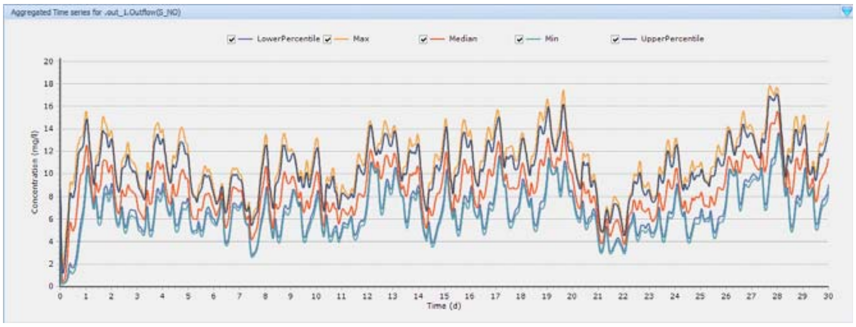


Figure 12.5 Aggregated Time series Criteria for Nitrate concentration in the effluent

12.1 Results Interpretation

Uncertainty Analysis is a very powerful tool that allows for associating a confidence interval to a prediction.

It appears that uncertainty over the nitrate concentration in the effluent (Figure 12.3 bottom) is much higher than that over ammonia (Figure 12.4): the 90% confidence region for nitrate (region between the 5%- and the 95%-ile) indicates that the concentration ranges between 3.5 and 10 mg/l for 50% of time, whereas the corresponding region for ammonia is 3 to 5 mg/l

This is perfectly logical, considering that the degrees of freedom for this example are the aeration set-point and the internal recycle, that have a major impact on nitrate - as proven by the GSA experiment too.

13 The Plant-Wide Model

Proceed as follows:

- Create a New Project, starting from the UCT template.
  - Select the UCT template from the list of Templates in the Getting Started
  - This will automatically create a New Project (Figure 13.1)

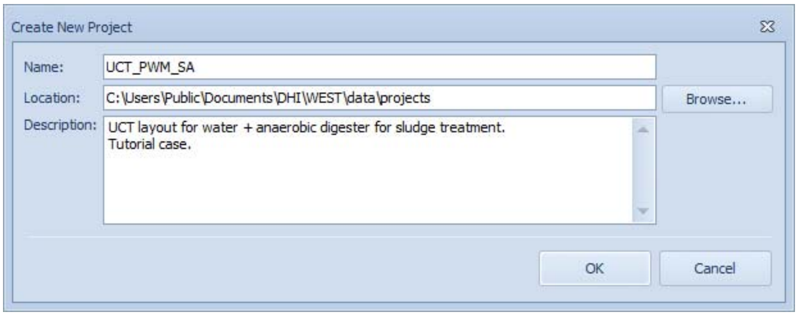


Figure 13.1 Create New Project dialogue, to create the PWM_SA experiment from the UCT template

- Change the project Instance to “PWM_SA”.
  - In the “Project | Miscellaneous” menu, click on “Block Library Setup” button
  - Select the “PWM_SA” Instance and confirm

- Double-click on the “out_Water” Block to activate the Effluent Generator and set the appropriate output vector (and model)
  - In the “General” tab page:
a) choose “Standard”
b) “Input-” and “Output Category” is “PWM_SA”
  - In the “Generate” tab page, click on the “Generate” button

- Do the same, for the “out_Sludge” Block

- Double-click on the “Municipality_1” Block to activate the Influent Generator and set the appropriate input vector (and model)
  - In the “General” tab page
a) choose “Standard”
b) choose “pHAlk” as both “Input-” and “Output Category”
c) deselect the “Enable C2F conversion” option

- In the “Data Import” tab page
  a) in “Time Series In”, delete the pre-existing data file (“WEST.BOD-COD.Month.Influent.txt”), then add the “UCT_PWM_SA.Influent.txt” file (located in the InputOutput folder)
  b) drag the file name to the “Time Series Out” box
- In the “Generate and Review” tab page, click on the “Generate” button
- An error message will be displayed regarding the cardinality of vectors not matching, and the link between the “Municipality_1” and the 2-way combiner Blocks will be erased. This is to be expected and will be corrected by inserting a Transformer

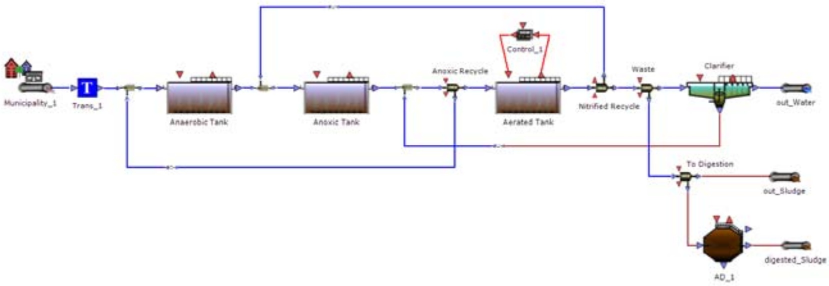


Figure 13.2 Final layout for the PWM_SA experiment

- Modify the template UCT layout, as follows - the final layout is shown in Figure 13.2
  - Create the Input “speciation” model, by inserting a Transformer Block between the Municipality Block and the Two-way Combiner
  - Move the return sludge from before to after the Anoxic tank

    a) place a “Two combiner” Block between the Anoxic tank and the “Anoxic Recycle”

    b) connect the sludge recycle to the new Block

    c) (optionally) replace the “Three combiner” Block between the Anaerobic and the Anoxic tanks by a “Two combiner”
  - Change the model for the Clarifier to “SecondaryPointSettler” (Property “ClassName” in the Properties pane)
  - Modify the sludge withdrawal system by wasting the activated sludge immediately after the Aerated tank
    a) move the “Waste” Block between the “Nitrified Recycle” flow splitter and the “Clarifier”

- Add the sludge treatment line

  a) place a “Two flow splitter” between the “Waste” and the “out-_Sludge” Blocks to divert a portion of the activated sludge to the digester; rename it to “To Digestion”

  b) place an “Anaerobic digester” and a “Waste” block on the canvas and connect them in sequence to the splitter
- Add a PI controller for the aeration of the “Aerated Tank”

  a) place a “PI Controller” Block immediately above the “Aerated Tank”

  b) connect its ingoing signal (“y_M”) to the DO and the outgoing signal (“u”) to the kLa of the ASU model

  c) (optionally) assign the Control Block and the two connections to the Control Layer

- (optionally) go through the Effluent Generator for the “Waste” Block that carries the digested sludge (same as done for the “out_Sludge” Block above)

- Set the parameters as indicated in Table 13.1

Table 13.1 New blocks to be added to the base TwoASU layout

Block	**Model (ClassName)**	**Parameters**	
		Symbol	Value
Anaerobic Tank	FixVolumeASU	Temp Vol Kla_Min	20 degC 19 L 0 d^{-1}
Anoxic Tank	FixVolumeASU	Temp Vol Kla_Min	20 degC 21 L 0 d^{-1}
Anoxic Recycle	AbsTwoSplitter	Q_Out2	150 L/d
Aerobic Tank	FixVolumeASU	Temp Vol KLa_CO2 Kla_Min	20 degC 35 L 5 d^{-1} 50 d^{-1}
Control_1	PI_Saturation	K_P u0	500 564 d^{-1}
Nitrified Recycle	AbsTwoSplitter	Q_Out2	450 L/d

Table 13.1 New blocks to be added to the base TwoASU layout

Block	Model (ClassName)	Parameters	
Waste	AbsTwoSplitter	Q_Out2	5.7 L/d
Clarifier	SecondaryPoint-Settler	Q_Out2	250 L/d
To Digestion	AbsTwoSplitter	Q_Out2	0.4 L/d
AD_1	UCTAD_BSM3P	V_gas V-Liq f_X_Retention	4 L 16 L 1

- Prepare the graphical output.
  - Create two Sheets ("pH" and "H2"), each containing one "Time series X(t) plot"
  - Drag the variable "p_H" for the Anaerobic, Anoxic, Aerated tanks (Algebraic Variables | "Speciation") and for the Digester to the first plot ("pH")
  - Drag the variables "C(S_H2)" (Algebraic Variables | "Concentration") and "VSS" (Output Variables | "Measured Data") for the Digester to the second plot ("H2")
- Execute the Steady-State Simulation
  - Set the simulation horizon to 200 days
  - Choose VODE as integrator
    a) Linear Solver: Diag
    b) Linear Multistep Method: BDF
    c) Iteration Method: Newton
- Execute the Dynamic Simulation
  - Set the simulation horizon to 30 days
  - Use the same integrator and integrator settings as for the Steady-State Simulation
- The results are shown in Figure 13.3 and Figure 13.4

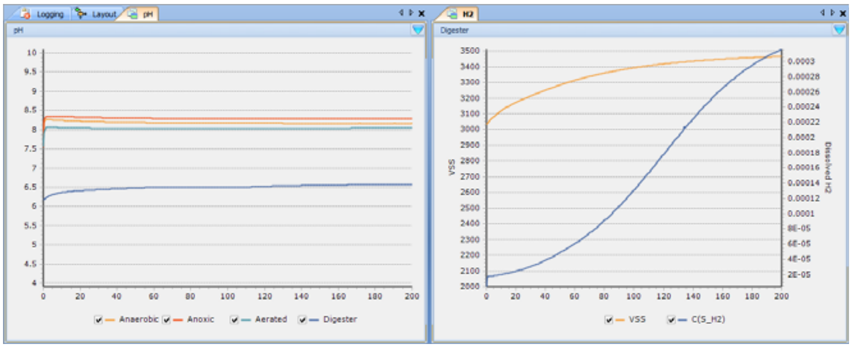


Figure 13.3 Steady-State simulation of the PWM_SA experiment

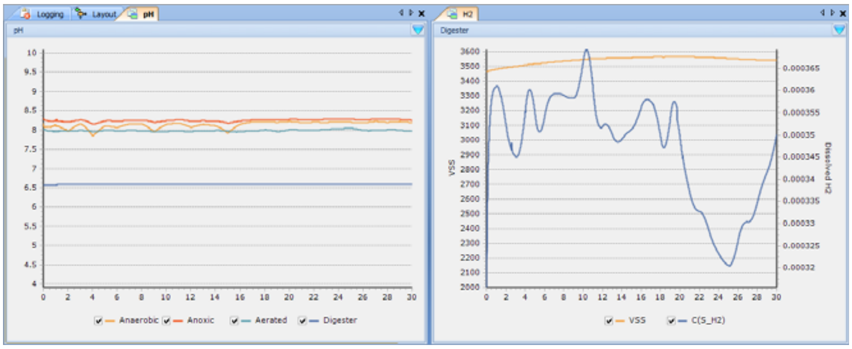


Figure 13.4 Dynamic simulation of the PWM_SA experiment

14 The TWOASU_IUWS Sample

Proceed as follows:

- Create a New Project, starting from the TwoASU template.
  - select the ModifiedLudzackEttinger template from the list of Templates in the Getting Started
  - This will automatically create a New Project (Figure 14.1)

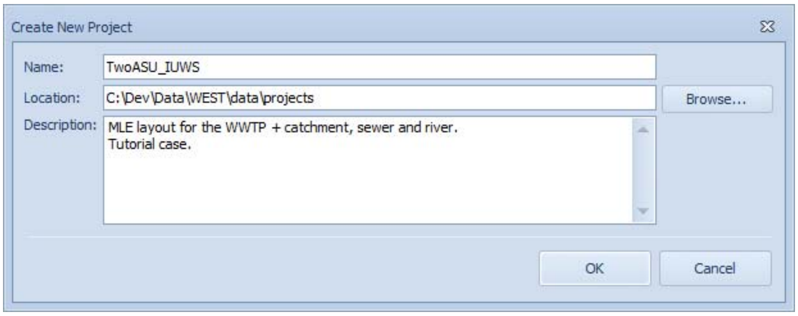


Figure 14.1 Create New Project dialogue, to create the IUWS sample from the MLE template

- Change the project Instance to “IUWS”.
  - In the “Project | Miscellaneous” menu, click on “Block Library Setup” button
  - Select the “WEST.IUWS.BlockLib.xml” Block Library
  - only 1 Instance is available, “ASM2dModTemp”: confirm
- Delete the Influent Block (“Municipality_1”) and the two Effluent Blocks (“out_Water” and “out_Sludge”), since the WWTP is going to receive the output of the sewer and will discharge into the river

14.1 Adapt the WWTP Layout

- Add the following Control Blocks to the WWTP (see Table 14.1):
  - A proportional (“P”) controller for aeration
  - A proportional (“P”) controller for sludge wastage that maintains the solids in the activated sludge tank at 3,000 g/m^3
  - A Ratio controller for the internal recycle (2x Q_In)
  - A Ratio controller for the sludge extraction (“Underflow”) from the clarifier (50% of Q_In)
- Create a top-level variable, to receive the temperature of the mixed liquor as data input:

  - Right-click in the canvas and choose “Top-level Interface Variables ...” from the context menu
  - Add the variable “Temp_ML” with the properties listed in Table 14.2

- Add a Data Input Block and rename it “Temp_ML”

- Double-click to start the Input Generator
  - in the “General” tab page: select the top-level variable “Temp_ML”
  - in the “Data Import” tab page:

    a) select the “TwoASU_IUWS.DataInput.txt” file (located in the InputOutput folder) in the “Time Series In”

    b) drag the column header “.Temp_ML” to the “Time Series Out” box
  - in the “Generate and Review” tab page, click on the “Generate” button

- Finally, connect the “Temp_ML” Block to the “Temp” manipulated variable of both the activated sludge tanks

Table 14.1 Control Blocks hat need to be added to the WWTP

Block	Model (ClassName)	Parameters	
DO	P_Saturation	KP y_S	100 2 mg/l
MLSS	P_Saturation	KP u0 y_S	-1 0 m^3/d 3000 g/m^3
NO3	Ratio	ConstantRatio	2
RAS	Ratio	ConstantRatio	0.5
Inflow	Sensor_Flow	--	
Anoxic	FixVolumeASU	kLa Vol	1 d^{-1} 4000 m^3
Aerated	FixVolumeASU	Vol	6000 m^3
Clarifier	Takacs_SVI	fns	0.001

Table 14.1 Control Blocks hat need to be added to the WWTP

Block	Model (ClassName)	Parameters	
Catchment_1	Catchment_Retention _Gravity	TotalArea Population Infiltration MaxDepressionStorage Q_ind Q_max V_Max	2 km2 3,000 IE 0 0 mm 100 m3/d 1 m^3/s 500m^3
Tank_1	Tank_Freeflow	Q_max H_Pipe V_Max IsPumpOn	1 m^3/s 0.5 m 100 m^3 0
CSO_1	CSOToRiver_Simple _FixConc	all default	
WWTPin	SewerToWWTP	Q_95_av Q_peak	0.015 m^3/s 0.5 m^3/s
fract	SewerToWWP _COD_NH4	all default	
River_1	RivVarVolumeRIVER	L W_b	1000 m 1 m
River_2	RivVarVolumeRIVER	L W_b	1000 m 1 m
Upstream	simple_Duflow_generator	Surface	10 km^2
WWTP2River	ASM2d_to_DuflowSimple	all default	

14.2 Set up the Catchment and the Sewer Layout

- Add the following Blocks, upstream to the WWTP (see Table 14.1):
  - A Catchment
  - A pipe (“Tank”)
  - A Combined Sewer Overflow (“CSO”)
  - A transformer (“Connector”), to convert the sewer outflow into a suitable inflow for the WWTP: rename it “WWTPin”
  - Another transformer, to convert the generic WWTP influent to an ASM2 influent: rename it “fract”
- Connect the Catchment (“Outflow” interface) to the Tank; and the Tank (“Overflow” interface, terminal “out_2”) to the CSO

- Connect the Tank (“Outflow”, terminal “out_1”) to the “WWTPin”; the “WWTPin” to the fractionator; and this latter to the input of the WWPT, i.e. the flow sensor “Inflow”
- Create a top-level variable, to receive the rainfall as data input (see Table 14.2)
- Add a Data Input Block and rename it “Rain”
- Double-click to start the Input Generator
  - in the “General” tab page: select the top-level variable “Rain”
  - in the “Data Import” tab page:

    a) select the “TwoASU_IUWS.DataInput.txt” file (located in the InputOutput folder) in the “Time Series In”

    b) drag the column header “.Rain” to the “Time Series Out” box
  - in the “Generate and Review” tab page, click on the “Generate” button

Finally, connect the “Rain” Block to the “Rainfall” manipulated variable of the Catchment Block

Table 14.2 Top-level variables for the IUWS case (Causality “Input” and Group “Measurements” for all)

Name	Type	Description	Unit
Temp_ML	CelsiusTemperature	Temperature of the Mixed Liquor	degC
Rain	Rainfall	Rainfall data	mm
Flow	Velocity	River flow velocity	m/d
Temp_Air	CelsiusTemperature	Air temperature	degC
Radiation	DensityOfHeatFlowRate	Solar radiation	W/m^2

14.3 Set Up the River Layout

- Add the following Blocks, downstream to the WWTP (see Table 14.1):
  - Two river stretches
  - A river input: rename it “Upstream”
  - A transformer, to translate the WWTP outflow into a suitable inflow for the River: rename it “WWTP2River”
- Connect the “Upstream” Block to the first river stretch (terminal “in_1”); and the first river stretch (terminal “out_1”) to the second stretch

- Connect the CSO to the first river stretch (terminal “in_2”)
- Connect the output of the WWPT, i.e. the “Outflow” of the “Clarifier” to the “WWTP2River”; the “WWTP2River” to the input of the second river stretch (terminal “in_2”)
- Create three top-level variables, to receive the river flow, the air temperature and the radiation as data inputs (see Table 14.2)
- Add three Data Input Blocks: “Flow”, “Temp_Air” and “Radiation”, respectively
- In the Input Generator of each one
  - in the “General” tab page: select the corresponding top-level variable
  - in the “Data Import” tab page:

    a) select the “TwoASU_IUWS.DataInput.txt” file (located in the InputOutput folder) in the “Time Series In”

    b) drag the corresponding column header to the “Time Series Out” box

    c) associate the header to the Component, if necessary
  - in the “Generate and Review” tab page, click on the “Generate” button
- Finally, connect the “Flow” Block to the data terminal (“in_1”, interface “rainfall”) of the River Input Block
- Connect the “T_Air” input to the data terminal (“in_3”, interface “T”) of the two River stretches
- And connect the “Radiation” input to the data terminal (“in_3”, interface “I0”) of the two River stretchs

14.4 Prepare the Graphical Output and Execute the Simulation

The following is only a suggestion for some plots.

- “Catchment” (Time series X(t) plot). Data series:
  - Rain (“Rain” manipulated variable of the catchment’s block)
  - Run-off flow rate (“Q_Out” of the catchment’s submodel “CRunoff” - to be selected in the Model Explorer)
  - Flow rates and water level (“Q_In”, “Q_Out”, “Q_over” and “WaterLevel” of the catchment’s submodel “Retention” - to be selected in the Model Explorer)

  - Flow rate (“Q_Out” of the catchment’s submodel “DWF” - to be selected in the Model Explorer)

- “Sewer” (Time series X(t) plot). Data series:
  - Flow rate (“Q_Out” and “Q_over”) and filling degree (“FillingDegree”)

- “ASU” (Time series X(t) plot). Data series:
  - Oxygen (“C(S_O)”), ammonia (“C(S_NH)”), nitrate (“C(S_NO)”) and phosphate (“C(S_PO)”) concentrations in both activated sludge tanks
  - Heterotrophic (“C(X_H)”), autotrophic (“C(X_AUT)”) and P-accumulating (“C(X_PAO)”) biomass and total solids (“C(X_TSS)”) in the aerated tank

- “SST” (Time series X(t) plot). Data series:
  - Flow rate (“Q_In”, “Q_Out” and “Q_Under_Actual”), solids concentration (“X_In”, “X_Out” and “X_Under”) and the height of the sludge blanket (“H_S”) in the clarifier

- “River Quality” (Time series X(t) plot). Data series:
  - Oxygen (“C(rO2)”) and ammonia concentration (“C(rNH4)”) in the two river stretches

- “River Water” (Time series X(t) plot). Data series:
  - Flow rate (“Q_In” and “Q_Out”), depth of water in the channel (“d”) and velocity (“vel_water”) in the two river stretches

Use the “VODE” integrator and set the absolute and relative tolerance to 0.001 and launch the Dynamic Simulation.

The results are shown in Figure 14.2 to Figure 14.5.

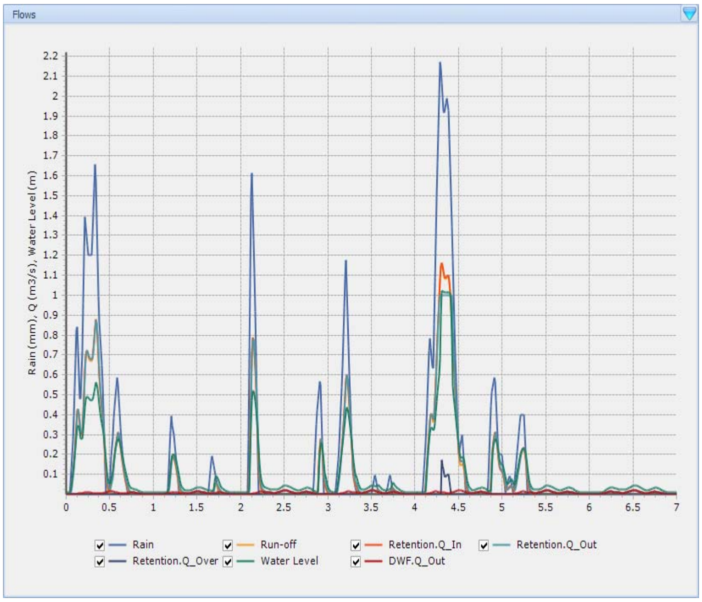


Figure 14.2 Rainfall and flow rate in the catchment

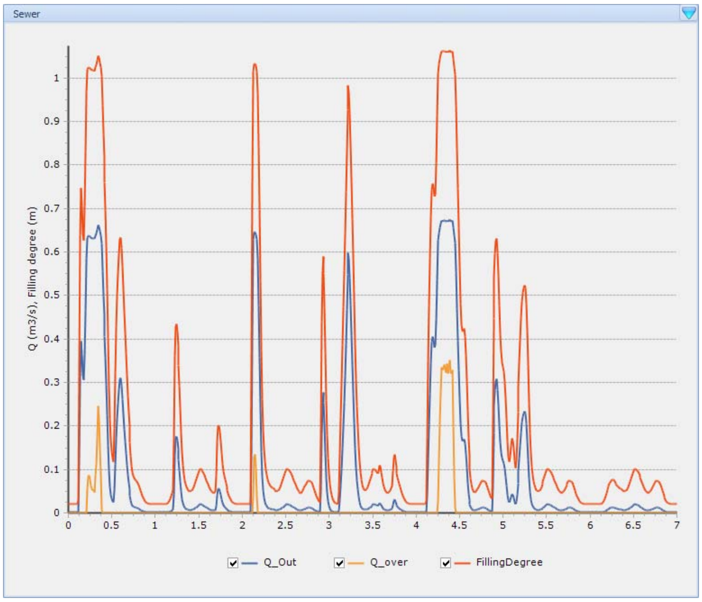


Figure 14.3 Flow rate and filling degree in the sewer

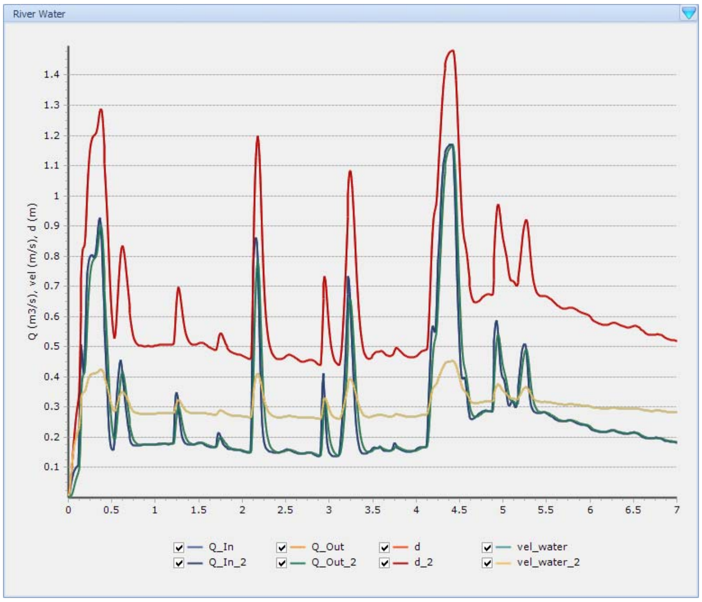


Figure 14.4 Flow rate, velocity and depth of the water in the two river stretches

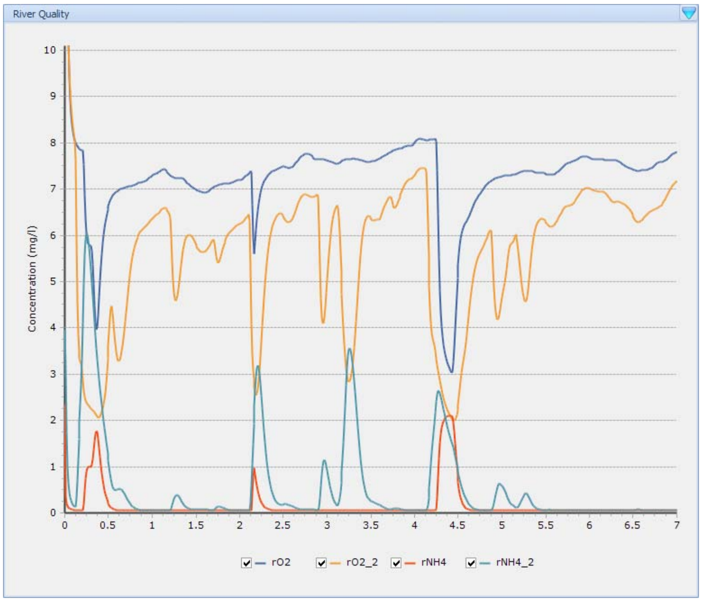


Figure 14.5 Dissolved oxygen and ammonia concentration in the two river stretches

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