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Ciclo de 20 MasterClass

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Enrico Remigi

WEST Product Owner (DHI, Water in Cities)
Environmental Engineer

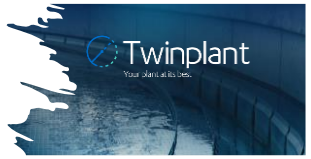
- Model Development
- Technical Support & Training
- Projects (30): process & energy optimization

Outline

About DHI

Case studies

Offline Studies - WEST



Online Solutions

About DHI

- Independent, private and not-for-profit organisation
- Main office in DK and 30+ offices in countries worldwide with total staff of more than 1,100
- Software products for water modelling – the MIKE suite
- Custom-made digital solutions for the water sector

We support the UN **sustainable development** goals.

DHI is a **leading, innovative, global advisory** company, integrating deep **domain knowledge** and **technology** to enabling new ways to use, manage and live with **wate**r and to protect water-related ecosystems.

Wastewater Treatment Services

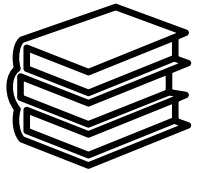
- Experts in analysing, modelling and optimising WWTPs
  - performance and energy audits » Feasibility Studies
  - bottleneck identification & optimization » Advanced Process Modelling
- We can help to:
  - Improve effluent quality
  - Increase plant capacity
  - Become energy neutral
  - Recover valuable resources » WRRFs
  - Establish automated model- and data-driven operations

Wastewater Treatment Services

Operation (online)	• Implementation of **Digital Twins** (integration ⇔ model) • Implementation of **real-time DSS** for operators and process engineers » to identify best operating strategy in dynamic conditions
Operation (offline)	• Optimization of operation **costs** (e.g. aeration, chem dosing, energy) • Assessment and optimization of advanced **control solutions** • Estimation of GHG emissions (e.g. N2O) • Operator training
Design	• Evaluation of design alternatives and **design verification** • Capacity assessment for different **scenarios** (e.g. peak load, population growth, new discharge, ..) • Study **upgrade** solutions

Outline

About DHI



Case studies

Offline Studies - WEST

Online Solutions

VIBY (DK)

CHALLENGE

- Insufficient capacity » unstable performance
- Short WWTP lifetime

SOLUTION

- Model-based process optimization & retrofitting
- Advanced control strategies (aeration, chemical dosing)

RESULT

- 30% capacity for < 2M Eur
- very limited interventions in new infrastructure

Client: Aarhus Vand

Partners: NIRAS, TechRas Miljø, EssDe GmbH

BJERGMARKEN (DK)

CHALLENGE

- High energy consumption due to excessive aeration

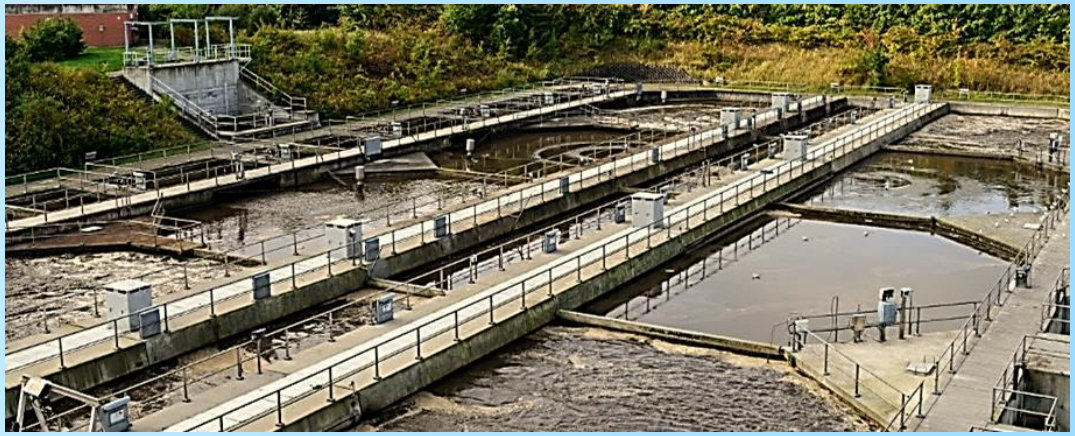
SOLUTION

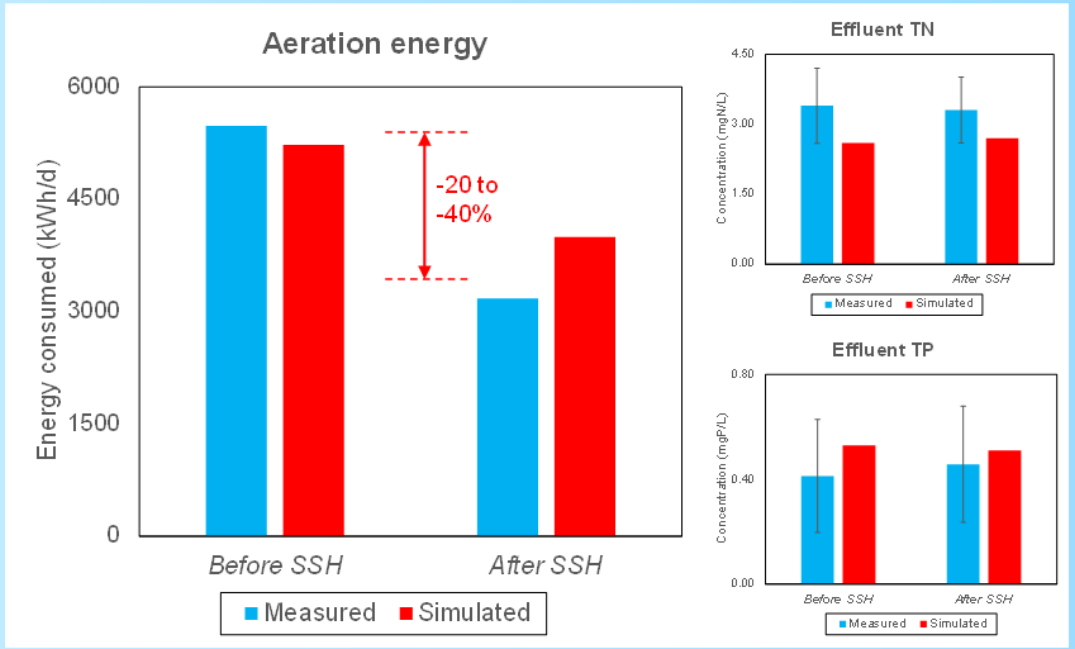
- Model-based process retrofitting
- Conversion of ARP process to side-stream hydrolysis (SSH)

RESULT

- -20% reduction in aeration energy use
- Long-term treatment stability

Client: FORS A/S





WEST LAFAYETTE (US)

CHALLENGE

- Reduce C-footprint to fulfil climate action plan

SOLUTION

- Process modelling to identify optimization potential
- Advanced control strategies (aeration, anaerobic digestion)
- Carbon footprint calculator

RESULT

- 60% energy neutral operation achievable
- $ 293,000 estimated yearly savings

Client: City of West Lafayette

BRESSO NIGUARDA (IT)

VISION

- Couple operator's experience, real-time data and model's predictive capability

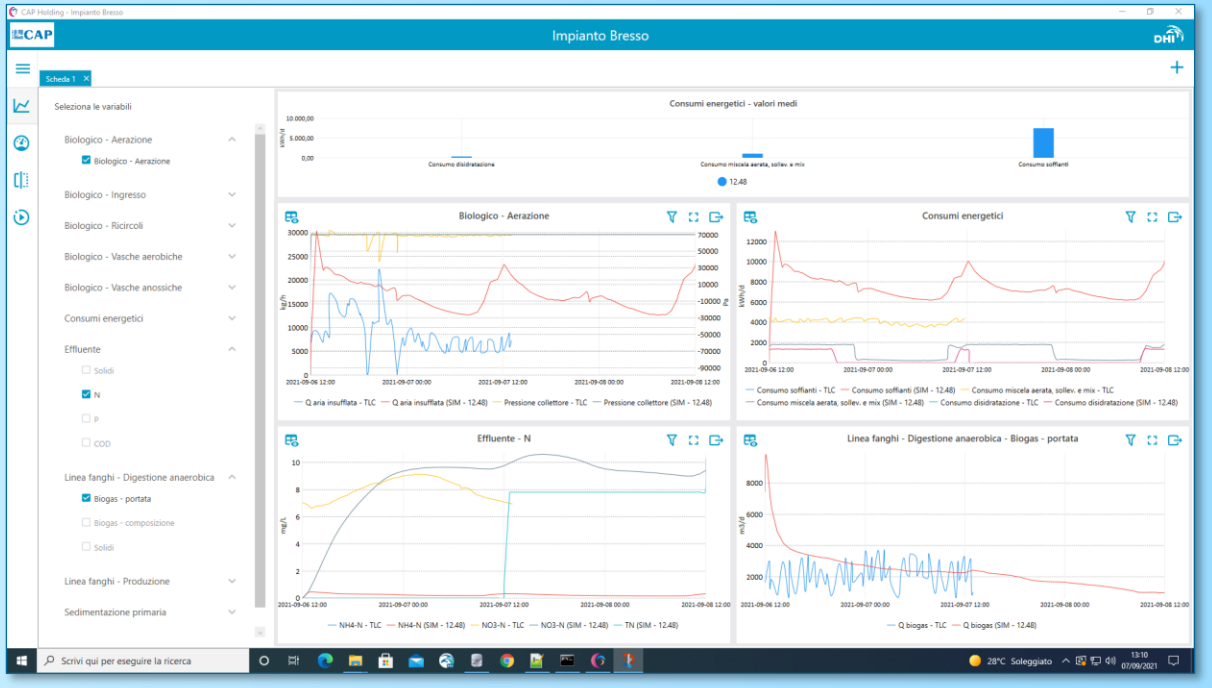
SOLUTION

- Digital Twin for plant monitoring, staff training and decision support
- Custom GUI, automatic data acquisition, WEST model, and scheduled execution of simulations

RESULT

- Running on premises

Client: Gruppo CAP



Outline

About DHI

Case studies

Offline Studies - WEST

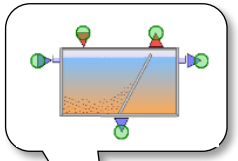
Online Solutions

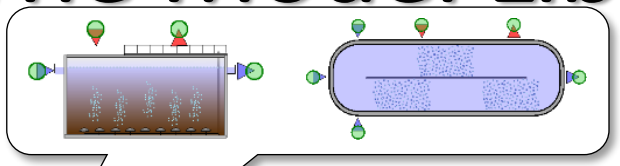
WEST

- Dynamic simulator for physical, chemical and biological processes
- Domains:
  - Municipal wastewater treatment plants (**WWTP**)
  - Transition WWTP » **WRRF** (Water Resource Recovery Facility)
  - Integrated Urban Water System (**IUWS**): catchment, sewer, plant, receiving water body
  - Other domains, e.g. (drinking) water treatment, industrial process water treatment, ..

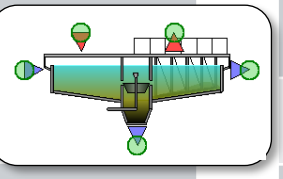
Generic platform for process modelling and simulation

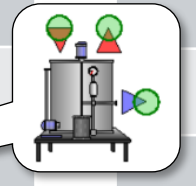
The Model Library

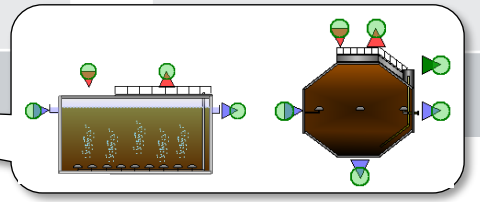




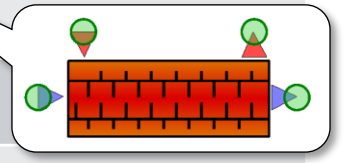
- Screening, grit removal
- Buffer tanks: equalisation, storm, ...
- Activated sludge, oxidation ditch
- Biofilm: MBBR, IFAS
- Alternated process: SBR, CFID, CFCD
- Membrane: MBR, external membrane
- Primary & Secondary Settling tanks
- Sand- and trickling filters
- Sludge dewatering units
- Chemical dosage units
- Aerobic and anaerobic digesters

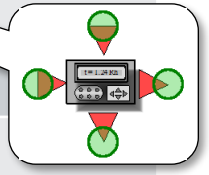


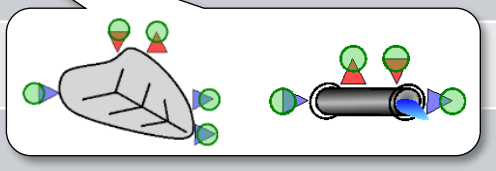




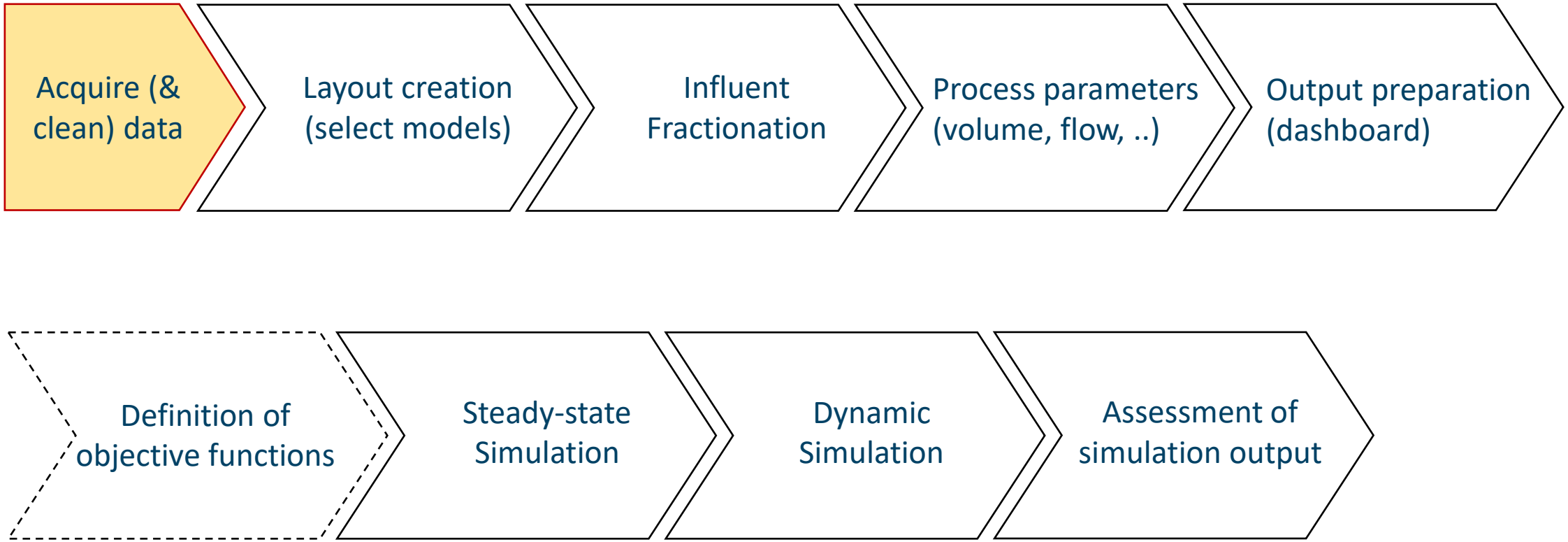
- Heat losses, sludge pre-heating, gas turbine
- Disinfection
- Sensors, controllers, timers
- Aerators and Blowers
- Pumps
- Catchment, Pipes, CSO, River







The Workflow in WEST



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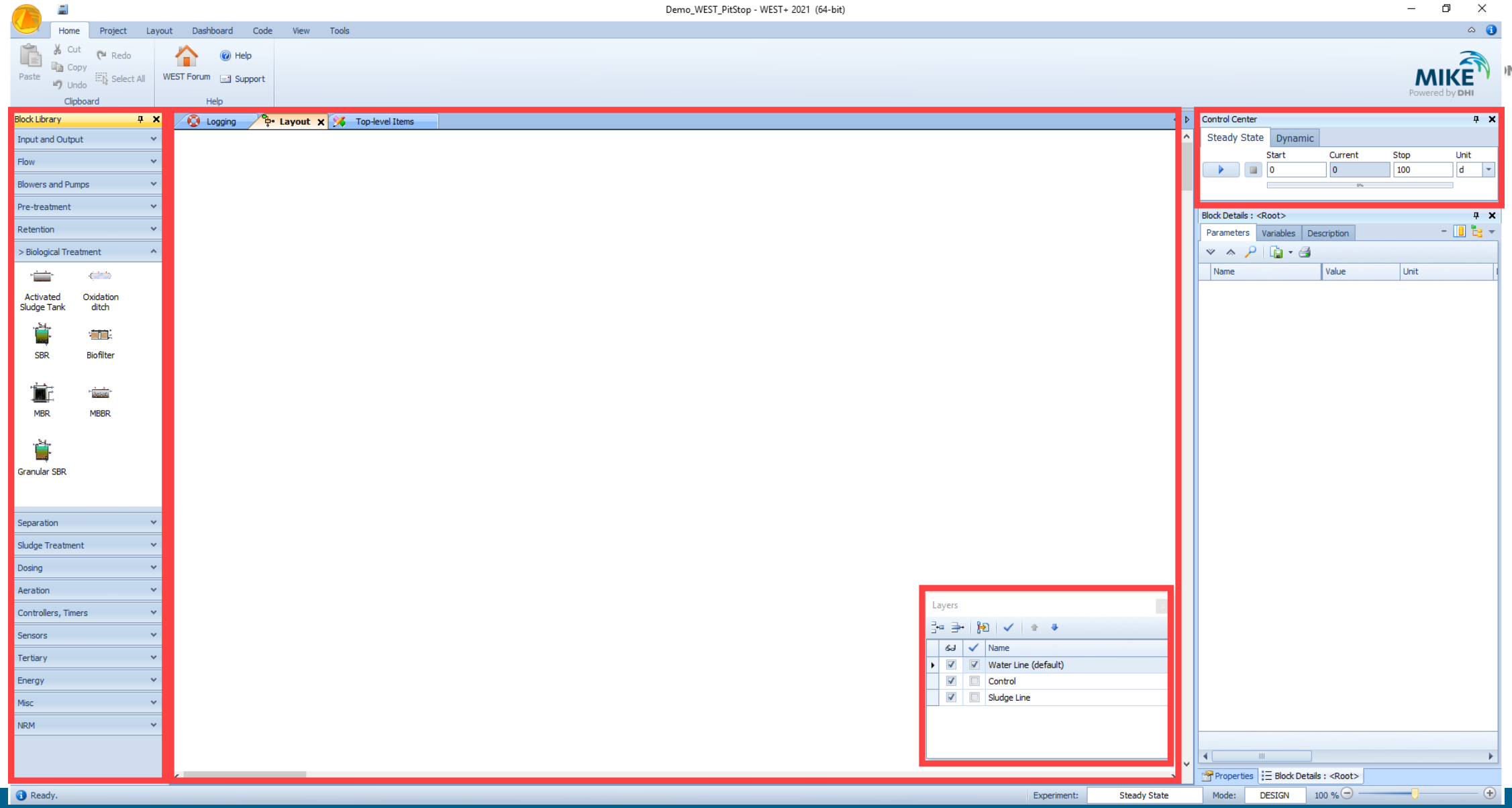
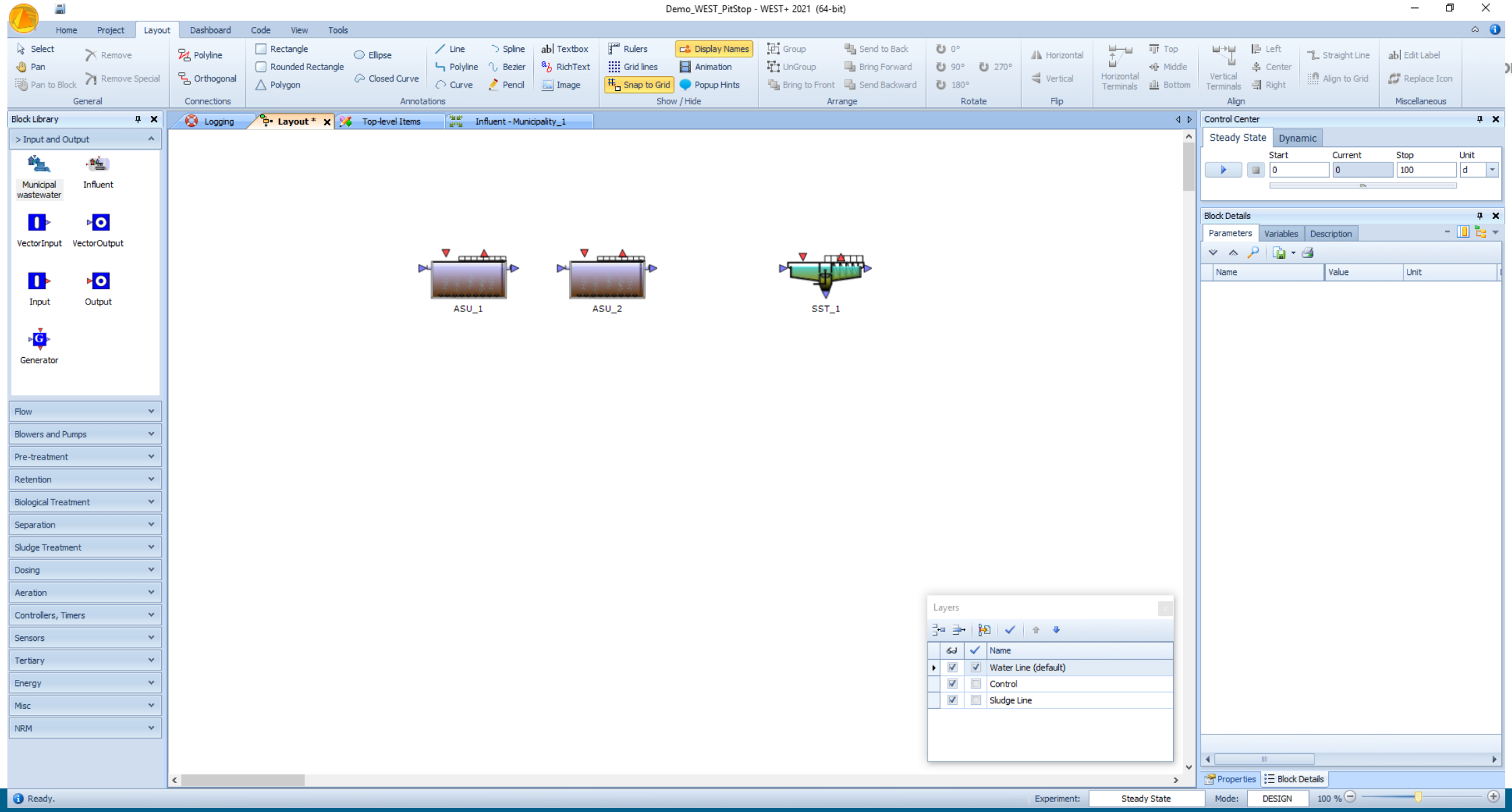


The Workflow in WEST



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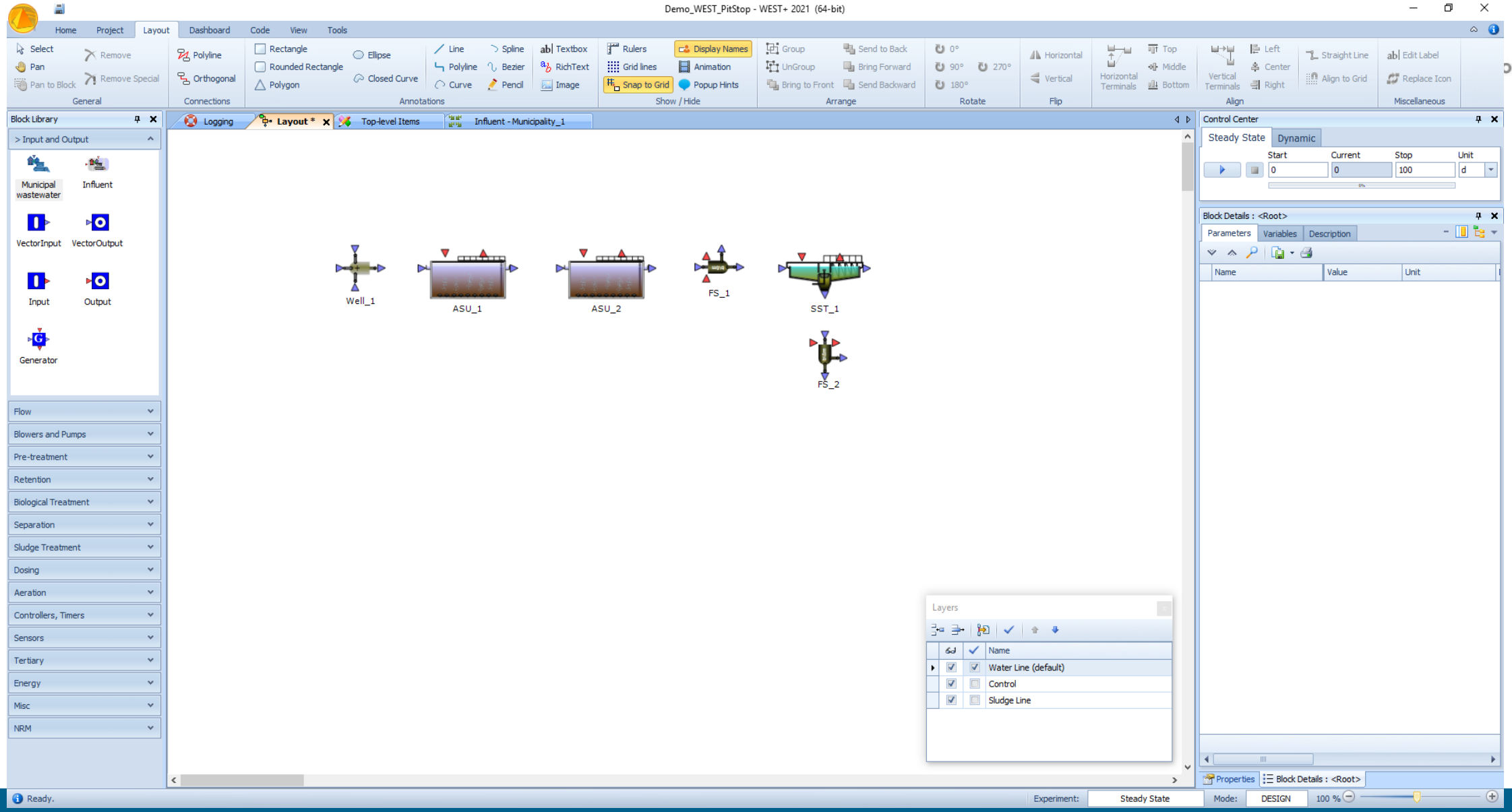

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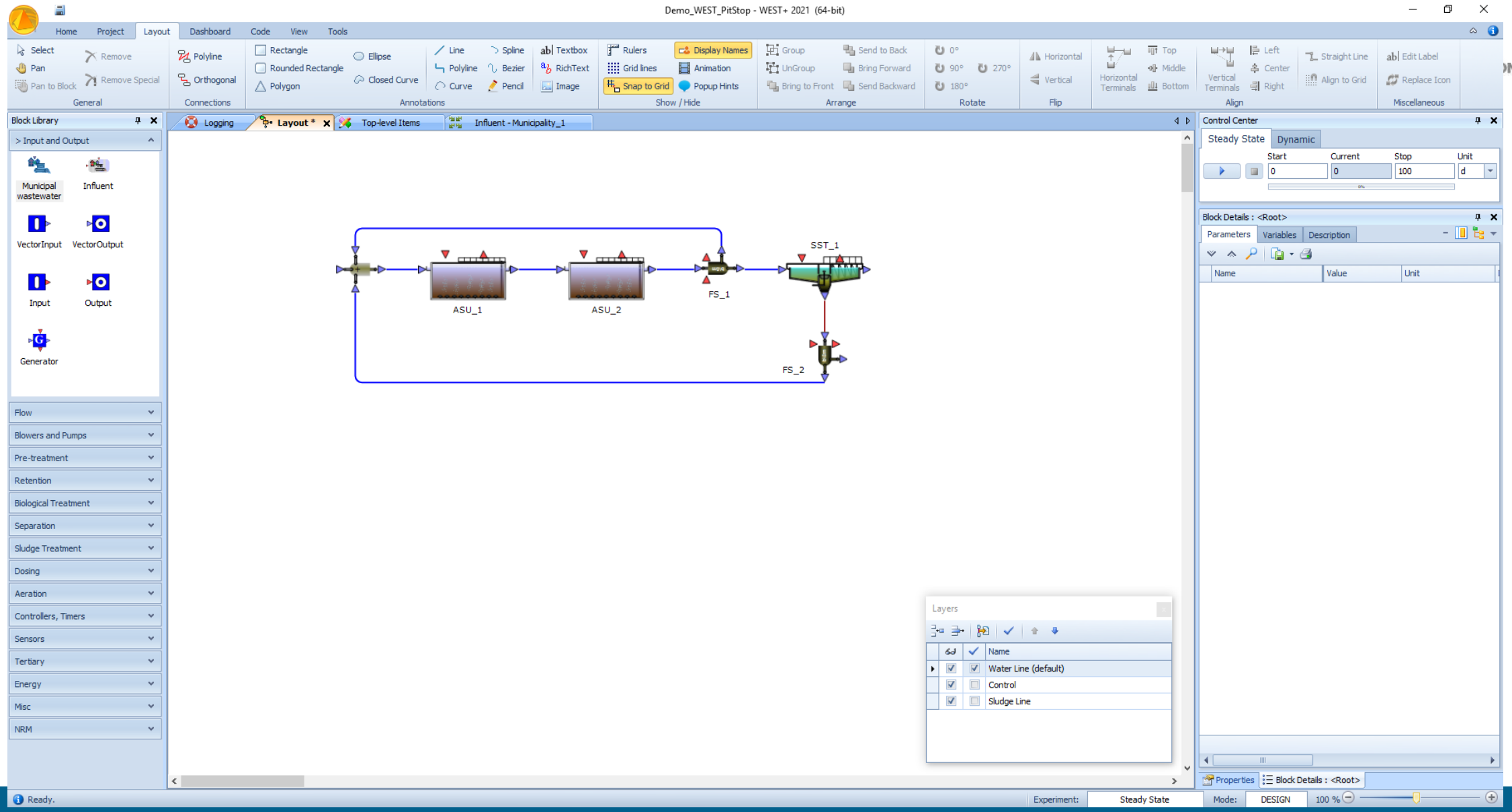

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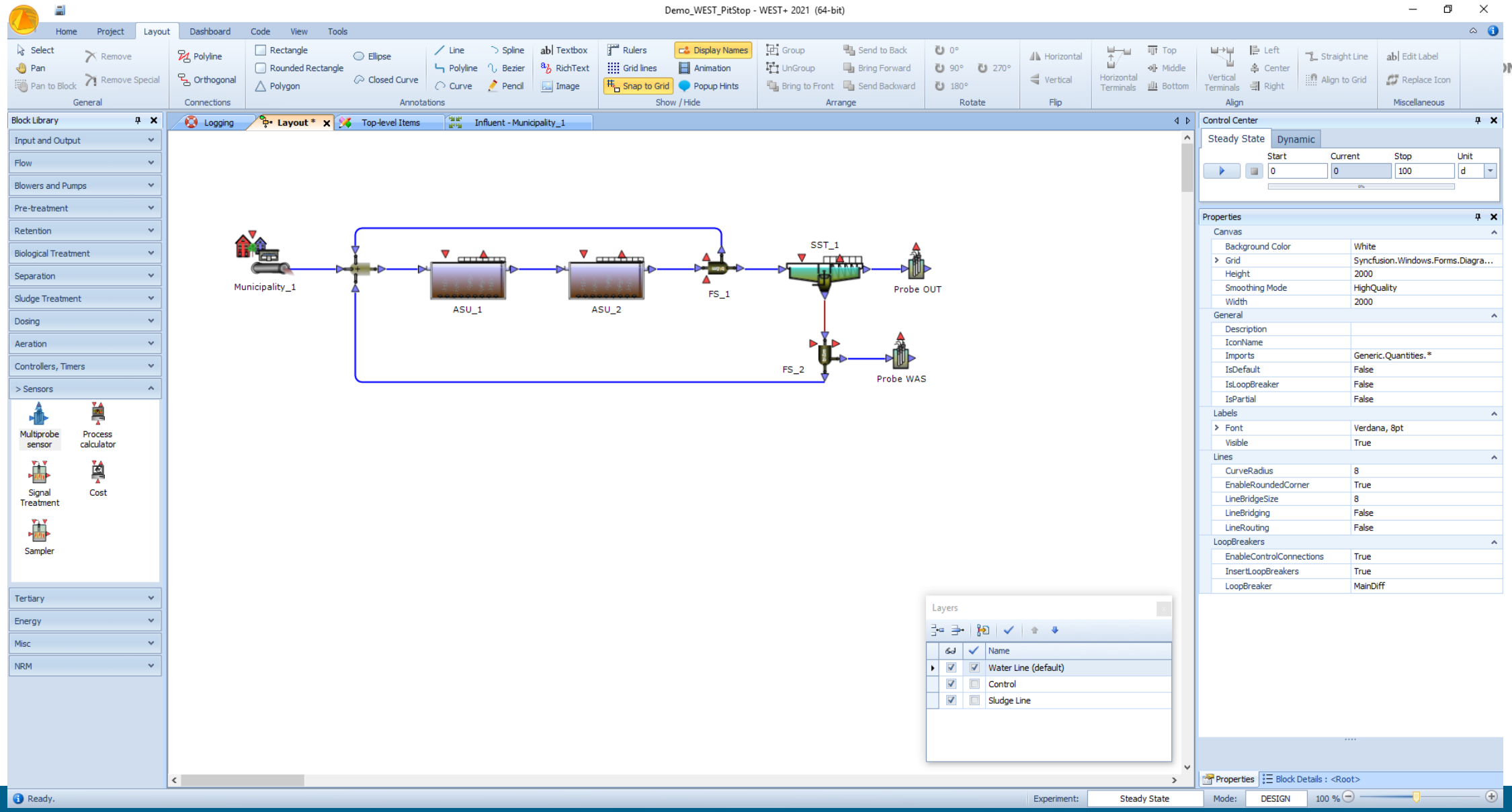
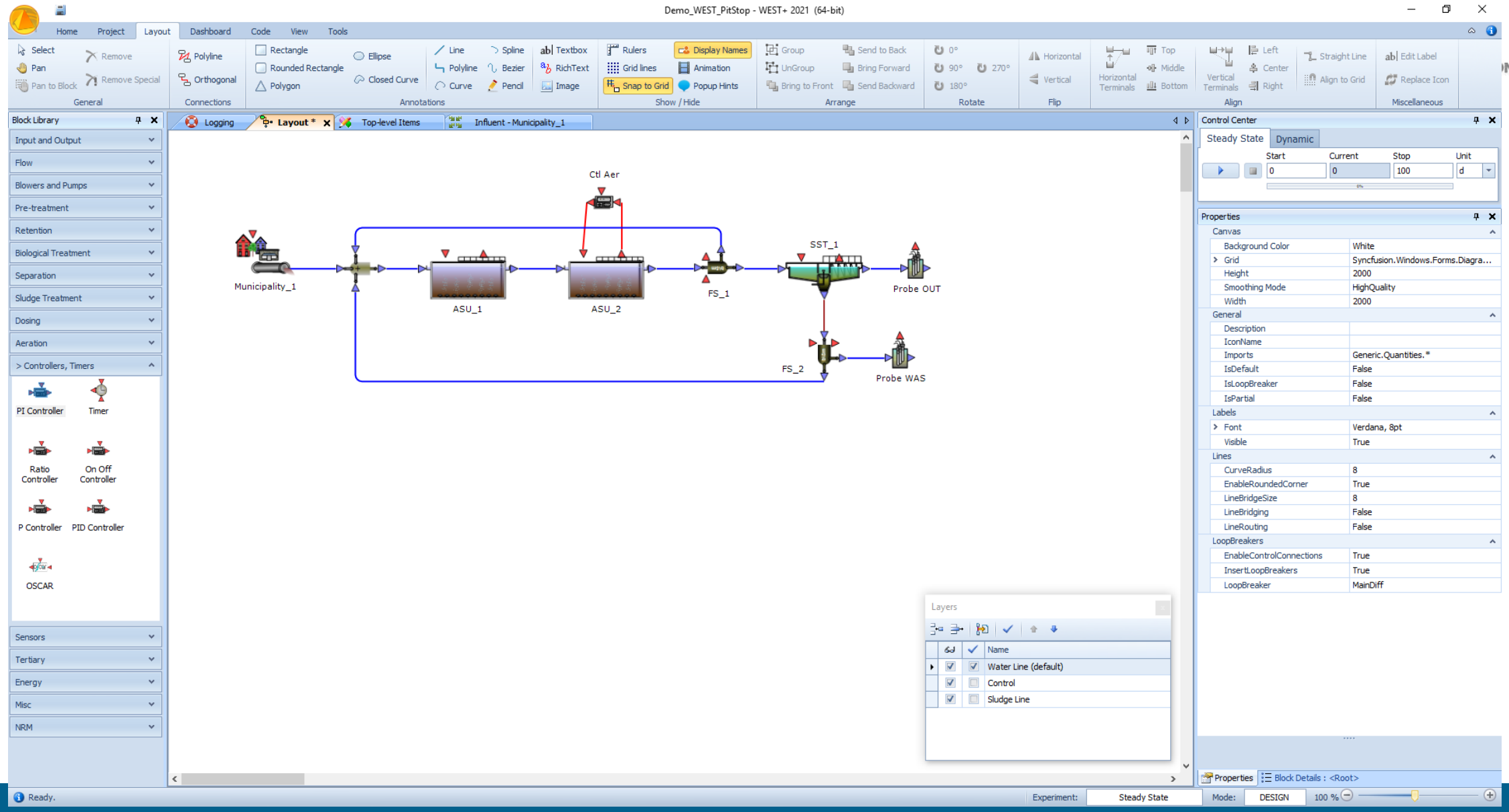


The Workflow in WEST



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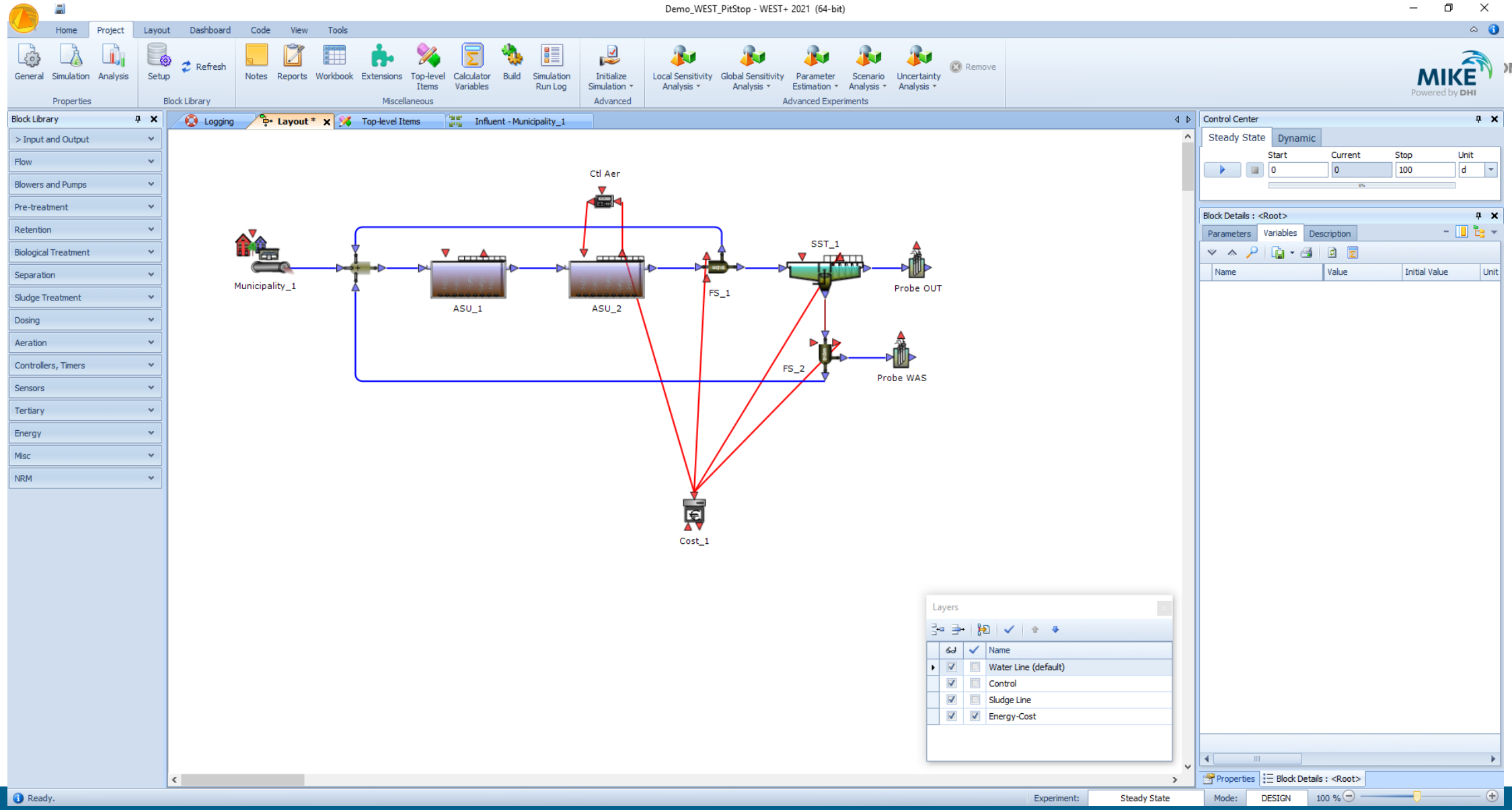

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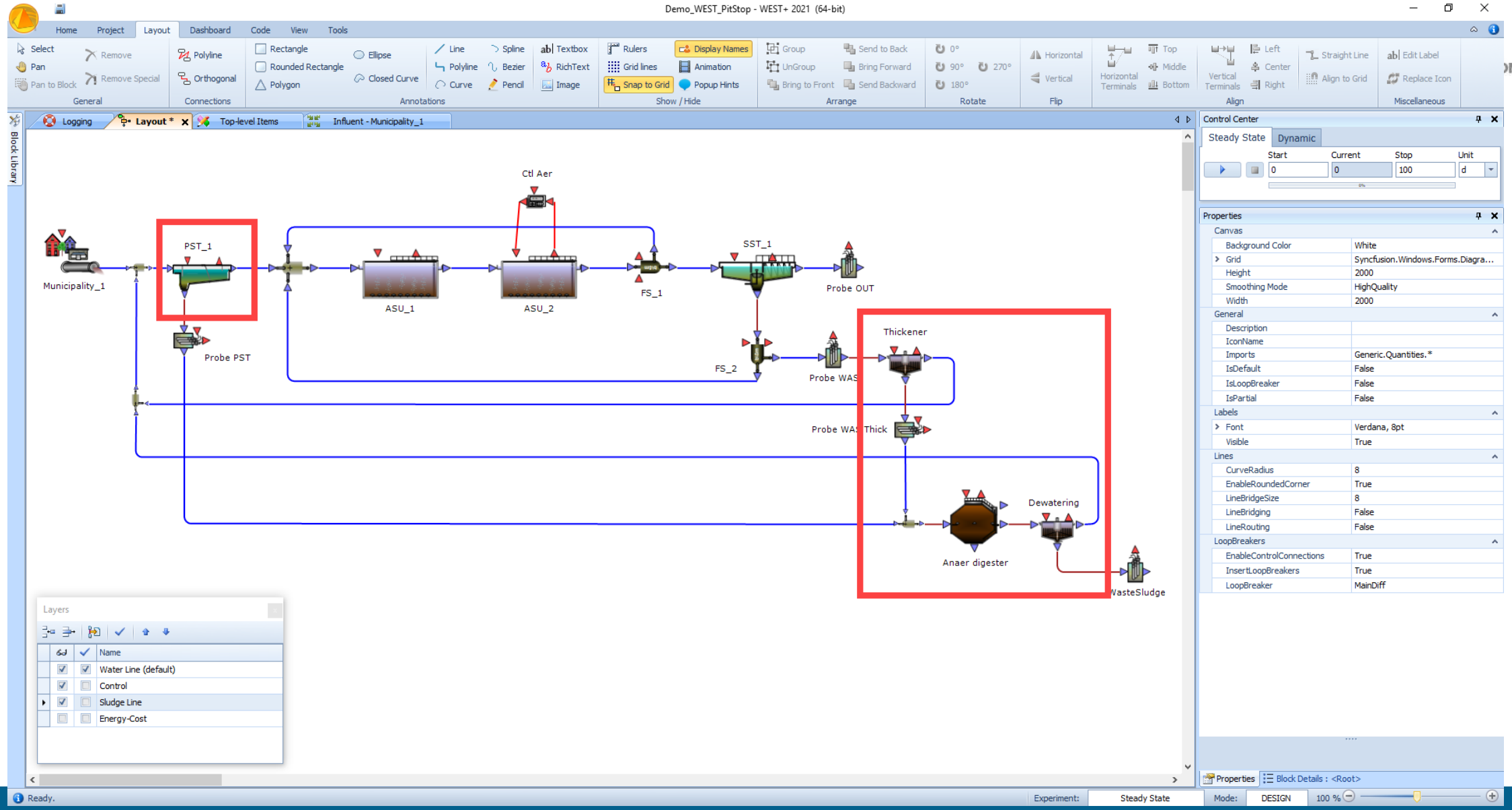

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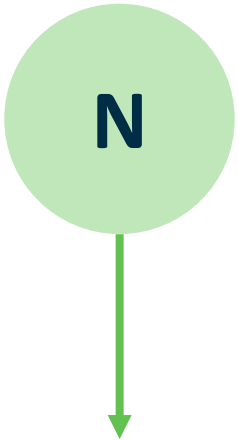
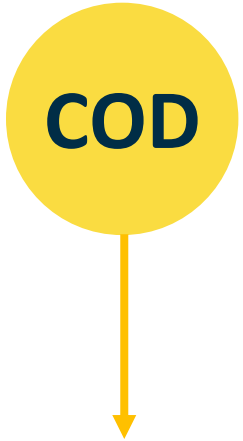
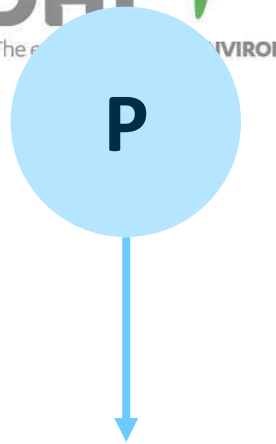






Organic N

S_{NH} = ammonium
S_{NO} = nitrate
S_{N2} = nitrogen gas

i_N

S_A = volatile fatty acids
S_F = fermentable (sugars, ...)
X_S = slowly degradable

S_I, X_I = not degradable

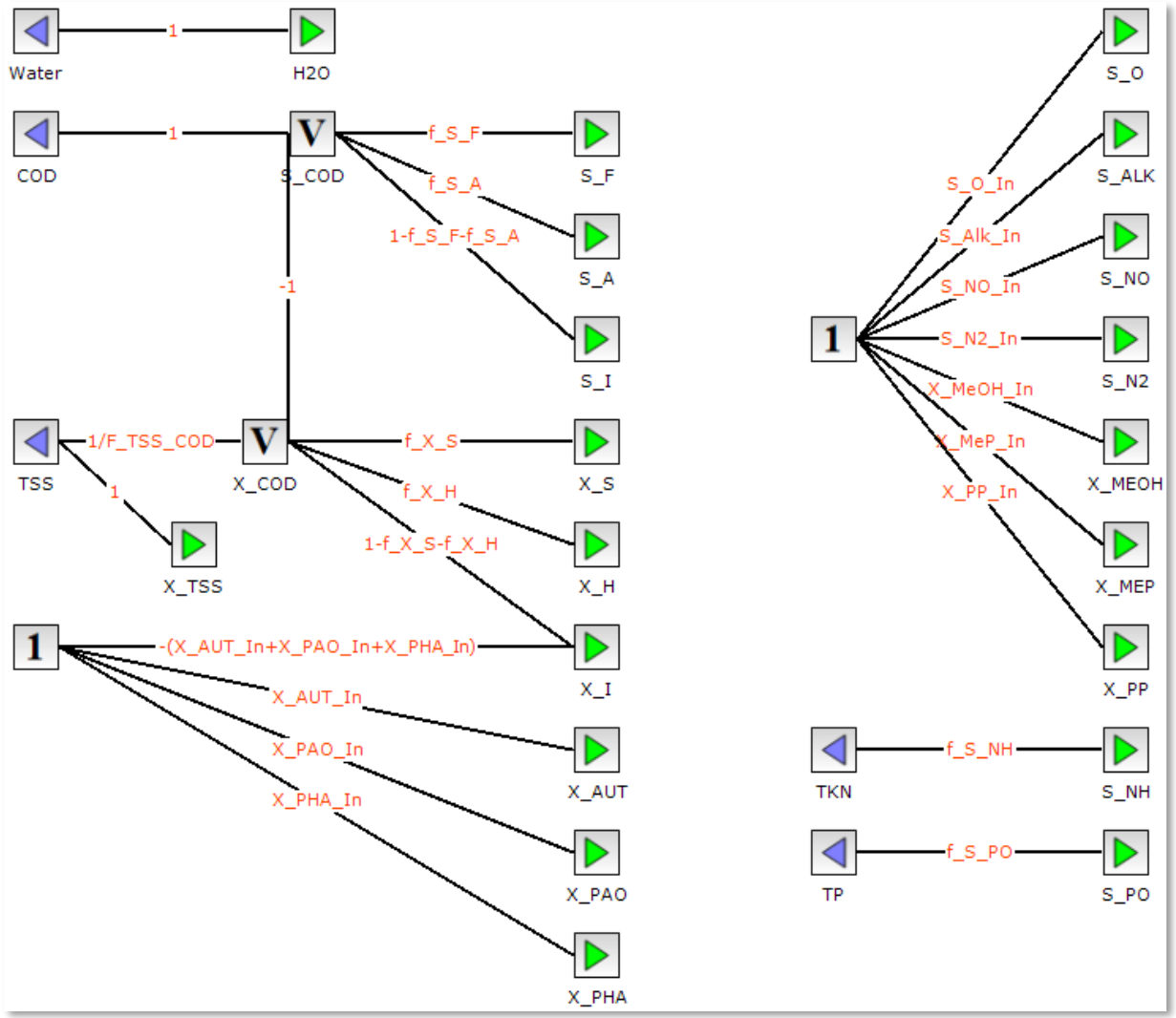
i_P

Organic P

S_{PO} = phosphate
X_{PP} = poly-phosphate
X_{MeP} = precipitates

X_H, X_{AUT}, X_{PAO} = micro-organisms

Influent Fractionation



f_S_F	0.375
f_S_A	0.25
f_X_S	0.69
f_X_H	0.17
f_S_NH	0.6
f_S_PO	0.6
F_TSS_COD	0.75

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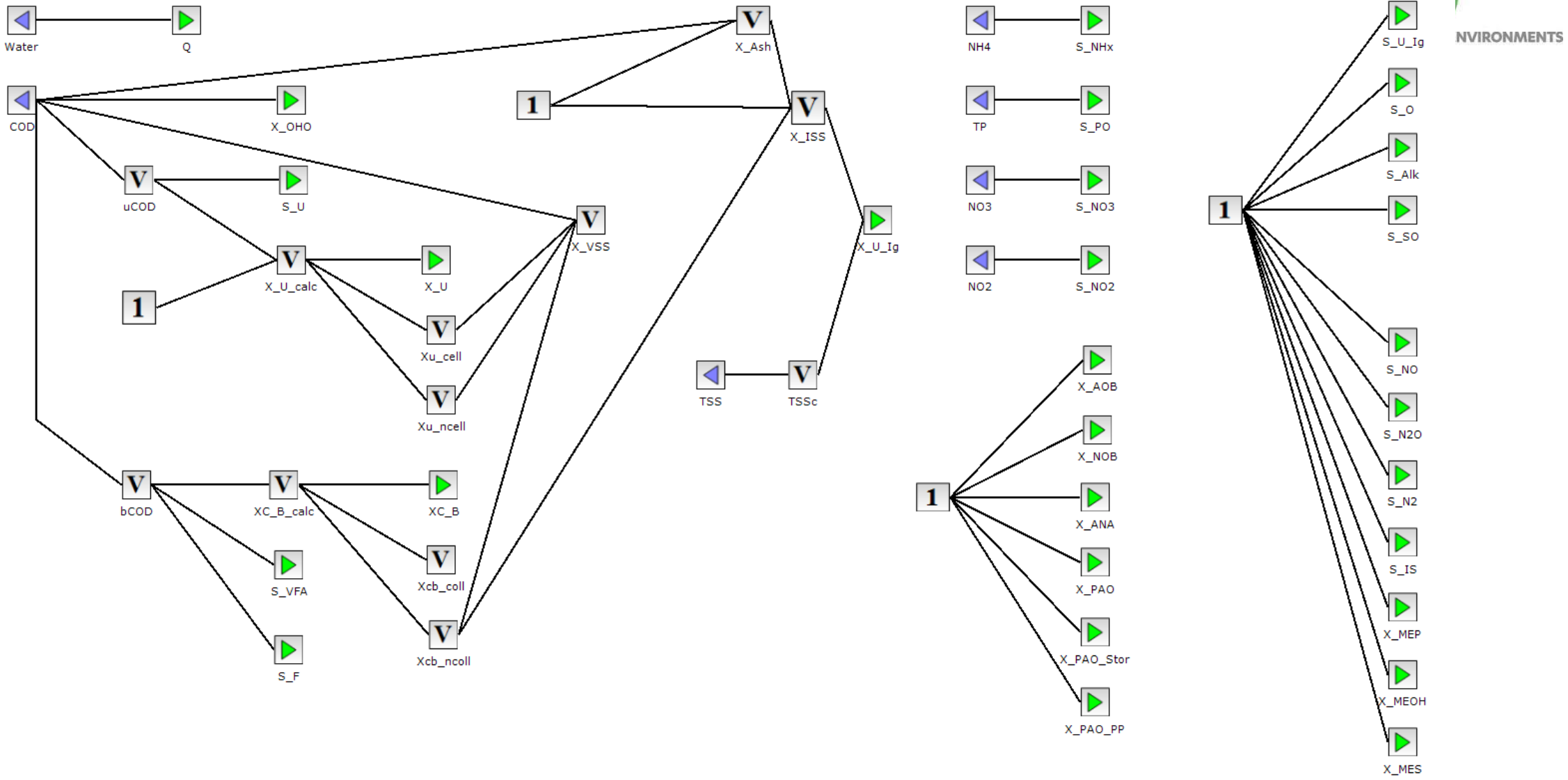
Influent Fractionation

MasterClass
patrocinada por:
NVIRONMENTS



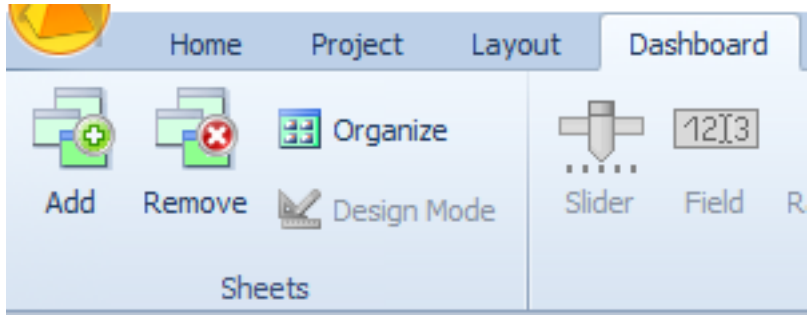
Process Parameters

Blocco	Blocco	From	To
Ctl kLa	Aerata	DO	y_M
		u	kLa
Eta del fango	Anossica	V_ASU	V_01
		TSS	TSS_01
	Aerata	V_ASU	V_01
		TSS	TSS_01
	S-Effluente	y_Q	Q_Out
		y_TSS	TSS_Out
	S-Fango Supero	y_Q	Q_Waste1
		y_TSS	TSS_Waste1
Cost_1	Aerata	AerationPower	AerationPower1
	R-ML	PumpingPower	PumpingPower1
	Sed Secondario	PumpingPower	PumpingPower2

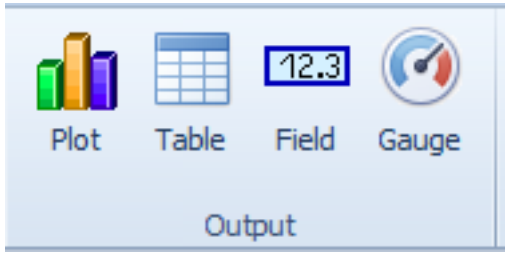
Influente	f_S_A = 0.25 f_S_F = 0.375 F_TSS_COD = 0.75
Anossica	Temp = 20 ºC kLa = 1 1/d Vol = 5,000 m3
Aerato	Temp = 20 ºC kLa = controllata Vol = 10,000 m3
Controllore PI	y_S = 2 (g/m3)
Ricircolo ML	Q_Out2 = 77,000 m3/d
Ricircolo RAS	Q_Under = 22,000 m3/d
Fango di supero	Q_Out2 = 385 m3/d

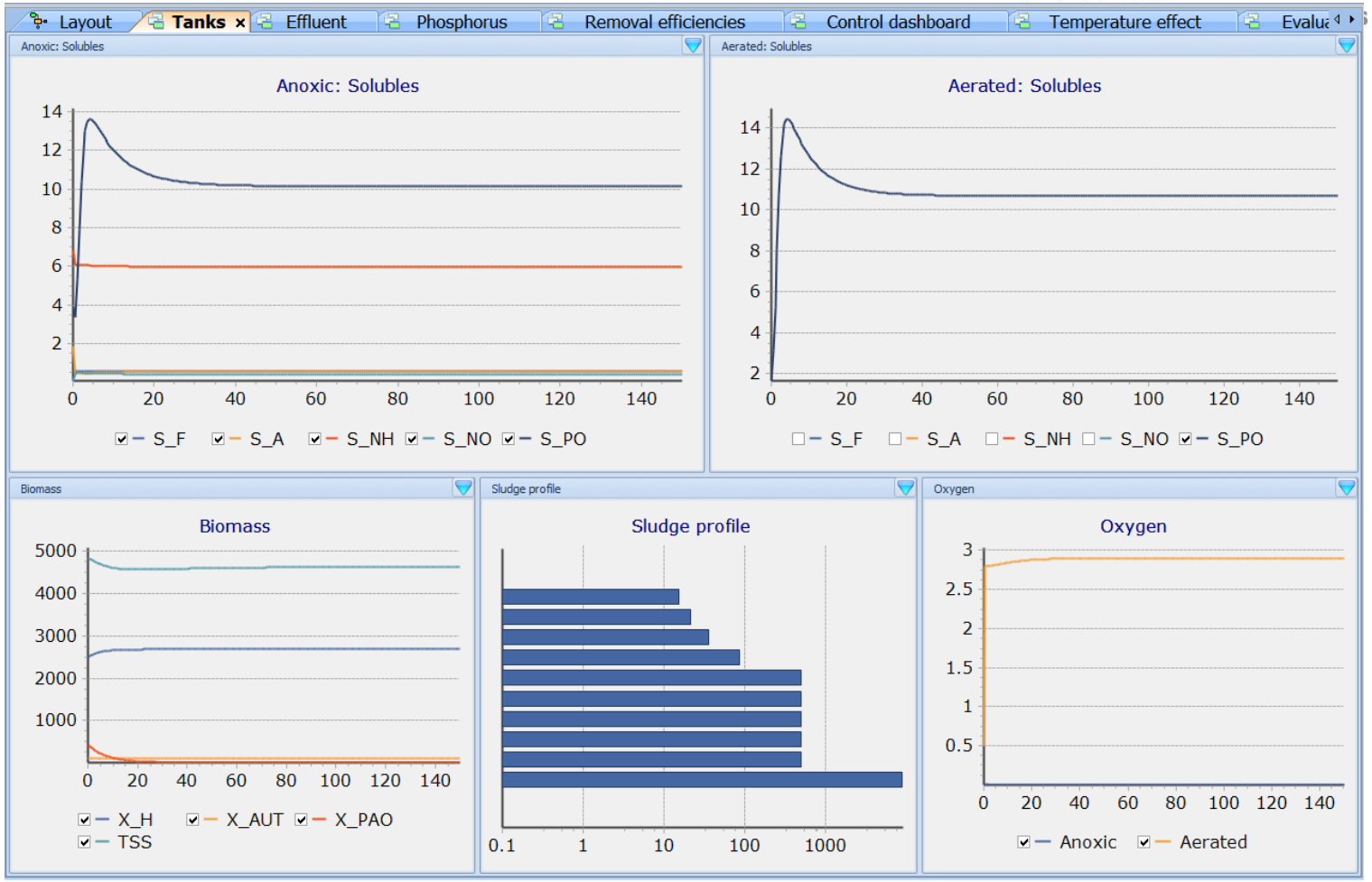
Dashboards for plots, tables, ..

1. Add a Sheet

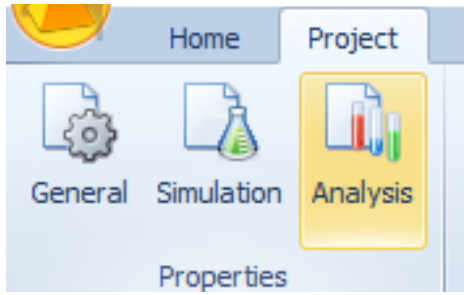


2. Add plot, table, field, ..

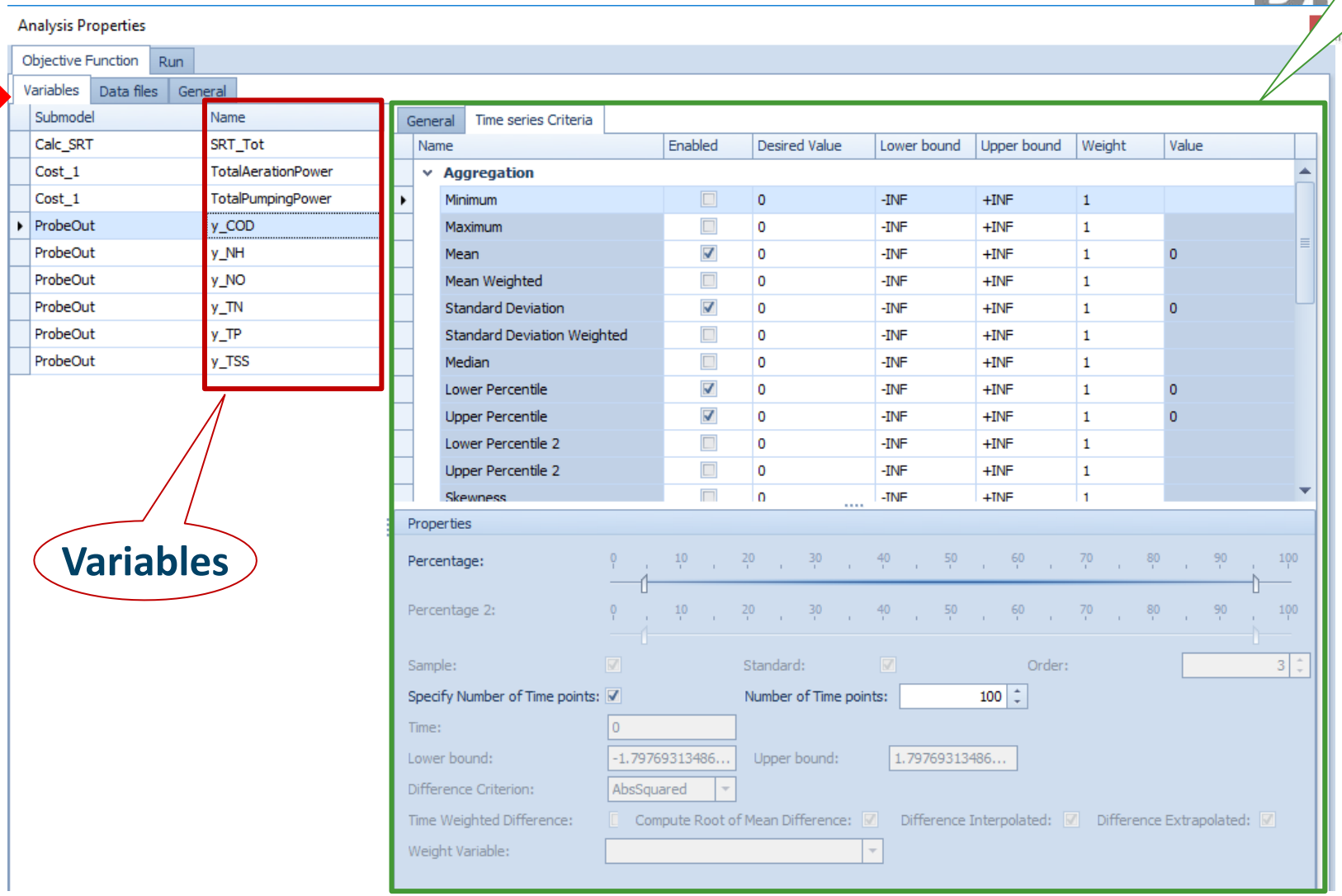




Stats and Objective Functions



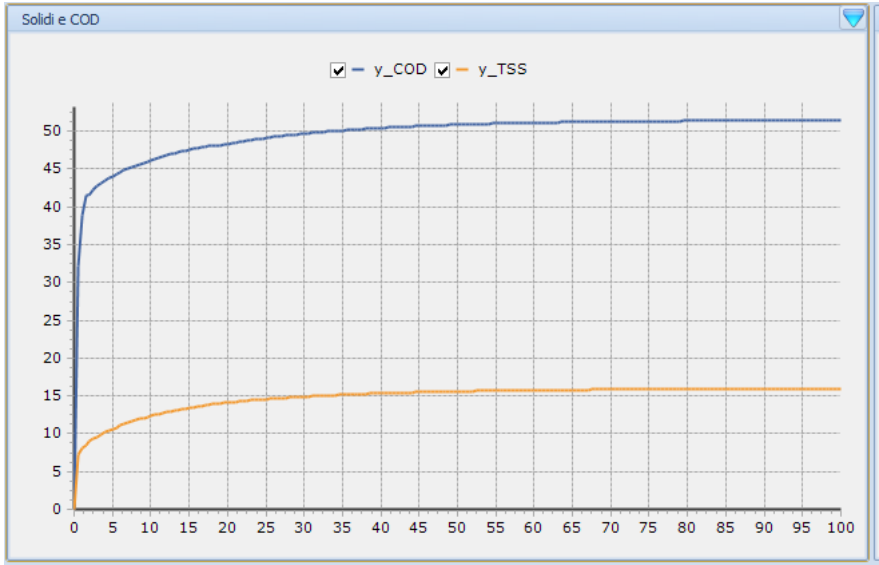
*** independent for steady-state and dynamic simulations

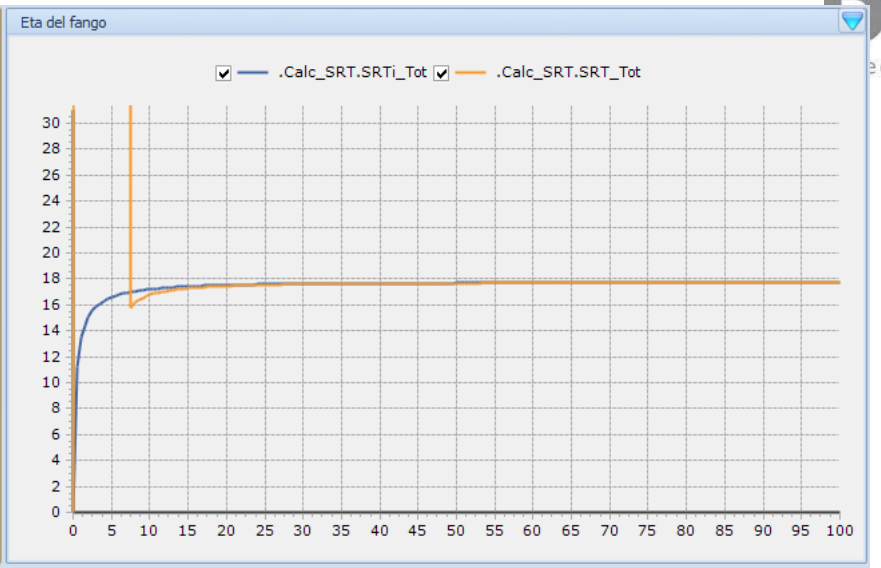


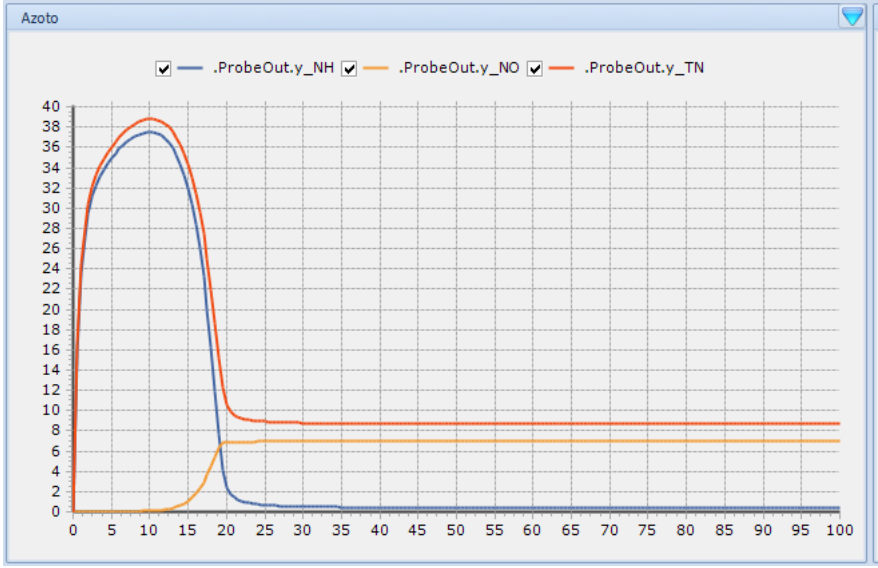
Criteria

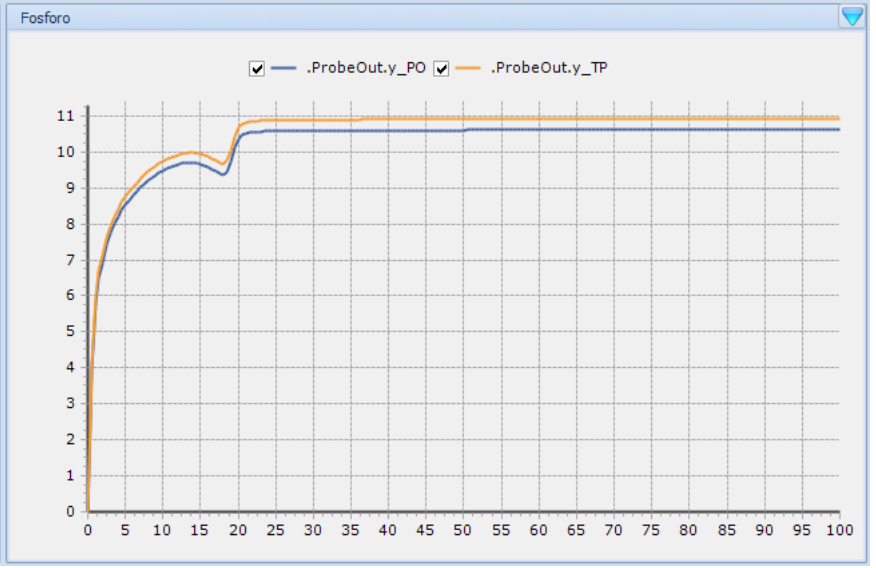
Statistics
Sub-objectives

Steady-state Simulation



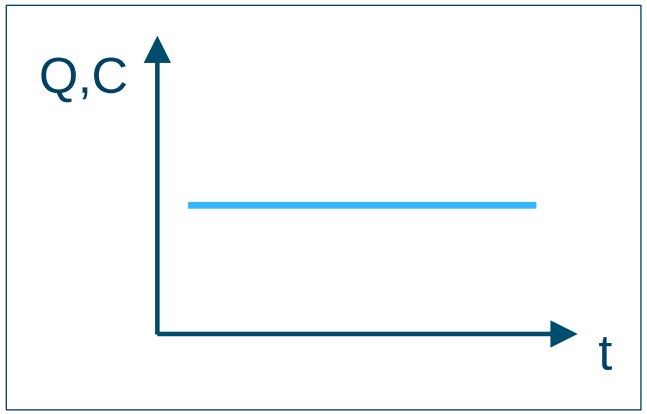






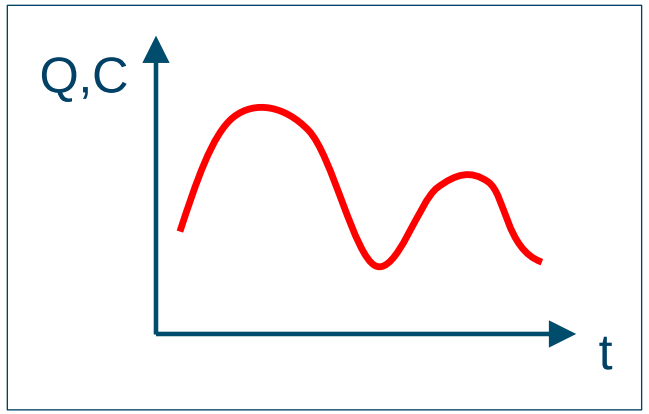
Steady-state → Dynamic

- Steady-state simulation
  - » Initial conditions for the system
  - » Baseline calibration



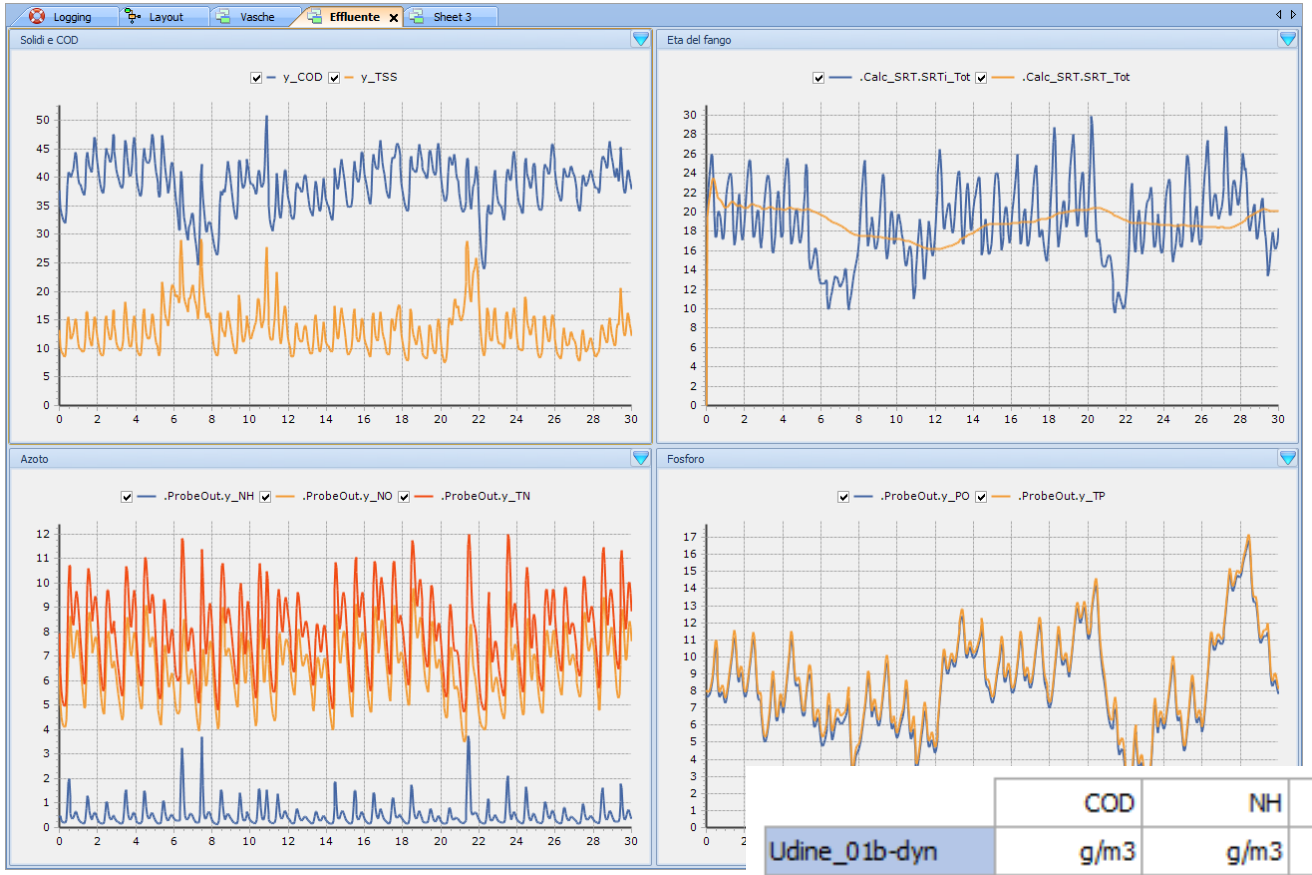
» Costant conditions (flow rate, concentrations) / long-term

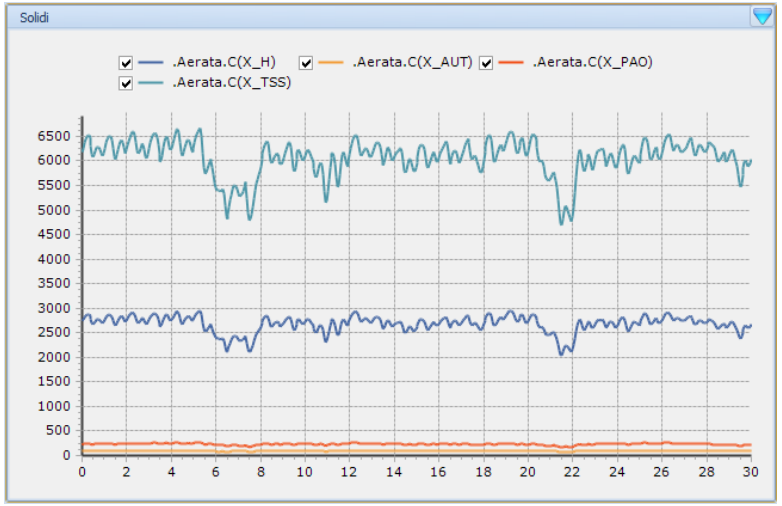
- Dynamic simulation



» Dynamic conditions (flow rate, concentrations) / relevant time window

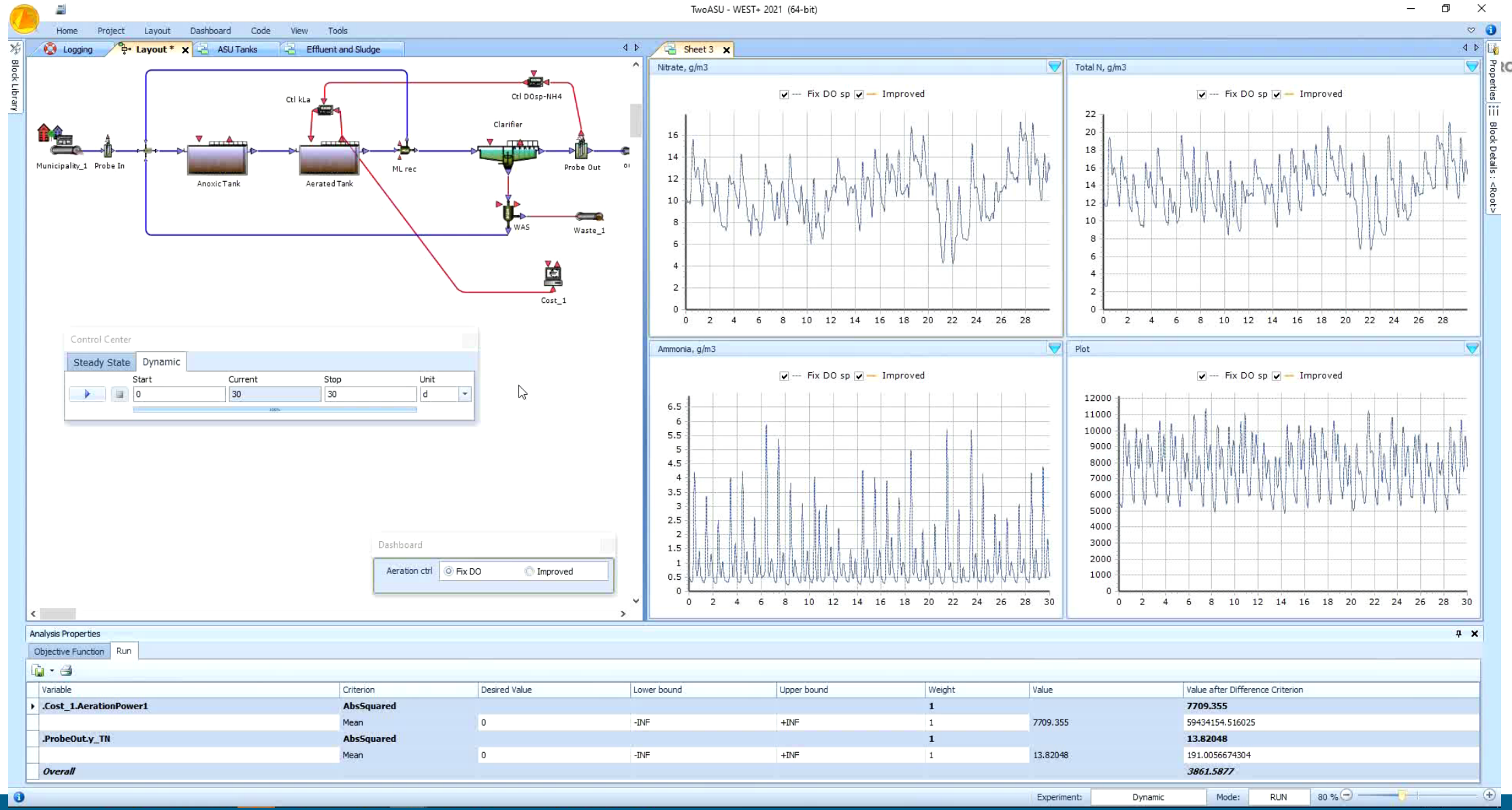
Dynamic Simulation



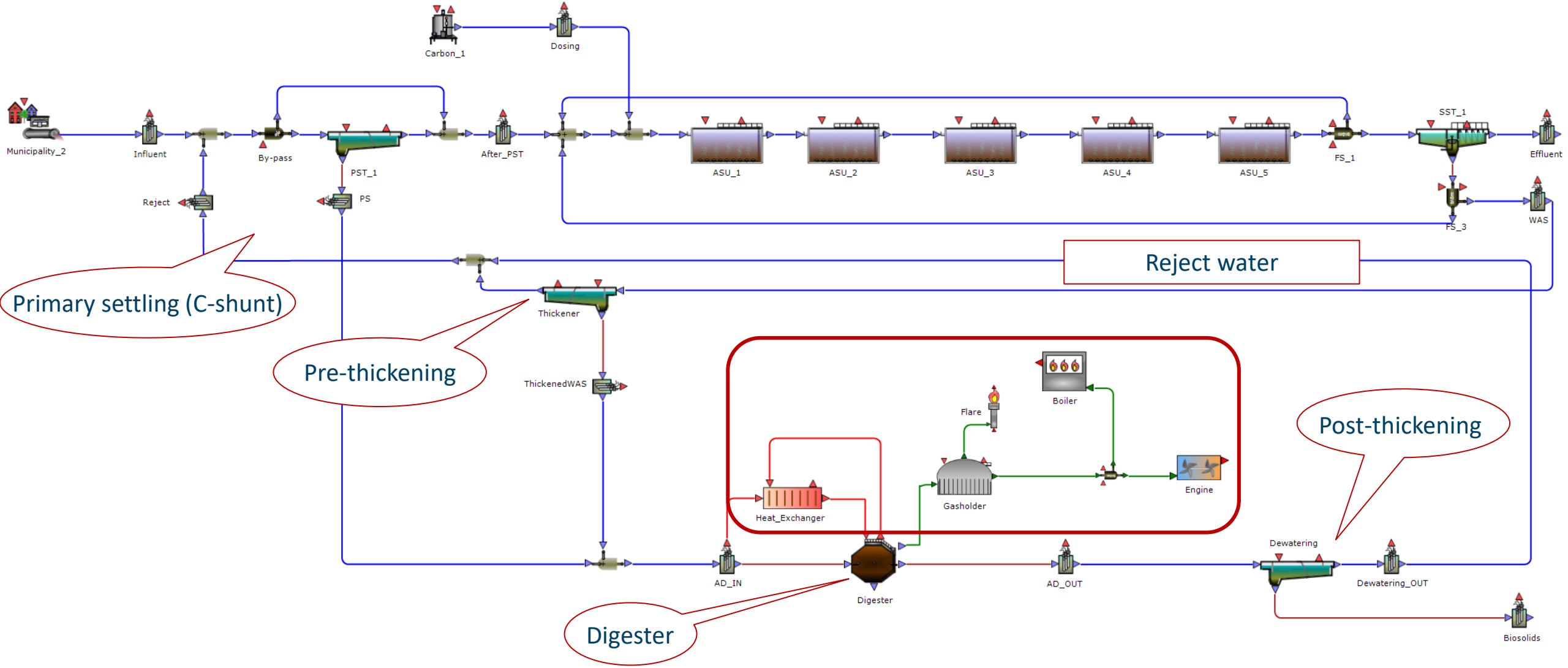


	COD	NH	NO	TN	TP	TSS	Aerat	Pumping	
Udine_01b-dyn	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3	kWh/d	kWh/d	
Mean	38.79	0.53	6.57	8.02	8.64	13.40	6962	3960	10922
Standard Deviation	4.32	0.47	1.30	1.62	2.82	3.83			
Lower Percentile	30.95	0.17	4.17	5.14	4.76	8.71			
Upper Percentile	44.70	1.54	8.69	10.69	13.63	20.48			

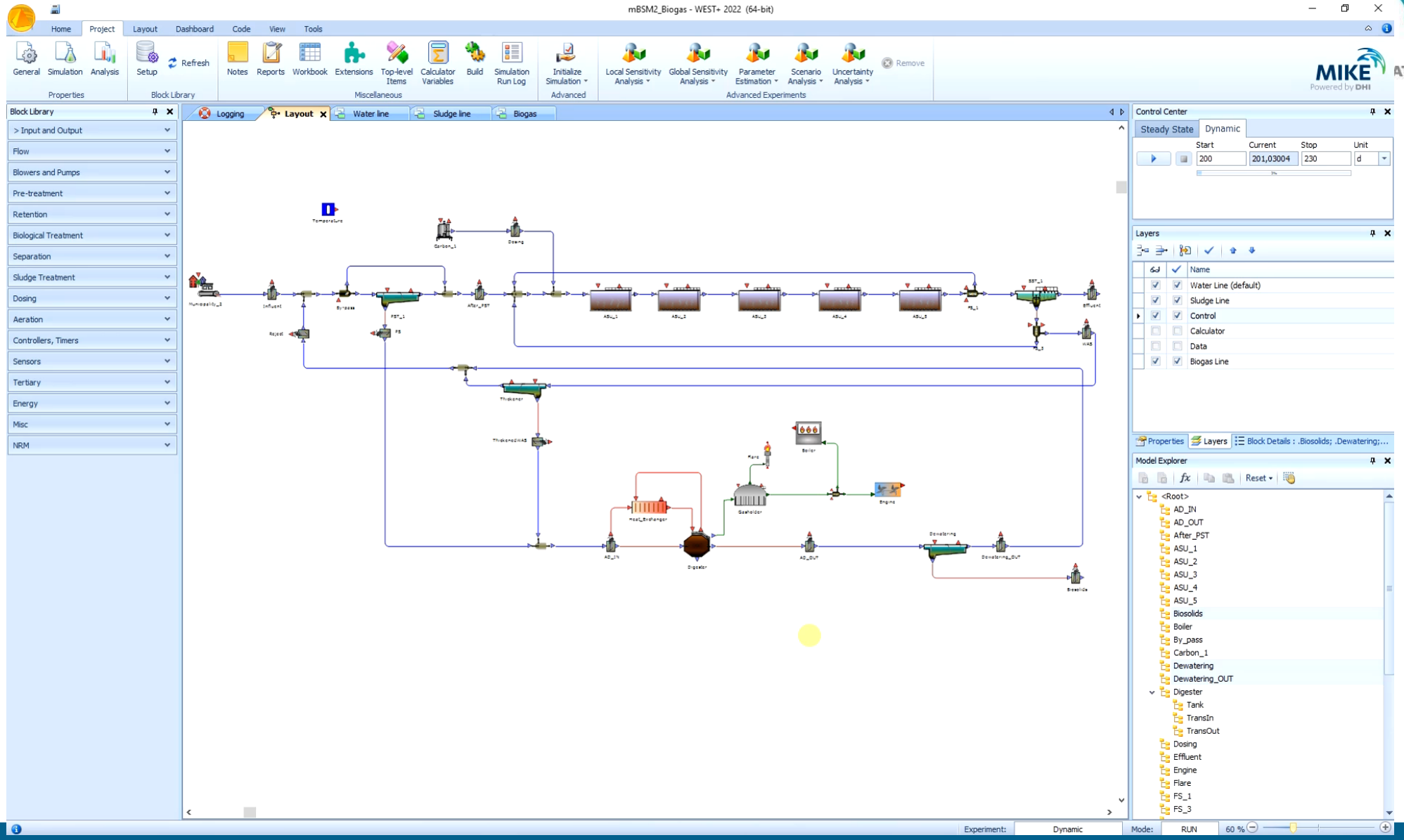
Control & Automation



Sludge line and biogas production



Energy Layer



Types of Experiments in WEST

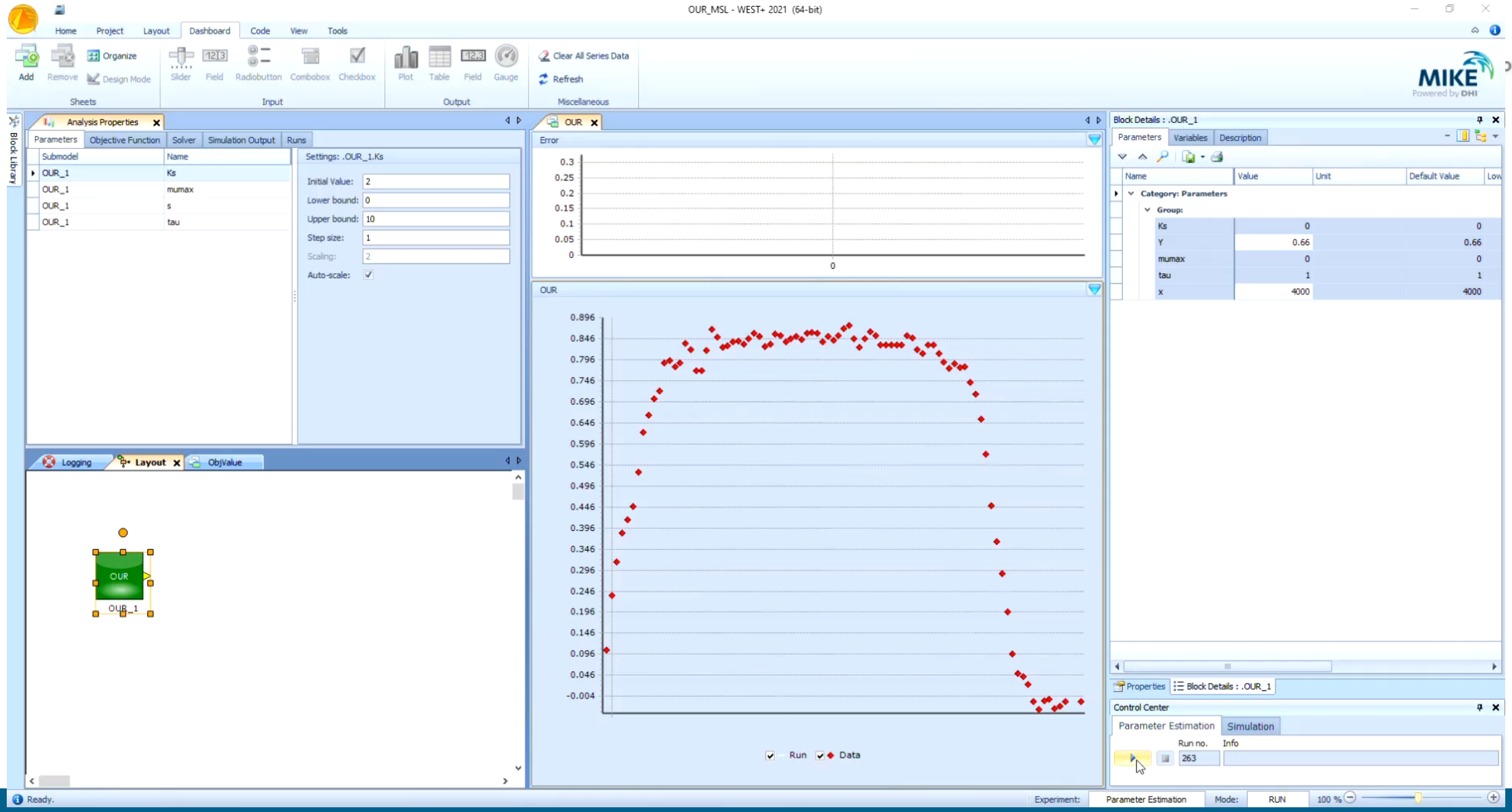
- Base Experiment = Objective Evaluation
  - Steady-state (SS) & Dynamic (DYN) simulations combined
  - Assessment of custom objective functions

- Advanced Experiments
  - To quantify the impact of change to a set of parameters, on a set of variables

Types of Experiments in WEST

Local Sensitivity Analysis	Sensitivity of a set of variables on a set of parameters Analytical method
Global Sensitivity Analysis	Sensitivity of a set of variables on a set of parameters Statistical method
Parameter Estimation	Minimise the objective function, by varying a set of parameters Goal: a) Compare measurements vs. model output » **Calibration** b) Combination of variables » **Optimization**
Scenario Analysis	Compare scenarios (variables) for different sets of parameters values
Uncertainty Analysis	Quantify how the uncertainty on the model parameters (input) propagates to the model variables (output)

Automatic Model Calibration

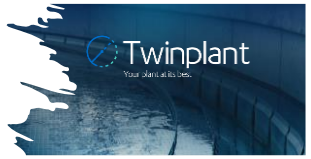


Outline

About DHI

Case studies

Offline Studies - WEST



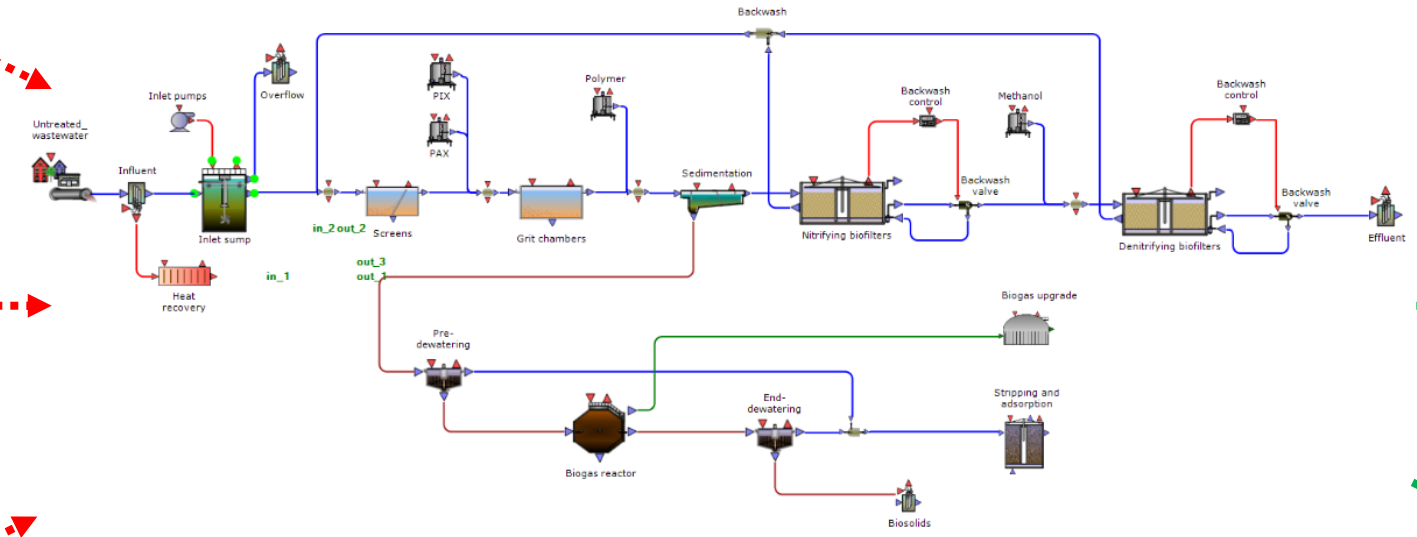
Online Solutions

From offline …

Laboratory measurements

Sensor data (historical)

Boundary conditions



Process model of a WWTP (WEST)

WWTP performance

Status in process units

Response to changing conditions

Input

Output

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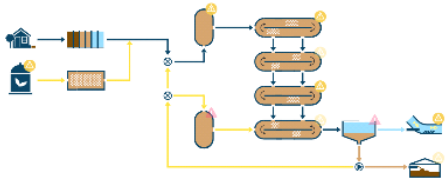
… to online



Graphical User Interface

Engineering *Operator* *Instructor*

7

5 6

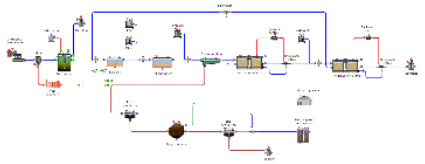
Automated scheduling
Data storage

4

Control system
(ABB 800 xA)

1

2 3



Data acquisition and pre-processing
DIMS-CORE

Process model
WEST

1. Online data acquisition from data historian
2. Transfer of pre-processed online data to data storage
3. Data input to process simulator and execution of simulations
4. Transfer of simulation output to data storage
5. Consultation of simulation results and online data through GUI, data export and report generation
6. Set up and execution of what-if scenarios, induced equipment faults
7. Implementation of tested operational alternatives (manual / automated)

The Digital Twin idea

- A Digital Twin is a digital replica of a physical entity, with its properties and characteristics that can be used for multiple goals (IWA, 2021):
  - The virtual entity (model) operates simultaneously with the physical entity (plant) » **Connectivity**
  - The interface between physical and virtual world is possible through continuous exchange of data » **Real time**
  - Service: from offline to **online (real-time & prediction)**

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(DigTwinOptim)

Fully automated plant | Bidirectional data connect. | ONLINE | Calibrated WEST model
(optional) data intelligence
Custom GUI
Data layer
Fully customised features
(eg alarms, report, ..)

DigDSS

Operation support (DSS) | Bidirectional data connect. | ONLINE | Calibrated WEST model
Custom (desktop/web) GUI
Data layer
History, Scenarios
(optional) Optimiser

PlantSimulator

Demonstration
Operator training | Long-term historical data
Detail controllers
(optional) data connection | OFFLINE | Calibrated WEST model
(optional) Custom GUI
(optional) DIMS data layer

Supervision

Troubleshooting
Upgrade | Plant visit
Design (steady state) data
Historical data
Controllers | OFFLINE | Mass balance
Report / suggestions
Baseline process model
Scenarios

Name
Drivers
Inputs
Outputs
Type

Conclusions

- When are process models used?
  - Different stages: project / upgrade / optimization / management
  - Offline vs. Online
- Worflow in WEST
  - Graphical setup of a process layout
  - Layout fractionation
  - Execution of the simulation: steady-state, dynamic and “advanced” experiments
- Model-based Solutions

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patrocinada por:

DHI
The expert in WATER ENVIRONMENTS

Muchas gracias por su atención.

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