UNIVERSITEIT GENT

BIOMATH
Department of Applied Mathematics, Biometrics and Process Control

MODEL CALIBRATION PROTOCOL FOR ACTIVATED SLUDGE MODELLING

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Outline

- Introduction
- The BIOMATH calibration protocol (4 stages)
  - Target definition of modelling exercise
  - Plant survey/data analysis and process characterisation
  - Steady state calibration
  - Dynamic calibration and evaluation
- Case study
- Conclusions

Introduction

- WWTP's are complex systems
- Complex models can help in:
  - Understanding the processes
  - Plant design
  - Plant optimisation
  - Plant control
- In practice
  - Which model to choose?
  - How to calibrate the model?

➡ need for calibration protocol

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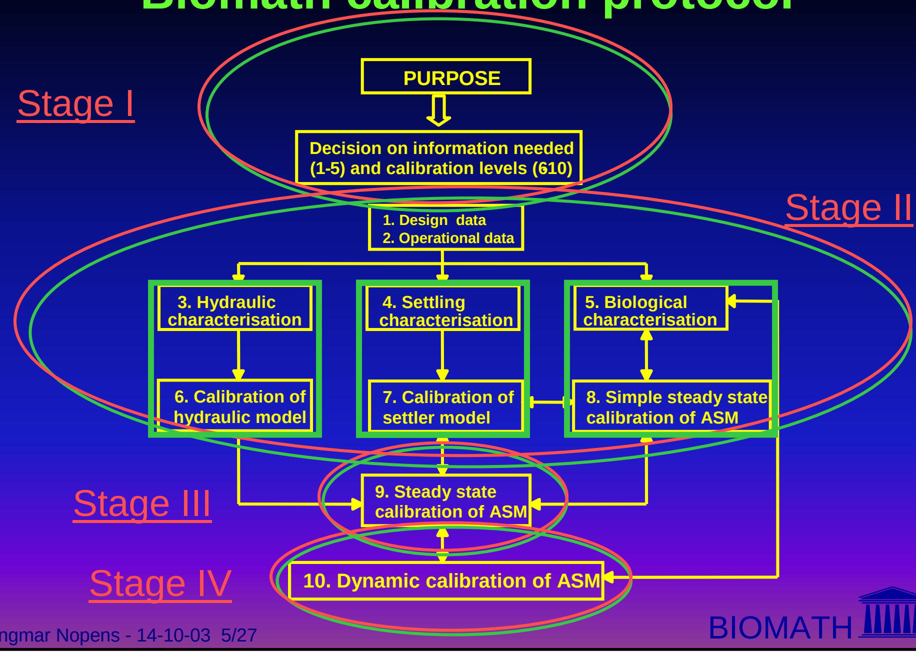
Biomath calibration protocol



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Biomath calibration protocol
Stage I – Target definition

- Usually based on available time/budget
- Possible targets
  - Optimisation/upgrade of existing plant
  - Cost reduction of operation
  - Development of control strategies
  - Combination of several targets
- Target determines
  - Information needed in Stage II
  - Calibration level (Stage III & IV)

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Biomath calibration protocol
Stage II – Plant survey/data analysis

- Design data
  - Plant layout/configuration, volumes, pumps, aerators,...
- Operational data
  - Flow rates, sludge recycle/waste, control strategies,...
- Measured data
  - Influent/effluent characterisation (COD,TKN,PO_4,NO_3,...)
  - On-line measurements (DO,T,pH,...)
  - TSS (RAS and effluent), sludge age/production,...
- Mass balances
  - Flow rate, sludge (including N & P)
  - Important for data quality check (e.g. sludge age)

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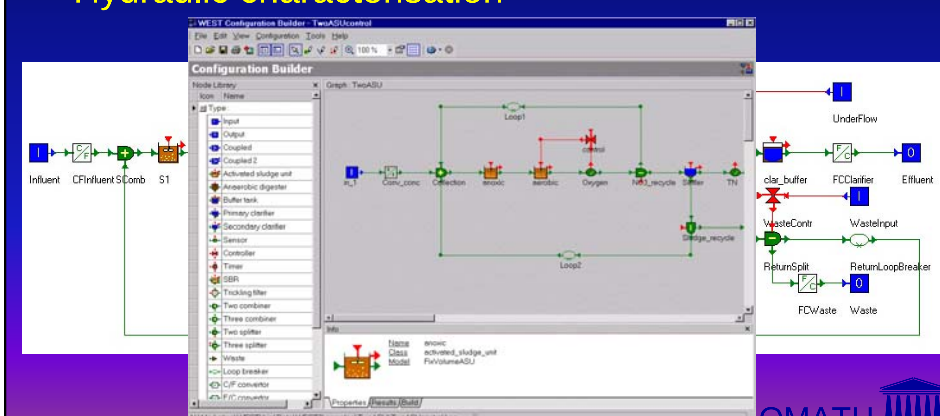
Biomath calibration protocol
Stage II – Mass transfer characterisation

- Oxygen transfer (K_La)
  - Variety of methods available in literature
- Hydraulic characterisation



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Biomath calibration protocol

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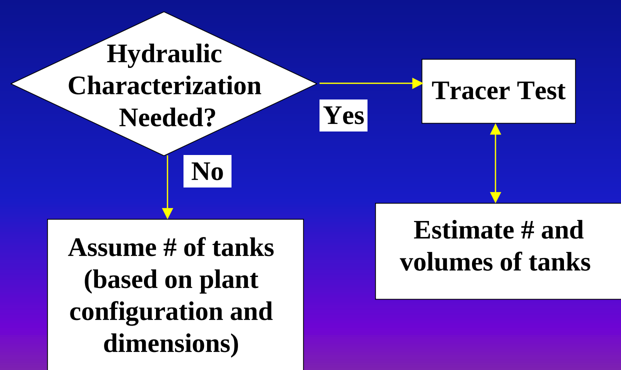


Determination of number of tanks

- Empirical equation (Chambers & Thomas, 1985)

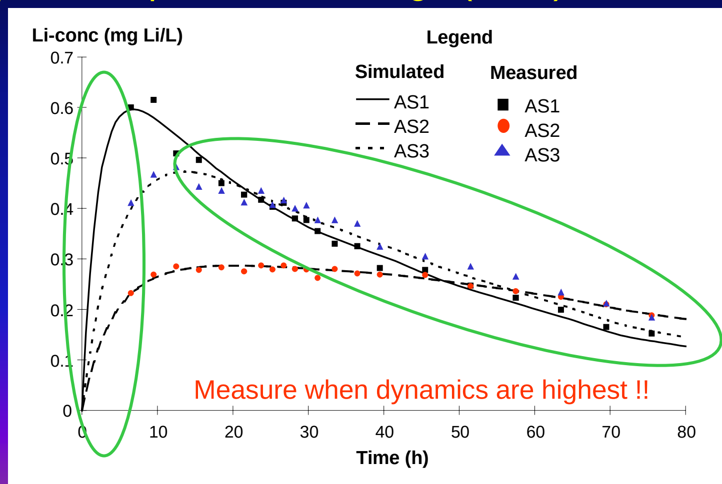
$$N = \frac{7.4}{W\,H} L\, Q_{in}(1+r)$$

where
L = length aeration tank (m)
W = width aeration tank (m)
H = depth aeration tank (m)
Q_{in} = average influent flow rate (m^3/s)
r = recycle ratio (-)

- Experimental evaluation : Inert tracer tests

Biomath calibration protocol
Stage II – Mass transfer characterisation

- Optimal Experimental Design (OED) & tracer test



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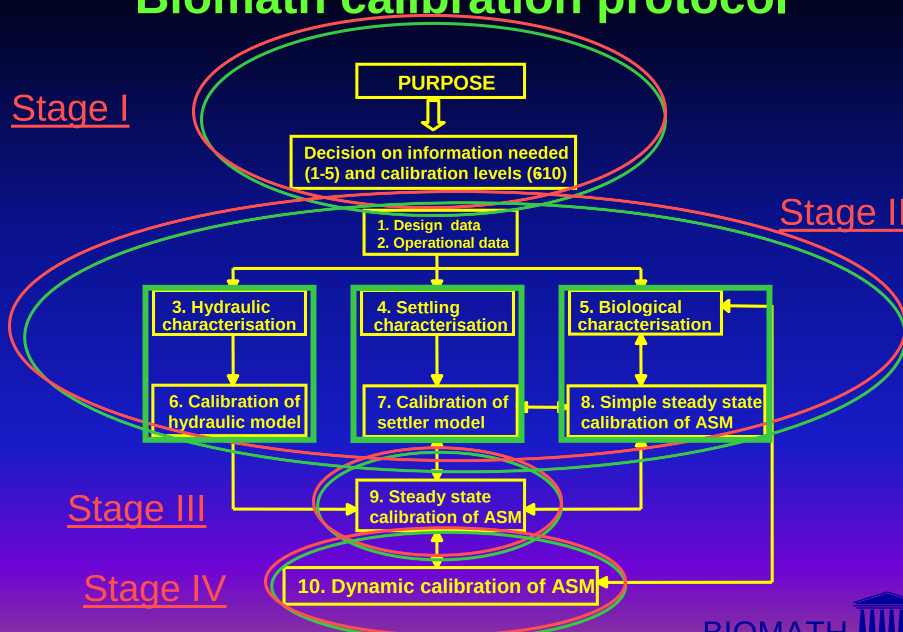
Biomath calibration protocol



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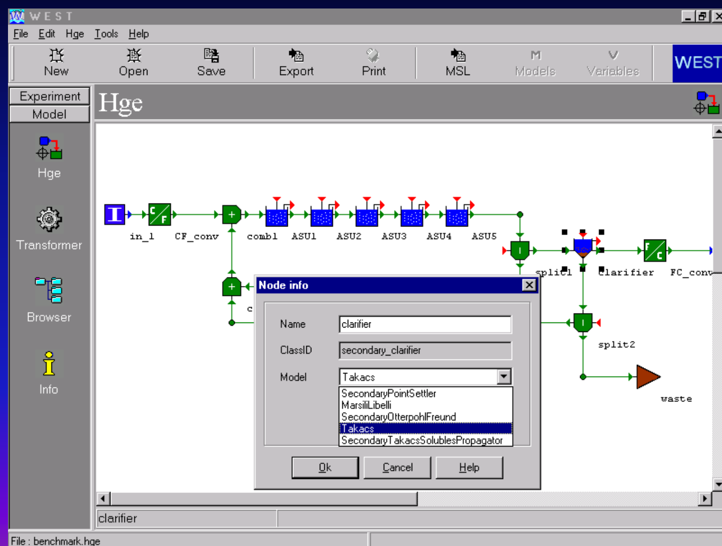
Biomath calibration protocol
Stage II – Settling characterisation



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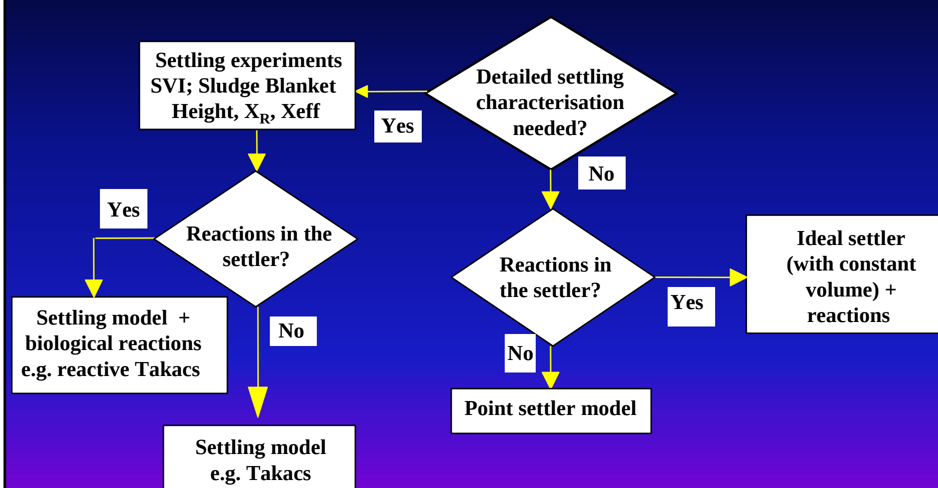
Biomath calibration protocol
Stage II – Settling characterisation



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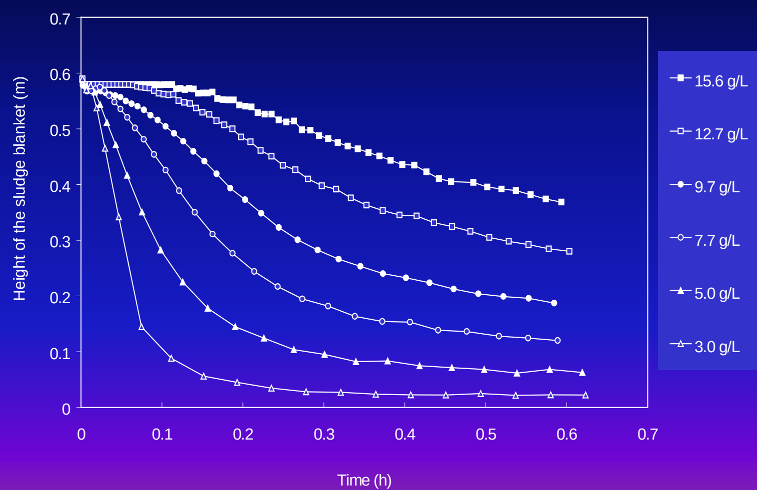
Biomath calibration protocol

Stage II – Settling characterisation

V_s decreases with increasing X



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Biomath calibration protocol

Stage II – Biological characterisation

- ASM family (1,2,2d,3) commonly applied
- Model selection
  - Biological processes (COD, N, P)
  - Target
  - Modifications/extensions
- Model parameters
  - Use defaults
  - Determine most sensitive parameters

→ Minimize calibration effort

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Stage II – Biological characterisation (2)

Calibration of biological processes in ASM

Influent wastewater characterisation

Estimates of kinetic/stoichiometric parameters

➡ COD, N & P fractionation

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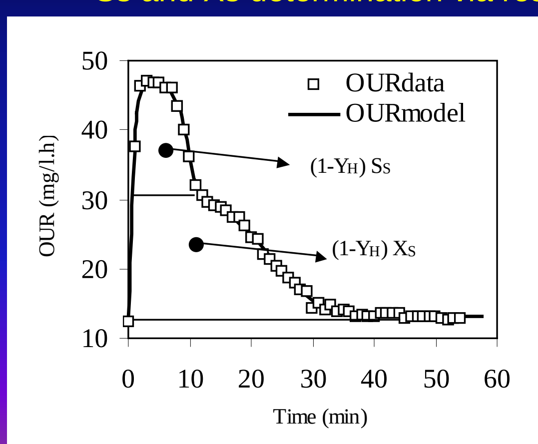
Biomath calibration protocol

Stage II – Biological characterisation (3)

- Influent wastewater characterisation
  - Ss and Xs determination via respirometry



$X_I = COD_{tot} – Ss – S_I - Xs$

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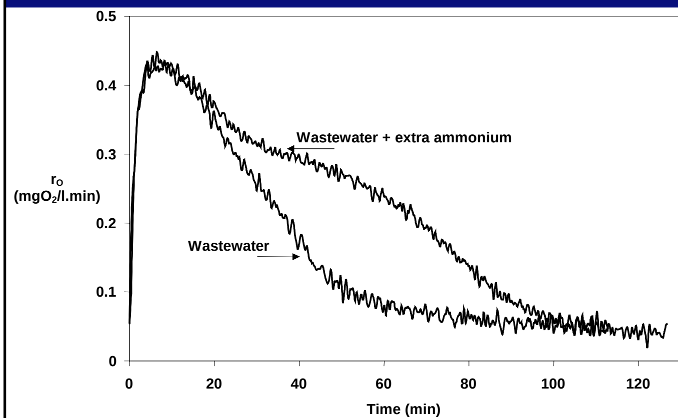
Biomath calibration protocol
Stage II – Biological characterisation (4)

- Parameter estimation of ASM
  - Estimates of kinetic/stoichiometric parameters



Identifiable parameters :

μ_H
K_S
μ_A
K_{NH}

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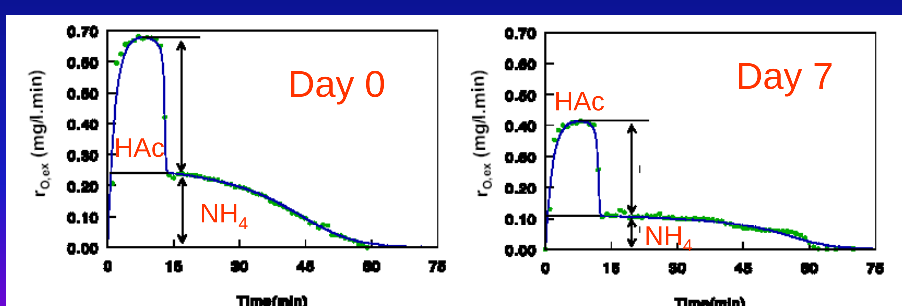
Biomath calibration protocol
Stage II – Biological characterisation (5)

- Parameter estimation of ASM
  - Estimates of kinetic/stoichiometric parameters
    Decay rates b_H, b_A



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Biomath calibration protocol
Stage III – Steady state calibration

- Averaged historical full-scale data = steady state
- Calibrate process models separately to fit
  - Average effluent data
  - Average sludge waste data
- Parameters to be calibrated are selected on basis of:
  - Expert knowledge / experience
  - Sensitivity analysis
- When unsatisfactory: back to stage I/ II

Biomath calibration protocol
Stage IV – Dynamic calibration

- Use dynamic influent profiles
- Biomass composition from steady state calibration
- Parameters to be calibrated
  - Expert knowledge / experience
  - Sensitivity analysis
- No automatic parameter calibration (too complex)
  - Based on experience
    (know which parameter to change when deviation occurs)
  - e.g. When effluent NH_4 too high, turn nitrifier growth rate
- When unsatisfactory: back to stage I/II/III

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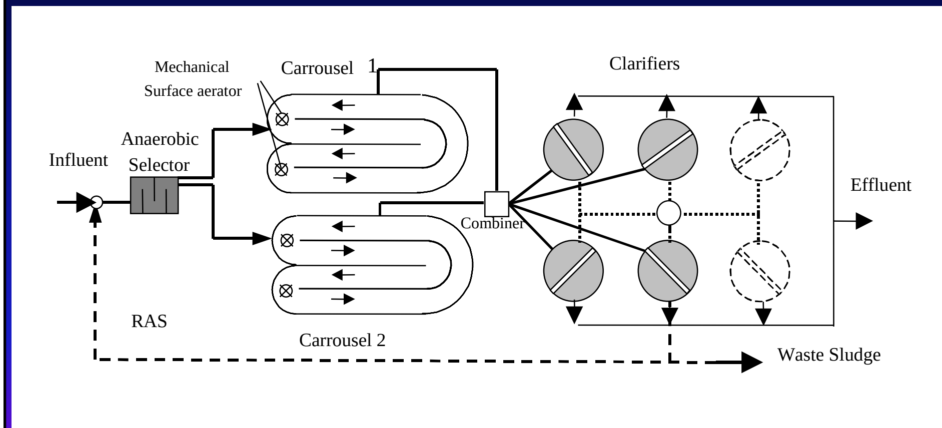
Case study - Stage I

- Target definition
  - Decrease effluent nutrient concentrations (N&P) of a carrousel type WWTP
- Information needed
  - Data of a previous measurement campaign available
  - No opportunity for additional measurements due to budget limitation
- Calibration level
  - No degrees of freedom left

Case study – Stage II

• Plant survey (1)

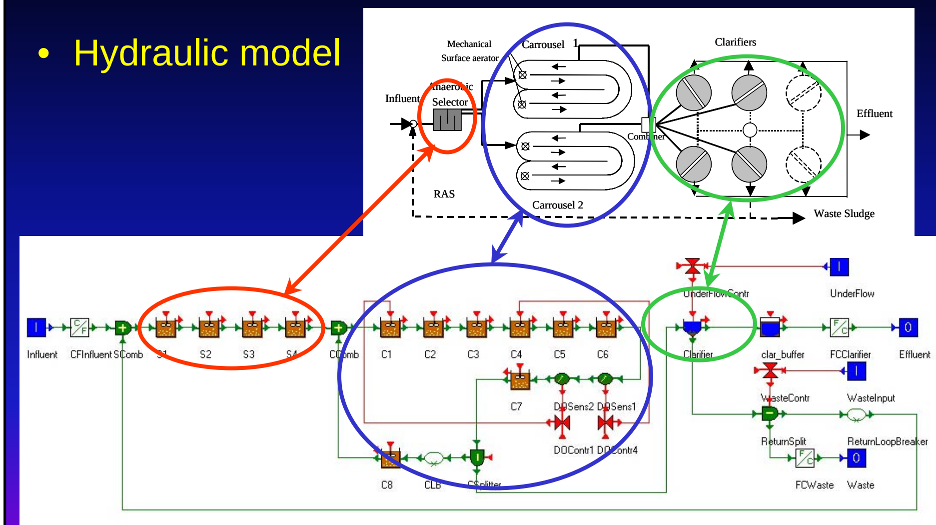


Case study – Stage II

- Plant survey (2)
  - 50.000 PE
  - Qin = 6.000 m^3/d (1.58MGD), Q_{RAS}= 8.434 m^3/d (2.2MGD)
  - HRT= 1.9 d
  - SRT= 20 d
  - DO control (day: 0.9-1.2 mg/L, night: intermittent aeration)
- Measurement campaign data
  - On-line: DO, NO_3
  - Effluent : PO_4, TSS
  - Influent : TSS + total/filtered (0.45μm)
    COD, VFA, BOD_5, TKN, NH_4-N, P
- Data quality check
- No additional characterisation steps (no money !)

Case study – Stage II

- Hydraulic model



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Case study – Stage III

- Steady State & Dynamic calibration

Parameter	Unit	ASM2d default	Calibrated
η_{fe}	-	0.4	0.8
η_{NO3hyd}	-	0.6	0.8
K_O	mgO_2/l	0.2	0.15
b_{PAO}, b_{PP}, b_{PHA}	day^{-1}	0.2	0.12
K_X	mgCOD/mgCOD	0.1	0.03
K_{OAUT}	mgO_2/l	0.5	0.2

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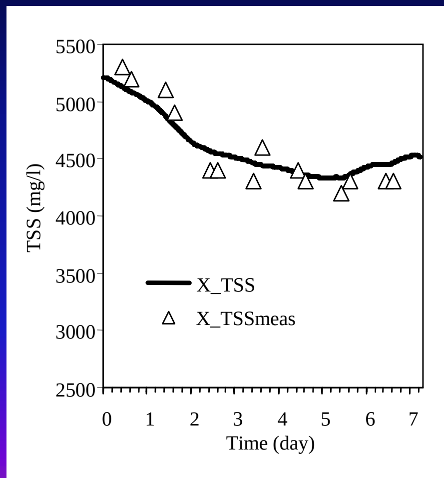
Case study – Stage IV

- Dynamic model calibration results - TSS



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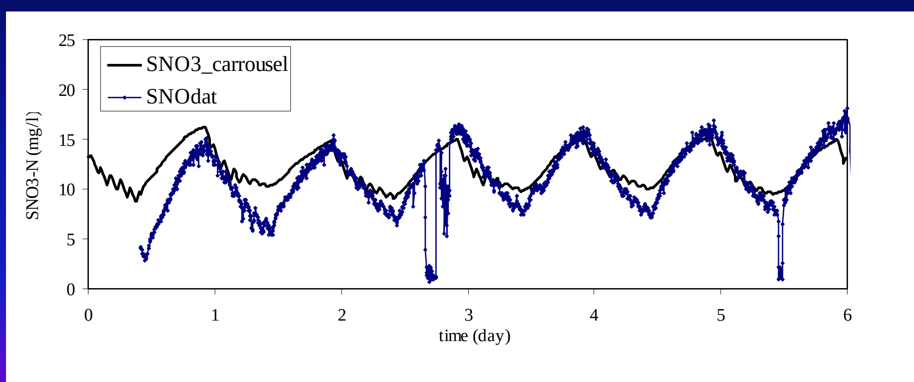
Case study – Stage IV

- Dynamic model calibration results - N



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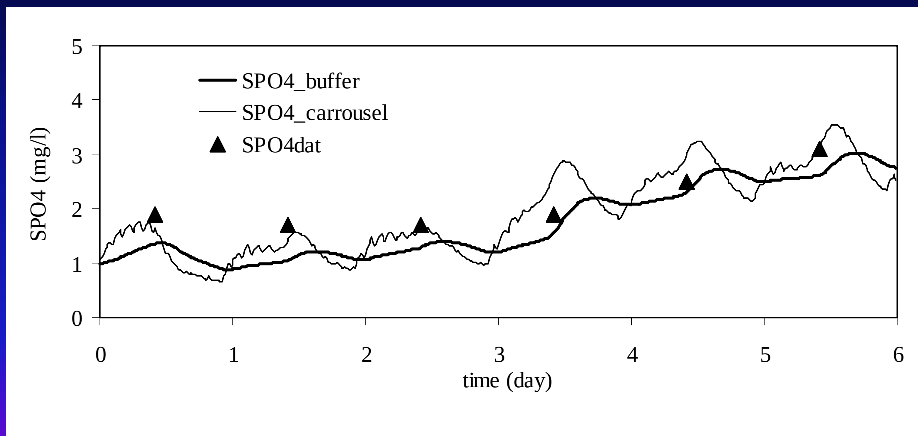
Case study – Stage IV

- Dynamic model calibration results - P



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Conclusions

- A practical, comprehensive calibration protocol was presented
- 4 stages
  - Target definition
  - Data collection/analysis and characterisation of hydraulics, settling and biological parameters
  - Steady state calibration
  - Dynamic calibration
- Influent characterisation based on respirometry
- Iterative approach
- “Design of experiments” is used where applicable
- Protocol successfully applied in case study