

The Advantages of having a Biological Wastewater Treatment Model from a Water Company Perspective

Darron Nutt and Sanjay Kumarasingham - Watercare Services

Mike McCoy – Better Technical Options Ltd

Matt Mates – AWT Ltd. New Zealand

ABSTRACT

A biological wastewater treatment model is considered essential for effective planning and operation of major wastewater treatment plant assets. Watercare Services Limited has recently developed a calibrated dynamic biological wastewater treatment plant model for its 300 ML/d Mangere Wastewater Treatment Plant. Watercare previously had a biological model, using BioWin[®] modelling software, limited to the biological nutrient removal part of the plant. This model was upgraded to include the whole plant, which included the liquids and solids treatment processes. Sludge thickening, sludge digestion, dewatering and all recycle streams were added to the model. Additional liquid stream processes added to the model included primary clarification and some flow bypasses.

This paper details:

1. The advantages to the Company of having a plant-wide model;
2. The considerations in the selection of a software package;
3. The methodology applied to building the model;
4. The methodology applied to calibrating the model;
5. Costs and financial benefits of developing the model;
6. Limitations to the model;
7. Several practical examples that have been applied;
8. Further modelling exercises that the Company is planning; and
9. Lessons learned.

KEYWORDS

Wastewater, Treatment, BioWin, Biological, Model

1 INTRODUCTION

Watercare (Watercare Services Limited) supplies bulk water and provides wastewater services to the Auckland region in New Zealand. Watercare owns and operates the Mangere WWTP (Wastewater Treatment Plant). Mangere WWTP is the largest wastewater treatment plant in New Zealand, serving a population of approximately 1 million p.e.. The plant is a modern treatment facility incorporating screening, primary settlement, step feed BNR (biological nutrient removal) incorporating eight stages of alternating anoxic/aerobic zones, secondary clarification, direct filtration and low pressure high-intensity UV disinfection on the liquids treatment stream. In the solids stream, sludge conditioning consists of primary sludge gravity thickening, dissolved air flotation, blended sludge gravity belt thickening, single-stage high rate mesophilic digestion, high-G centrifuge dewatering and lime stabilisation. Ancillary processes include odour control, biogas recovery and energy generation, chemical dosing (ferric chloride, polymer, sodium hypochlorite and chlorine gas), effluent reuse, internal plant air and plant water systems and internal recycles.

The plant was upgraded from pond treatment with the Project Manukau upgrade. This upgrade was completed in 2004. Several improvements have been incorporated since the upgrade, e.g. dissolved oxygen control to the BNRs.

In order to predict and demonstrate the future capacity of the BNR plant, the contractor for Project Manukau, using BioWin[®] modelling software supplied by EnviroSim Associates Ltd, created a model of the BNR system. Model outputs were based on future predicted flows and loads. The contractor was able to re-rate the plant capacity using the model to demonstrate that future contractual flows and loads were able to be treated by the BNR plant.

Watercare recently commissioned BTO Ltd (Better Technical Options Ltd) to upgrade the existing BNR model to include the entire treatment plant. The additional solids stream treatment processes added to the model included sludge thickening, sludge digestion, dewatering and all recycle streams. The additional liquid stream processes added to the model included primary clarification and some flow bypasses. The model upgrade has recently been completed and Watercare is now actively using the model.

2 THE ADVANTAGES TO THE COMPANY OF HAVING A PLANT-WIDE MODEL

2.1 MODEL USES AND BENEFITS

A wastewater treatment plant biological model can be a useful tool for a variety of tasks, including planning, design, operations, plant optimisation, cost saving and recovery, training, trade waste control and risk management. Models can be built on individual process units, but where a model becomes the most useful is when the entire plant is input and the effects of all process streams are analysed. The following section details some of the advantages to Watercare of having the wastewater model.

2.1.1 PLANNING

Watercare is able to use its model to analysis the treatment plant for future anticipated influent and effluent requirements. Effluent quality standards specified in the resource consent have been derived on mass loading to the receiving environment but are expressed as concentrations. As flow to the plant increases over time, the eventual concentration of pollutants in the effluent will have to reduce to maintain the same or improved mass loading to the environment. It is likely, that to improve effluent quality with increasing flow and changing influent quality, either new technology will have to be employed and/or internal recycles will have to be treated. The model has been able to assess various future upgrade options and assist with the formulation of the Asset Management Plan. Both capex and opex can be estimated more accurately by analysing the model outputs.

2.1.2 DESIGN

It is standard practice to use a calibrated wastewater model to design wastewater treatment plants. The Mangere Wastewater Treatment Plant was no exception.

A contractual condition of the Project Manukau upgrade was for the contractor to demonstrate that the plant could treat anticipated future influent. The methodology of proving the plant's BNR future capacity was to build a calibrated dynamic model of the BNRs and simulate using contractual future peak loadings. This was sufficient for the contractor to demonstrate the capacity of the plant.

2.1.3 OPERATIONS

A complete plant model can be used as an ongoing operational tool to evaluate changes in plant performance and to evaluate the effect of process changes without risking plant non-compliance. This is particularly useful when taking process units out of service for maintenance.

The treatment plant has used the model to assess operational changes caused by a change in loading to the plant over the Christmas holiday period when trade waste discharge is virtually non-existent in Auckland. The impact in this period is lower rbCOD, which dramatically affects the denitrification capacity of the BNR process.

As a faultfinding tool, a model can be used in a proactive manner to predict and evaluate plant upsets and troubleshoot the cause of plant process performance issues.

2.1.4 PLANT OPTIMISATION

The model can be used to evaluate the plant as a whole by changing one aspect of the operation and to evaluate the overall effect on the plant. An example of this would be to evaluate the effect of sidestream treatment on struvite production. An additional use as a process optimiser would be to run the model on the digester to see what the effect of changing plant characteristics have on gas production.

2.1.5 COST SAVING AND RECOVERY

Any of the evaluations used for process optimisation can be just as easily used for plant cost optimisation. An example of this would be to measure the effect of sidestream treatment on chemical usage or aeration use in the BNRs.

2.1.6 TRAINING

A complete plant model can also be used as a tool for operator and engineer training. The operator/engineer is able to change different aspects of the plant and see the effect on the plant without having to carry out a plant wide test or risk consent failure. The speed of the model allows the operator/engineer to make changes, such as influent characteristics, dissolved oxygen or sludge age, and view the effect of the changes immediately. Graphical output of treatment parameters is a particularly powerful feature for training.

2.1.7 TRADE WASTE CONTROL

The ability to carry out scenario analysis on trade waste discharges is a very powerful tool. It enables the plant engineer to carry out influent changes to the model that are linked to trade waste discharges and evaluate the effect on the plant. This can be used to evaluate risks of trade waste non-compliance as well as accidental spills or discharges. The model is particularly useful in evaluating trade waste components and their effect on the plant and is therefore useful in setting individual trade waste discharge consents and the overall trade waste strategy and bylaw.

2.1.8 RISK MANAGEMENT

A complete plant model can be used to model the effect of events outside normal operating conditions. Such events include: -

- Christmas and Easter holidays where low trade waste loading causes a lower COD:TKN ratio in the influent,
- Prolonged wet weather where higher influent flow and solids (TSS and VSS) could be expected and
- Times of toxic influent loading where biological activity could be affected.

Operations personnel can action alternative operating procedures or contingency plans, which have been developed with the assistance of the plant model, when these events are expected or encountered.

3 THE CONSIDERATIONS IN THE SELECTION OF A SOFTWARE PACKAGE

3.1 SELECTION CRITERIA

3.1.1 PACKAGES

There are many wastewater-modelling packages on the market. Most are based around the ASM (Activated Sludge Model) family of mathematical models and are not fundamentally different. Several models do have their own proprietary calculations, based on their own research or experience.

Commonly used, commercially available, packages include BioWin, WEST, GPS-X, STOAT and SASSPro. Some consultants have their own in-house proprietary software.

The authors did not undertake the process of software selection as there was already a BioWin[®] model created for the BNR plant and software was previously procured. Accordingly, this paper does not suggest or recommend any package. The BioWin modelling package that Watercare uses has wide spread penetration in the wastewater industry. Most of Watercare's required criteria were satisfied using the BioWin[®] package.

The following section provides a guide on what may be relevant to the user when selecting a package. It is advised that a full investigation be performed when selecting software.

3.1.2 DYNAMIC OR STEADY STATE MODELLING ABILITY

Some software packages can only run simulations using average day flows and loads. This is called steady state modelling and assumes that the system is in a steady state. Steady state modelling is all that is required to check sizes of process units and to perform basic faultfinding of treatment processes.

More advanced packages can perform dynamic modelling using diurnal flows and loads or changing conditions over hours, days, weeks or even over the year. Dynamic modelling provides far more information on the behaviour of treatment plants over time. Changes in conditions or process changes can be better analysed than with steady state modelling.

3.1.3 EASE OF USE

All software packages have various degrees of difficulty of use. Fortunately, most suppliers provide demo versions of their software and it is recommended that these be obtained, usually by downloading off the supplier's website, as part of the selection criteria.

3.1.4 GRAPHICAL INTERFACE

Most software packages have graphical interfaces where plant configuration can be input graphically and output data is displayed in graphs and charts. These features can usually be evaluated using a demo programme.

3.1.5 FUNCTIONALITY

It is important to know what you require from a software package. Some biological wastewater models only analyse for activated sludge. Some only analyse for a number of activated sludge process configurations, e.g. MLE[®], step feed, Bardenpho[®], etc. Most advanced software packages allow any process configuration to be input.

Some packages have digester models, clarifier models, struvite models, etc. Again, the demo programmes will provide the user with the necessary functionality to make an assessment.

3.1.6 TRAINING

Using a wastewater model not only requires sufficient knowledge to use the model but also sufficient wastewater treatment process knowledge and experience. Most software suppliers provide various levels of software training to suit the level of process knowledge and experience. Some companies provide worldwide training courses, usually visiting most regions once or twice a year. Others may only have training courses in the country or region that they reside and, therefore, travel time and expense to travel need consideration.

3.1.7 SUPPORT

When analysing a software package, be sure to check on what level of support is offered. As wastewater simulation is a very complex activity, it is likely that support is required from the software company when building and operating the model.

3.1.8 COST

Cost of modelling software usually increases with higher levels of functionality and support offered. Costs are discussed in *Section 7*.

3.1.9 CONNECTABILITY TO SCADA AND OTHER ON-LINE DATA SOURCES

With some software packages, it is possible to use on-line data such as that from SCADA or laboratory results databases to continuously update and calibrate the model. This data also can be used to predict short-term plant outputs and behaviours to assist with process control.

3.1.10 CONNECTABILITY TO OTHER SOFTWARE PACKAGES

Some models are able to integrate with software packages. For example a model could integrate with: -

- A package that produces preliminary plant designs and costing,
- A river quality model,
- A treatment cost model, or
- A sewer network hydraulic model.

4 MODEL DEVELOPMENT OVERVIEW

A specifically configured, calibrated and verified kinetic plant model is a very powerful and useful tool for WWTP owners and operators, but only if developed correctly with a good knowledge of the operating plant, the plant data and the kinetic model used.

A final developed model can be used as an operational tool for: process optimisation, cost optimisation, future treatment evaluations, plant capacity studies, future planning, plant troubleshooting, equipment evaluation, identifying plant bottlenecks and operator training.

The methodology to develop, calibrate and verify a model for a specific WWTP generally follows the following steps:

1. Determine the model use and required outputs
2. Configuration of the specific WWTP in the model
3. Gather the appropriate data to populate and calibrate the model
4. Calibration of the model
5. Verify the calibrated model
6. Use the final model

Even if the modelling process generally follows the six steps noted above, model development is very much an interactive process.

5 THE METHODOLOGY APPLIED TO BUILDING THE MODEL

5.1 MODEL USE AND REQUIRED OUTPUTS

The methodology used to build a model for a WWTP depends in many ways on the specific use the model is being developed for. For example, a model being developed to design a greenfield WWTP will be developed significantly different than a model developed to optimise an existing WWTP. This is due partly because of the intended end use and partly dependent on the information available to develop the model.

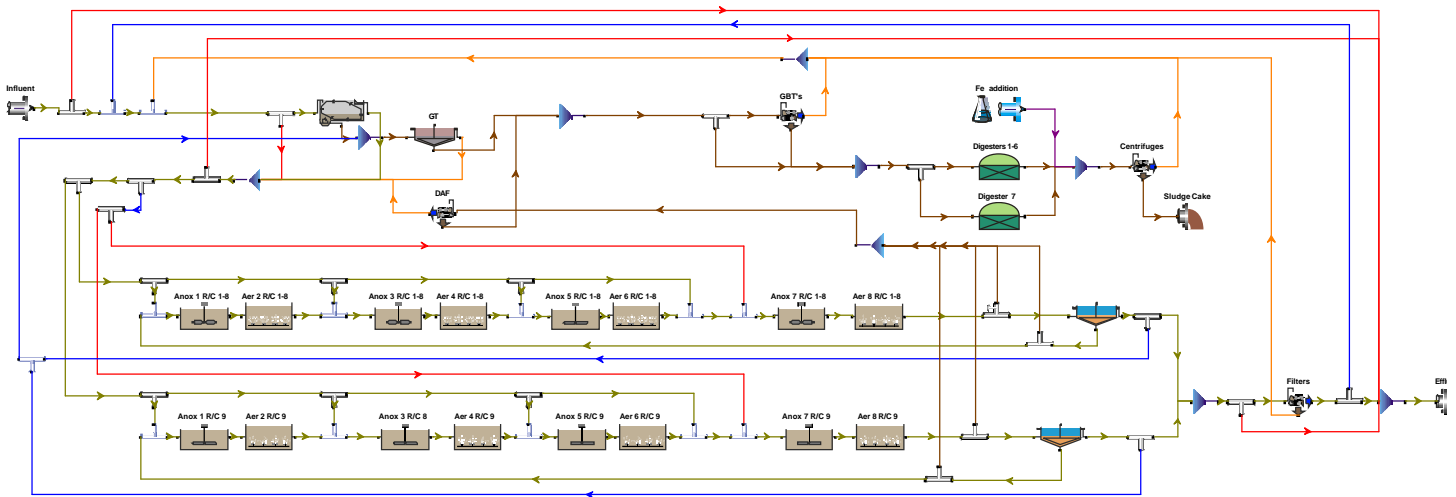
In this particular case, the model developed was an operational tool to be used for: process optimisation, cost optimisation, future treatment evaluations, plant capacity studies, future planning, plant troubleshooting, equipment evaluation, identifying plant bottlenecks and operator training.

As the model developed for the Mangere WWTP was to be used as an operational tool, as much detail of the process and the influent and sidestreams as possible was added. In this way the impact on the treatment process could be monitored by making various changes in sidestream performance.

The model included the components of the primary sedimentation tanks, gravity thickeners, biological reactors, clarifiers, DAFs, belt press thickeners, centrifuge dewatering, digesters, chemical dosing and tertiary filters.

The plant wide Process Model for the Mangere WWTP had been assessed using the BioWin[®]3 process simulator of which the configuration output can be seen in *Figure 1*.

Figure 1: Model layout for the Mangere WWTP



5.2 CONFIGURATION OF THE SPECIFIC WASTEWATER PLANT MODEL

In this step of developing a model for a specific Wastewater Treatment Plant configuration, the model was configured with the physical, chemical and operational parameters from the plant. This included the plant layout with the different process units along with all the flow streams shown to duplicate the actual plant configuration.

The process arrangement that was developed in the model to duplicate the Mangere WWTP can be seen in *Figure 1*. Along with the process arrangement of the model the unit sizes, number of units and stream inputs were entered into the model. As the model is primarily a kinetic process model, particular attention was paid on the inputs into the biological parts of the WWTP. This included the various zones in the reactors as well as their size and layout including mixing and aeration aspects.

5.3 GATHERING OPERATIONAL PLANT DATA AND POPULATING THE MODEL

The gathering of the data to populate the model was a fundamental part of the process. Without reliable data the model would not produce reliable or consistent results.

The population of the model was the step where the data collected from the intensive sampling period was inserted into the model skeleton.

The Mangere WWTP had a significant amount of data related to its operation and performance that had been gathered over several years. This data was manipulated using traditional methods of mass balance and stoichiometric calculations, to come up with a set of reliable input data including wastewater characterisation that was input into the model. The calibrated model provided a level of confidence and reduced risk in both operations and future design.

Although this is only briefly touched on in this paper, the development of reliable influent characterisation for the plant was an important, although difficult, and time consuming part of the process of modelling the plant.

The wastewater characterisation was carried out through detailed sampling, analysis, and using the BioWin® “Influent Specifier” to produce the data that was inserted into the model as a starting point for model calibration.

One area of missing data that was highlighted during the development of the model was that of diurnal data of a weeklong intensive period that showed performance data from all parts of the plant at the same time. For this reason, one week of hourly sampling was carried out to collect input and performance data from the plant including all side streams as well as the main biological process.

The other aspect of collection of data as well as configuration of the model that was fundamental to its success was the input from knowledgeable plant operational staff. These were particularly important for this plant and model due to the numerous recycles and return flows from both internal plant processes as well as external plant returns.

The model was populated with two sets of data; one being the steady state, average conditions, influent data from the Mangere plant and the second being the dynamic, average conditions, influent data from the Mangere plant.

The steady state influent data represented the average of the flow and loading conditions and was represented by 11 parameters as shown in *Table 1*. The dynamic data represented the same 11 parameters sampled hourly for 7 days to show diurnal and weekly trends.

Table 1: Steady state influent data for the Mangere WWTP BioWin®3 model

Parameter	Unit	Value
Flow	m ³ /d	244,000
Total COD	mgCOD/L	820
Total Kjeldahl Nitrogen	mgN/L	60
Total P	mgP/L	12
Nitrate N	mgN/L	0
pH		7.2
Alkalinity	mmol/L	4
Inorganic S.S.	mgTSS/L	70
Calcium	mg/L	15
Magnesium	mg/L	15
Dissolved oxygen	mg/L	0

As an example, *Figures 2, 3 & 4* show the dynamic influent data for the Mangere WWTP. These trends are a good example of showing the needs for detailed influent sampling, as the different parameters change significantly through the day and week. If modelling was just carried out using average data or even daily diurnal data, problems associated with peak daily and weekend loads could easily be overlooked.

Figure 2: Dynamic Influent Flow Data for the Mangere WWTP

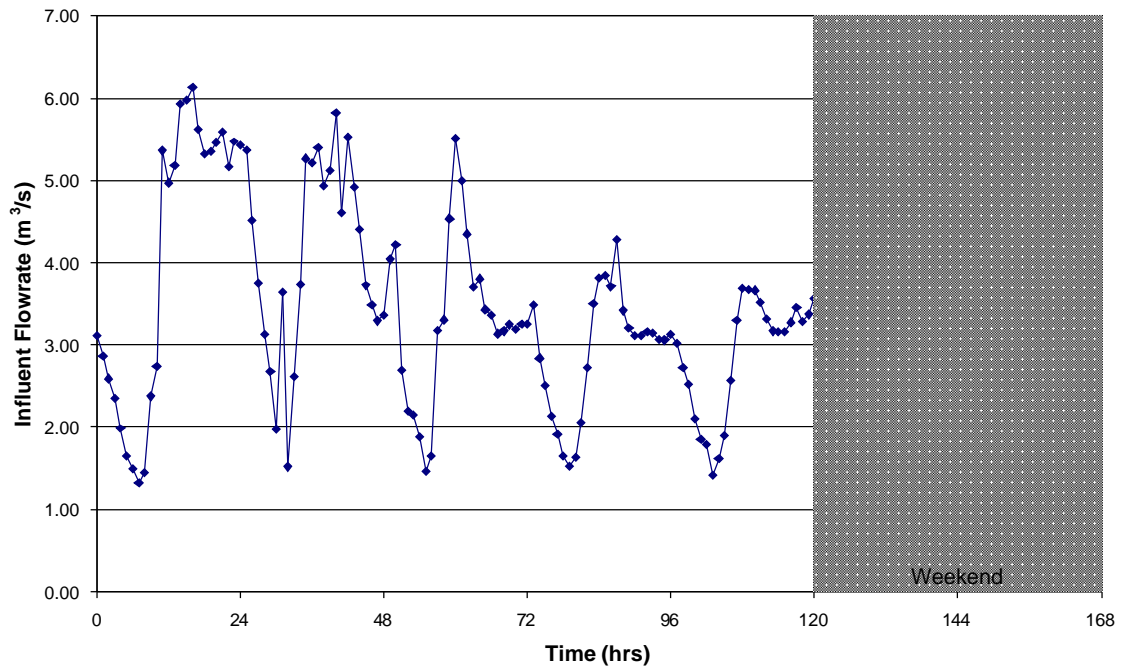


Figure 3: Dynamic Influent COD and TSS Data for the Mangere WWTP

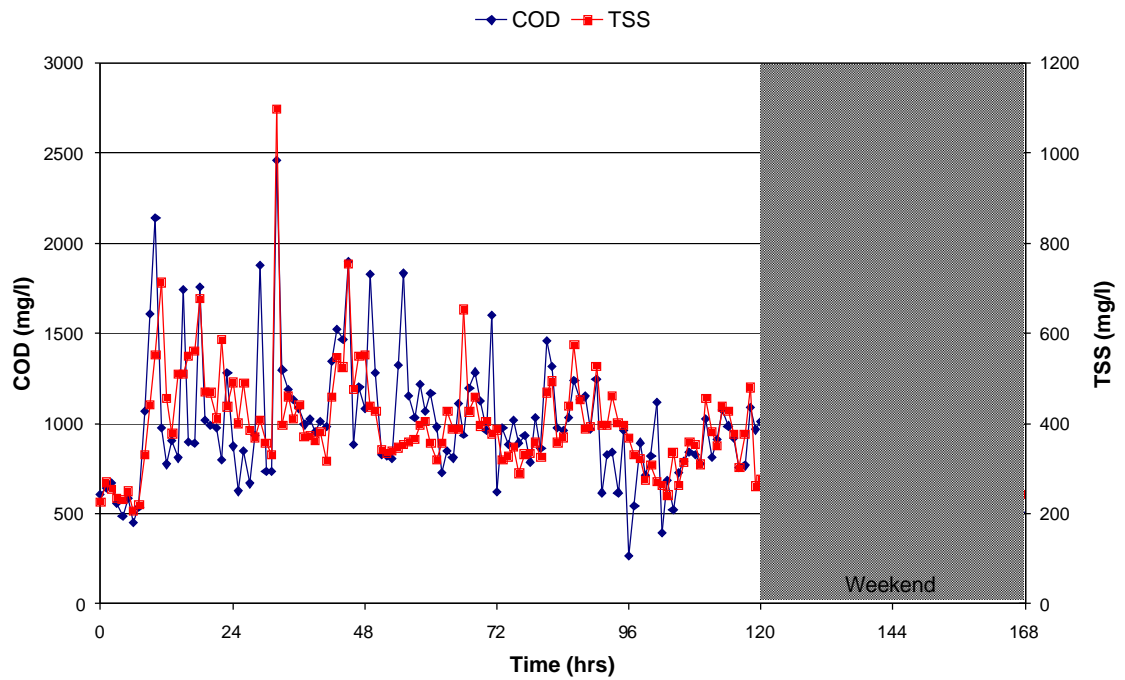
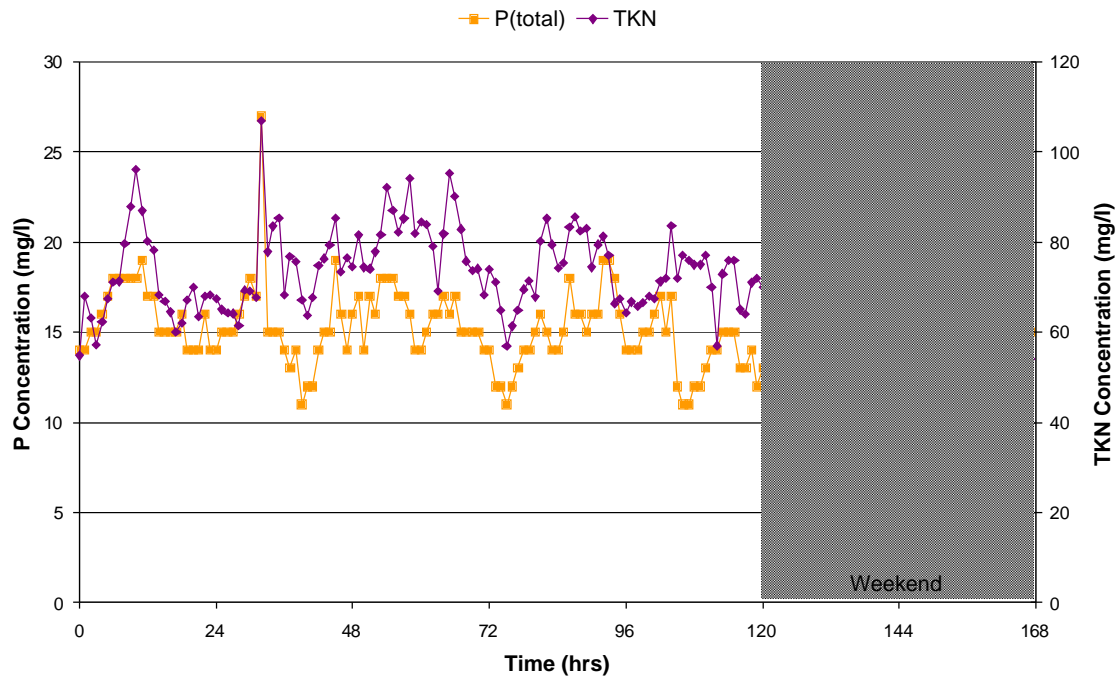


Figure 4: Dynamic Influent TKN and TP Data for the Mangere WWTP



6 THE METHODOLOGY APPLIED TO CALIBRATING THE MODEL

6.1 CALIBRATION OF THE PLANT MODEL

Model calibration was the first stage testing or tuning of the plant specific model to a set of data not used during the original development of the model.

The model calibration underwent two stages; a first general calibration of the model under steady-state conditions and a more detailed dynamic calibration.

The steady state and dynamic model was calibrated using average flow data from the period 1 February 2007 to 28 February 2007.

The calibration of the model involved the manipulation of the model and its numerous parameters in order to adjust errors that were highlighted between the model outputs and the actual plant data. This was an area of model development that required a very detailed understanding of wastewater processes and their kinetic and stoichiometric parameters.

With the detailed amount of work carried out previously in characterisation of the Mangere WWTP influent and the amount of work that had gone into developing the kinetic and stoichiometric parameters of BioWin[®]3 there was only minor adjustments to the kinetic and stoichiometric parameters of the model as well as to the plant unit process performances.

6.2 VERIFICATION OF THE PLANT MODEL

Verification or validation of the model was the testing of the calibrated model against an additional set of plant data, preferably under different conditions, to further examine the range of validity of the calibrated model.

This step of model development is often overlooked but is very important to give confidence in the calibrated model under different input data.

The calibrated model for the Mangere plant was verified under a period of higher influent flow rates from the period 11 March 2007 to 11 April 2007.

7 COSTS AND FINANCIAL BENEFITS OF DEVELOPING THE MODEL

7.1 MODEL COSTS

Typical costs on developing a wastewater model are presented in *Table 2*.

Table 2: Typical Costs to Develop a Full Plant Model

Item	Cost (NZD)
Software	\$2,000 to \$15,000 purchased or \$1,000 to 3,000 per year leased
Wastewater Characterisation Sampling and Analysis	\$20,000 to \$150,000 depending on budgets
Model Development	\$10,000 to \$100,000 depending on complexity
Training	\$5,000 to \$30,000 depending on numbers and experience

A budget for a full plant model for small plant would start at around \$50,000 whereas a large plant model could cost up to \$250,000.

It is not necessary for the water company to purchase the model software as most consultants have licenses for commercially available modelling software or their own propriety software. Software purchase is only required if the company wishes to use the models in-house.

The cost of the Mangere model was estimated to be about \$250,000 for both:-

- Phase 1 – Wastewater characterisation and BNR model development and
- Phase 2 – Full plant model development.

It is important to provide the model with as much information about the influent as possible. The COD and N fractionations are especially important for model calibration and diurnal data is important for dynamic modelling. It is critical that sufficient budget for influent sampling be provided and savings made on sampling and analysis up front may prove a false economy. For plants over 100,000 p.e., at least \$100,000 should be budgeted for influent wastewater characterisation.

7.2 FINANCIAL BENEFITS

The Mangere WWTP has an operational budget of over \$25M per year. The model would pay for itself in the first year by reducing operating costs by a mere 1%.

Dissolved oxygen control alone has reduced opex by around \$400k per year by reducing airflow to the aerobic tanks by 21.5%. This saving, predicted by the BioWin[®] model, was critical in the decision for capital approval.

New process units cost several to tens of millions of dollars on a plant the size of Mangere. All upgrades require thorough investigation and modelling is critical to analysing upgrade options in planning investigations and in the production of subsequent designs. For example, a plant the size of Mangere, the fraction of unbiodegradable particulate COD (f_{up}) entered into the model's wastewater influent icon can have a tremendous impact financially in real terms. The reason being that with a high F_{up} , a higher SRT (more MLVSS) is required but the "work" that the additional VSS is doing is not great. In the case with higher f_{up} values for example, this

would require more aeration and clarifier capacity in the future, which has huge implications. Getting an accurate representation of the plant with the model ultimately serves the ratepayers.

Process models predict the timing of plant upgrades. Watercare has planned \$0.5 billion in capital expenditure and over \$0.6 billion in operational expenditure for wastewater treatment over the 20-year Asset Management Plan. Process models are critical in formulation and justification of capital and operating expenditure in the Asset Management Plan.

8 LIMITATIONS TO THE MODEL

An important part of kinetic modelling of WWTPs is understanding that models have limitations. If the model is used for a purpose that it was not developed for or is not capable of modelling, the user will get unreliable or misleading information. Some of these limitations are not limitations of the model itself but limitations of the modeller's understanding of the model capabilities.

A BioWin[®] model still requires the user to make careful decisions, based on knowledge of the wastewater treatment process. For example, some of the items BioWin[®] will not automatically perform in relation to experiences at the Mangere WWTP are noted below: -

- Indicate a toxic compound or series of toxic compounds entering the treatment plant and washing out the biological process, for example, a chemical that reduces the nitrifying biomass rate or population in secondary treatment. The model is only responsive to variation in load and wastewater characteristics as related to what is biologically degradable.
- The model does not automatically calibrate the waste fractionation by itself or change unit process operating parameters. The model does post alarms that alert the user that areas of changes are probably necessary in regards to processing the wastewater in the model calculations. The model does not encompass the operational items that might need adjustment due to site-specific limitations. The model usage from an operations perspective requires that the user has a full understanding of the wastewater treatment process and plant machinery that is being modelled.
- The model does not automatically change the mass fractions of wastewater concentrations or kinetic parameters in relation to varying waste conditions entering the plant. The model allows variation of the influent conditions but the waste is fractioned in a fixed-mode (i.e. sCOD:COD and rbCOD:COD for example). In the case where weekly flow and loads on to the plant vary with industrial discharge, the fractions of biodegradable and unbiodegradable COD and N can have rate effects such that reactions are more or less biologically rapid..
- The model does not indicate the impact the wastewater and operation of the plant in regards to microbiological quality of secondary sludge and the settling behaviour in the secondary clarifiers. The model will not automatically adjust the Vesilund equations, so careful consideration must be made in clarifier modelling, based on sludge quality.
- The model will not predict
 - Foaming in secondary treatment bioreactors
 - Foaming in digestion processes
- BioWin[®] requires the user to define solids thickening and dewatering parameters for solids stream processing, regardless of sludge quality that may occur. This requires the user to have knowledge of impacts related to SVI, volatile solids destruction in stabilisation processes and downstream dewatering unit process machinery.
- BioWin[®] will not predict the sludge dewatering ability exiting an anaerobic digester as in the case of Mangere with fairly high VSS:TSS ratio conditions in the sludge waste stream(s).

- The model does not have a disinfection component in which it will predict bacteriological or viral quality or log reductions throughout the unit processes or the whole wastewater treatment process.
- The model is not tied into specific machinery per se. For example, the model does predict air usage in secondary treatment but does not readily determine blower kW required. From a designer's vantage point this is probably fine, although sometimes laborious. From an operator's perspective, it is important in determining how many aeration blowers must be available for service.

9 SEVERAL PRACTICAL EXAMPLES THAT HAVE BEEN APPLIED

9.1 OVERVIEW

Once the model had been developed, calibrated and verified it was used to run various simulations. A few of the simulations that the model was used for at the Mangere plant are briefly discussed in the following sections.

9.2 DO CONTROL

All nine BNR units at the Mangere WWTP comprise of four aerobic zones and four anoxic zones. A single valve controlled the DO on the four aerobic zones on each BNR unit according to the lowest DO reading in the four zones. This caused the other three zones to be over aerated, causing significant power wastage in addition to higher total nitrogen concentration in the effluent due to additional rbCOD consumption.

A modelling exercise showed up to 25% saving on airflow, and therefore power, if individual air valves controlled all four aerobic zones on the 9 BNR units. The cost savings predicted at \$380,000 per year provided a payback of less than 2 years on the capital cost of \$761,000 to perform this upgrade. The system only needed to have a 10% saving to show a positive NPV, therefore, the decision to install was straightforward.

The upgrade was installed in 2006 and the plant has since realised about 21% savings in aeration power (13,000kWh/d), slightly less than the idealised 25% predicted by the model. This was expected as the installed control had time lags causing minor over aeration. The upgrade also enabled enhanced process control, increased process stability and lower effluent nitrogen concentrations.

9.3 PLANT SETUP DURING SUMMER LOW LOAD

One of the operational aspects of the Mangere WWTP is the configuration of the biological reactors during the summer low load period. The model was used to determine the optimal configuration of the plant for cost savings while still ensuring compliance.

The Mangere WWTP has nine process streams with the ability to take out of service any number of streams dependent on maintenance or performance needs. The model was used to run the calibrated model under low load summer conditions, running both the nine and eight process stream configuration. In this way, process operators were able to determine what conditions the plant performed with eight streams and under what conditions the change over to add the ninth stream took place to ensure plant compliance.

9.4 SECONDARY SLUDGE VOLATILE CONTENT INCREASE

As part of an optimisation project, the ability to increase the volatile solids in the secondary sludge was investigated using the plant model. The model was run with modified configurations on the BNR system.

The Mangere WWTP BNRs are step feed, designed to remove nitrogen. The configuration has eight zones: - zones 1, 3, 5 and 7 operate as anoxic zones and zones 2, 4, 6 and 8 operate as aerobic zones. Zones 5 and 7 have the ability to be aerated.

The Biowin model output alerted the operations team of the following:

- Having additional aerobic mass fraction within the reactor reduced the alkalinity
- Switching Zone 5 and Zone 7 from anoxic to aerated impacted on pH and alkalinity

10 FURTHER MODELING EXERCISES THAT THE COMPANY IS PLANNING

10.1 Overview

Watercare is planning a number of investigations using its model for future upgrades and operations. Examples of such investigations are detailed below.

10.2 PROJECT INFLUENT COST MODEL

Watercare is currently undertaking a large influent study called Project Influent. The company has an extensive database of influent characteristics as it enters the treatment plant but has limited knowledge on the characteristics of influent at the sources, except for Trade Waste.

Project Influent involves a large amount of influent catchment sampling and analysis to determine the flows and loads coming from domestic populations, commercial premises, trade waste, seawater ingress, groundwater infiltration and stormwater inflow. The understanding of the individual components that make up trade waste will enable various future scenarios to be analysed.

The treatment model will be run with various predicted influents and plant effects analysed. This will allow more accurate forecasting of Asset Management Plan capital and operational expenditure.

10.3 SIDESTREAM TREATMENT

About 25% of the nitrogen loading to the Mangere BNRs is from internal recycles, mainly the centrate from the centrifuges. A number of technologies have or are being developed to treat these low carbon, high nitrogen waste streams. Watercare plans to model various processes in order to establish whether sidestream treatment is a viable option and to evaluate the various processes.

10.4 TRAINING

The intention is to include process operator training using the model. A course will be created that will provide process operators the opportunity to learn about plant behaviour without the need to modify the treatment process.

10.5 STRUVITE

Struvite, or magnesium ammonium phosphate, forms inside pipes and on pumping equipment and valves causing major blockage necessitating high removal costs. It is a common problem on wastewater treatment plants, including Mangere WWTP on the digested sludge line. The BioWin[®] model can be used to predict struvite formation and a project will be undertaken to find a solution to reduce the incidence of struvite formation.

10.6 CHEMICALLY ASSISTED SEDIMENTATION

CAS (Chemically assisted sedimentation) in the primary tanks has the potential to defer upgrading of the BNR system, required due to future biomass growth. CAS would reduce the colloidal content and sCOD of the primary effluent onto the BNR process but increase the loading on the solids stream in the form of metal salt complexed sludge. CAS could increase biogas production, but in contrast, could create a carbon shortage or nutrient shortage in the BNRs depending on the stoichiometric dosing and method of flow pacing. Watercare intends to analyse the positive and negative effects of installing CAS using its wastewater treatment model.

10.7 DIGESTERS

As the population of Auckland grows, additional solids will be collected in the primary tanks and sent to the digesters. A number of projects to increase digester capacity for growth are in the Watercare Asset Management Plan. Modifying digester operation may defer some capital expenditure. For example, the digesters may be run at a higher temperature in the mesophilic zone or the digesters may be run in a combination of mesophilic and thermophilic, or entirely thermophilic.

Watercare plans to investigate these options by modelling the digesters with various operating regimes and analysing their effects on other process streams. To perform this task, it is likely that an additional digester-specific model will need to be developed.

11 LESSONS LEARNED

Detailed below are some of the issues learned during the development of the calibrated model for the Mangere plant.

1. Get as much quality data as possible for the plant to enable detailed characterisation of the plant influent and calibrate the model.
2. Spend as much time as possible at the plant with operational staff to understand all the unique characteristics related to the plant layout and performance under different scenarios.

12 CONCLUSIONS

The Mangere WWTP biological wastewater treatment model has proved to be an important tool for Watercare's Planning and Operations Teams.

The model is only as good as its input and full understanding of each site-specific unit process and associated machinery.

The model must be used in conjunction with the knowledge as to what can be realistically achieved by unit processes and machinery, based on previous machine operating parameter limits and analytical data from the plant.

REFERENCES

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NOMENCLATURE

ASM	Activated Sludge Model
BNR	Biological Nutrient Removal
CAS	Chemically Assisted Sedimentation
COD	Chemical Oxygen Demand
f_{up}	Unbiodegradable Particulate COD Fraction
MLVSS	Mixed Liquor Volatile Suspended Solids
NPV	Net Present Value
rbCOD	Readily Biodegradable Chemical Oxygen Demand
sCOD	Soluble COD
SRT	Solids Retention Time
SVI	Sludge Volume Index
TKN	Total Kjeldahl Nitrogen
TSS	Total Suspended Solids
VSS	Volatile Suspended Solids
WWTP	Wastewater Treatment Plant