

DERCETO : AN ONLINE PUMP SCHEDULE OPTIMISATION SYSTEM

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ABSTRACT

The introduction of an online software optimisation tool has reduced power costs for water distribution by more than 12 percent for Wellington Regional Council. Pumping charges can be a large cost in production for treated water, especially when river levels run low and greater demand is placed on well fields which have high pumping requirements. The ability to pump water to reservoirs during low power charge periods and let it gravity feed into the reticulation system during peak periods makes WRC's water distribution systems an ideal candidate for Derceto, an optimisation tool produced by Beca Consultants.

Derceto was installed in June 2000 and has produced substantial savings in power costs from day one. Savings have also been achieved in chemical consumption. During the software development period energy prices were changed from four-hourly blocks to a simple two-tier structure. This made it more difficult to achieve the gains originally targeted, however by using a new strategy to minimise coincident maximum demand network charges Derceto did achieve savings in excess of those originally projected. Derceto can handle energy periods down to the half-hour, with separate prices for each and every point of consumption if required.

Reduction of any potential risk was a high priority, and there are multiple levels of back-up provided for both local and remote controls. Derceto may have its setting over-ruled by the local PLC at the water treatment plant if reservoir levels drop below critical settings. Local controls on each reservoir start the supply pumps if the level drops below a critical level just below Derceto's minimum set-point. These back-up systems are rarely invoked, however it is comforting to know they are there just in case.

KEYWORDS

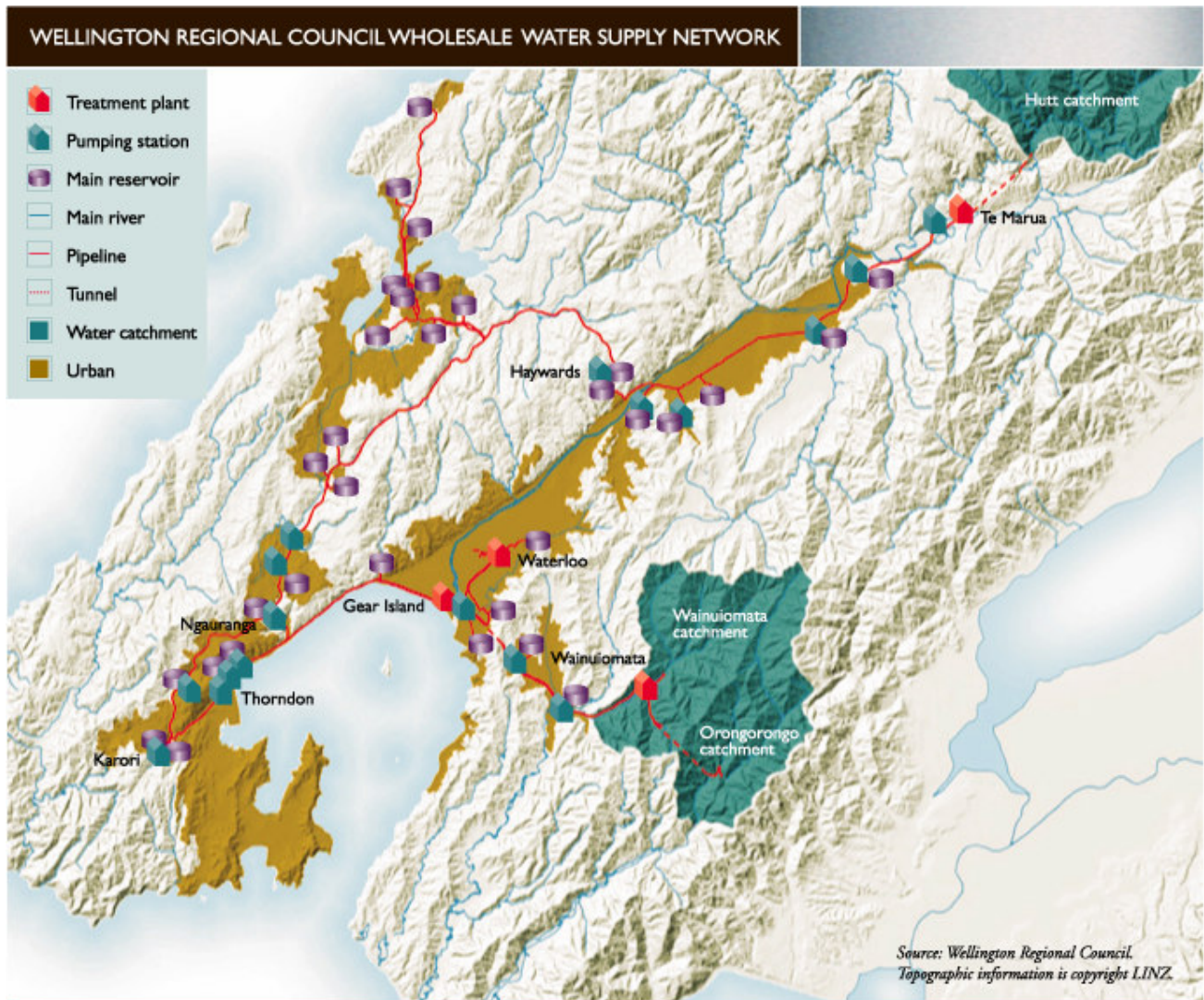
Water Distribution, Power Tariffs, Pump Scheduling, Optimisation, Energy Efficiency

1 INTRODUCTION

The Water Group of the WRC is the water wholesaler in the Wellington area. Water is sold to four city councils. The councils distribute water through their own systems. The urban population of the four cities is 348,000.

Water is supplied from four Water Treatment Plants (WTPs); Te Marua, Wainuiomata, Waterloo and Gear Island (emergency standby plant) as shown on Figure 1: Wellington Regional Council Wholesale Water Supply Network. The average annual daily demand (AAD) is approximately 145MLD.

Figure 1: Wellington Regional Council Wholesale Water Supply Network



It is possible to move water from any treatment plant to any supply point. However the system normally operates as two separate distribution systems. One distribution system is the Te Marua WTP supplying Upper Hutt, Porirua and Wellington. The other is the Waterloo, Gear Island and Wainuiomata WTPs supplying Lower Hutt and Wellington. Both distribution systems are cross-linked by the Ngauranga Gorge pumping station that is operated only when required.

Prior to optimiser installation, control systems generally responded to immediate information. For example, if a reservoir level falls to a certain point a pump or additional pumps would start or a valve opens in the case of

gravity filling. The system would not know how long the pumps would operate for once they started. Plant outputs would generally be set by operators to match expected demand.

The Water Group identified the potential to optimise the delivery of water from the WTPs to the customers. The key objectives for any optimisation were to:

- Maintain supply of water within system constraints,
- Use the cheapest source of water, and
- Reduce overall power costs.

As a first stage an optimiser was implemented for the Wainuiomata/Waterloo system (which includes Gear Island). Commissioning was completed at the end of June 2000.

2 THE WAINUIOMATA/WATERLOO SYSTEM

The Wainuiomata/Waterloo supplied system has an average daily demand of approximately 55 percent of the overall system. Power requirements are higher for the Wainui/Waterloo system with an annual cost of approximately \$900,000 or 60 percent of the overall system power cost.

The Wainuiomata/Waterloo system includes:

- Three WTPs supplying water; Wainuiomata, Waterloo and Gear Island,
- Eleven customer owned reservoirs; Wainuiomata No. 1 and 2, Point Howard, Gracefield, Naenae, Rahui, Ngaio, Onslow, Rahui, Carmichael and Macalister, and their associated WRC owned pumping stations,
- The Wellington City Council low level zone, and
- Water pumped up or gravity fed down the Ngauranga Gorge to/from the Te Marua system when required.

The Wainuiomata WTP treats river water from the Wainuiomata and Orongorongo catchments. This water requires full treatment to achieve high quality drinking water. Water is gravity fed from the WTP treated water reservoir to Wellington. The plant maximum capacity is 60MLD with a typical output of 30MLD.

Photograph 1: Waterloo Water Treatment Plant in the Hutt Valley. Derceto runs from this central location with telemetry and WAN links to all reservoirs and treatment plants



The Waterloo and Gear Island plants treat aquifer water that requires pH adjustment to reduce corrosion. Water is pumped from wellfields then boost pumped to Wellington and Lower Hutt. The Waterloo plant capacity is 115MLD with a typical output of 60MLD. Gear Island is an emergency standby plant with a plant capacity of 27MLD.

2.1 COST INFORMATION

Derceto supplies water from the lowest cost source based on fixed or calculated chemical and power costs. Pumping is scheduled to minimise costs. Power costs include both network and energy charges. Three quarters of the power costs for Wainuiomata/Waterloo system are for the Waterloo WTP.

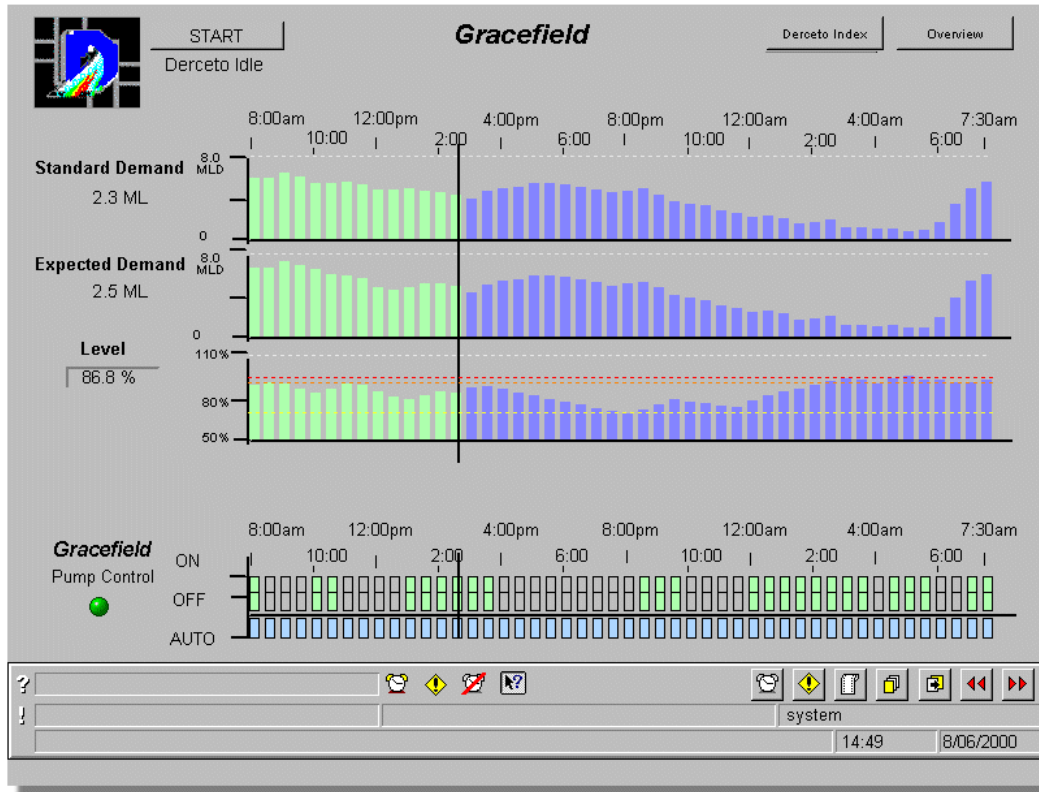
Energy charges are a two-tariff per day structure with different rates for weekends and weekdays where the tariffs change every month for each pumping station and WTP. If in the future the cost structure is altered, Derceto can handle half-hourly power tariff changes for each point of supply. The low tariff period (night tariff) is from midnight to 8am. For instance, for the Waterloo WTP night tariffs vary throughout the year from 1 to 3.5c/kWh and day tariffs from 2.7 to 5.5c/kWh.

Network charges are a monthly charge based on coincident maximum demand (CMD) and anytime maximum demand (AMD). The CMD charge is the highest half-hour power consumption for the month between 8 and 10 a.m. and 5.30 and 7 p.m. on any weekday. The AMD charge is the highest half-hour power consumption for the month, AMD charge is \$7.72/kVA, and CMD charge is \$4.31/kVA. The target is avoidance of CMD and minimisation of AMD charges.

2.2 SYSTEM OPTIMISATION

Derceto operates by scheduling pumps and WTPs 'over the top of' the existing centralised PLC and telemetry control systems. Requests are made to existing WTP control systems or via existing telemetry to pumping stations. Complex software, including Mixed Integer Programming along with a hydraulic model and nearly 20 user interface screens, form Derceto.

Figure 2: Operator screen for Gracefield reservoir pump schedule



The use of a graphical easy to use front end Derceto, as shown in figure 2, has made it simple for the operators to view the pump schedules, and allows manual adjustment of pump schedules to facilitate maintenance requirements. Individual pumps or water treatment plants can be scheduled on and off in half hour blocks up to 24 hours in advance. Derceto optimises around these manual settings, making sure for example that plenty of water is transferred into a reservoir before a pump station is scheduled off for maintenance. The graphical screen also provides information on projected versus standard demand profiles and predicted reservoir levels for the next 24 hours.

Optimisation takes account of daily demand variations, available supply capacity, system constraints, and chemical and power cost information. At 8am every day optimal pump and WTP daily schedules are prepared for 48 half-hour periods until 8am the following day, then every half-hour these schedules are updated based on real time demand data and reservoir levels.

Water is supplied from the lowest cost source of water. Typically, reservoir levels are lowest at midnight and highest at 8am to coincide with lowest energy tariffs and maximise night pumping. Having the reservoirs full at 8am allows storage to be used to avoid pumping during the 8 to 10am CMD period. Reservoir levels are increased before 5.30pm to enable reservoir storage to be used to avoid pumping during the 5.30 to 7pm CMD period.

Derceto predicts reservoir levels and supply day demand. Demand can vary significantly within each day, from day to day, from weekday to weekend and from season to season. Standard weekday and weekend day demand curves for winter and summer are stored in the optimiser for each reservoir. At 8 am, the standard demand curve is adopted. Every half-hour an algorithm adjusts the predicted demand curve based on reservoir levels and pump flows or actual demand telemetered from customer demand meters. The algorithm has rules to prevent corrupt telemetry information from contaminating the demand profile.

Derceto maximises the use of the limited available operating reservoir capacity. Pumps and WTPs are scheduled to maintain reservoir levels between operator adjustable minimums and maximums dependent on their availability.

Reservoir levels generally range from 60 percent to 95 percent. Local controls override optimiser control by starting or stopping pumps in case levels go beyond present minimums and maximums.

An iterative process then solves the mass balance for the available sources of water and the demands. Supply point pressures are also maintained between operator set minimums and maximums. Finally the water sources have production schedules generated that maximise use of the cheapest source of water while staying between operator adjustable minimum and maximum flows. Where a mass balance cannot be achieved, for example during a period of water shortage, Derceto allows for a smooth reduction in reservoir target levels.

A further complication has been introduced by allowing for scheduling and automatic adjustment to take place when water is transferred either up or down the Ngauranga Gorge. This transfer point is very close to a pressure supply point making it critical to correctly schedule sufficient flow to maintain acceptable pump pressures while avoiding over pressurisation of some areas.

Derceto solves the pump schedule every half-hour, and more often if required, taking into account changing demand patterns and adapting as required. Hydraulic systems are inherently non-linear and difficult to optimise using conventional tools such as Linear Programming. Research around the world has concentrated on non-deterministic tools such as Neural Networks and Genetic Algorithms, (Wu & Simpson, 2001). Derceto on the other hand is completely deterministic, meaning there are no potential surprises when it is faced with completely new scenarios that may not have been contemplated during its design. Derceto has proved to be very robust, even during extreme situations when telemetry has been lost during electrical storms and water sources have been severely rationed. Derceto always produces the lowest cost pump schedule solution, despite source limitations or changing demand. It is based on a previous system developed for New Plymouth (Bunn & Helms, 1998).

2.3 IMPLEMENTATION

The initial pre design study was implemented in late 1998, and concluded that savings of around 10 percent could be achieved. Design work commenced in mid 1999 and was completed in March 2000. Site commissioning followed final design until the end of June 2000. Site commissioning included three weeks of operational scenario testing. As part of the design process an extensive risk assessment was carried out. A project control group was set up involving management, plant supervisors and distribution staff. The prime function of the project control group was to guide and monitor project implementation.

Implementation of Derceto meant the system was far more integrated. Using a hydraulic model within Derceto meant pump performance, instrumentation and metering had to be calibrated and brought into line across the system. Data consistency had to be in place to ensure interfaces between Derceto, plant control and telemetry systems were robust. A review of pumping equipment was carried out as a check on the impact of any additional pump starts from Optimisation. Reservoir level equipment was calibrated to ensure that available reservoir storage is fully utilised.

It also took a period of time and operator training to gain confidence and understanding of optimiser scheduling between given minimums and maximums rather than the traditional control response to immediate requests.

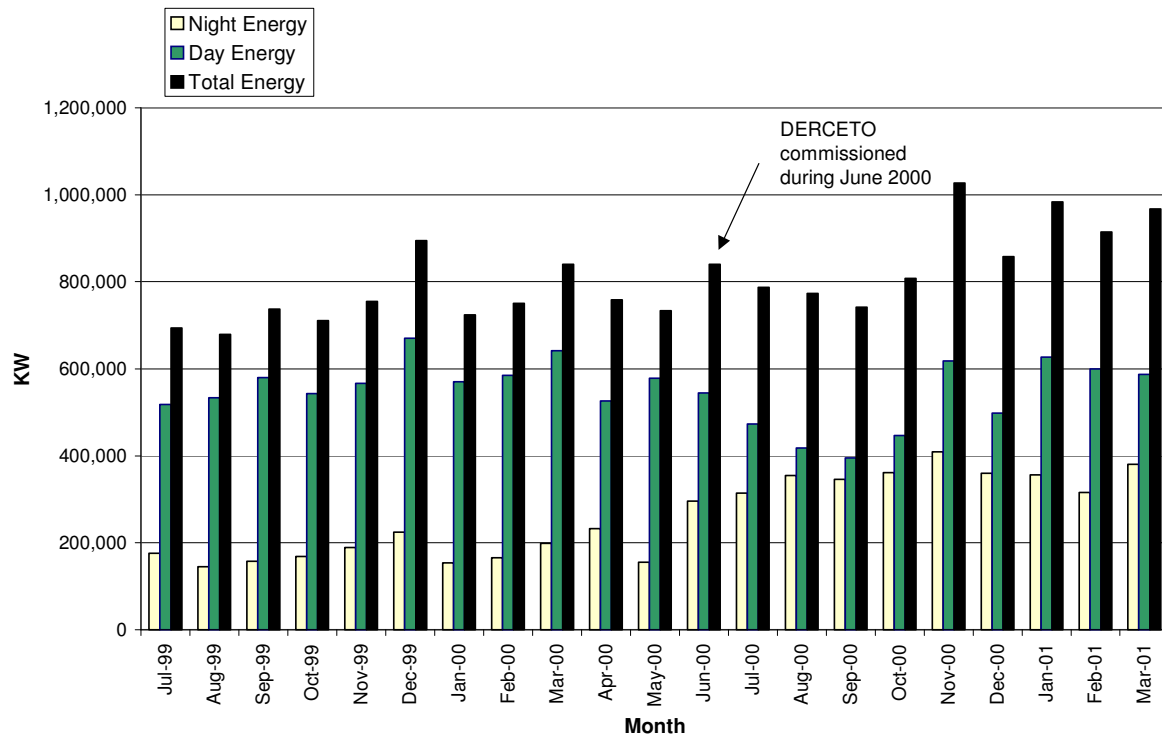
2.4 BENEFITS

2.4.1 ENERGY SAVINGS

Power savings are predominantly from shifting pumping from high day tariffs to lower night tariffs. It is estimated that energy savings for the first nine months of operation were approximately \$40,000. This amounts to approximately 10 percent of the energy bill.

The shift in pumping to night rates is particularly noticeable at Waterloo WTP, as shown in Figure 3: Waterloo WTP Energy Use. For Waterloo WTP night pumping has increased from approximately 23 percent to 40 percent.

Figure 3: Waterloo WTP Energy Use.



Approximately 80 percent of energy use under optimiser control is at Waterloo.

Other pumping stations have also shown increases in night pumping since commissioning of Derceto of approximately from:

- 10 percent to 50 percent for Moores Valley Pumping Station
- 15 percent to 30 percent for Wainuiomata Pumping Station
- 20 percent to 40 percent for Point Howard Pumping Station
- 17 percent to 30 percent for Kaiwharawhara Pumping Station

2.4.2 NETWORK CHARGE SAVINGS

Network charge saving opportunities are mainly from CMD avoidance and it is estimated that savings of approximately \$35,000 have been made for the nine months. CMD avoidance is more attainable in the winter demand months when there is more reservoir storage in relation to demand. The greatest opportunity for CMD savings is at Waterloo WTP where approximately 80 percent savings have been achieved. CMD avoidance is

very dependent on operational requirements (such as system shutdowns, the availability of Wainuiomata WTP water every day to maintain pressure at Thorndon, pump failures, etc.) and demand.

If the CMD charging regime could be altered to a daily rather than monthly basis, savings could be increased since one single transgression in a month can result in substantial additional cost. Transgressions into CMD periods are almost always triggered by unusual operating requirements, such as pumping water up the Ngauranga Gorge to assist the Te Marua plant. It is unlikely that these can be avoided.

AMD savings are significantly harder to deal with as the cost of transgression depends on how late in the month a peak occurs. If it is at the start of the month then a new limit can be set under which energy can be consumed for no additional network cost. If the limit is breached at the end of the month there are few days left in which to take advantage of the new limit, increasing the marginal cost of water substantially. Derceto applies a rule that accurately reflects the changing marginal cost of water as the month progresses. The rule must use an accurate cost basis rather than an arbitrary penalty since it would be possible to shift water production to an alternative facility if the marginal cost was set unreasonably high.

2.4.3 CHEMICAL COSTS

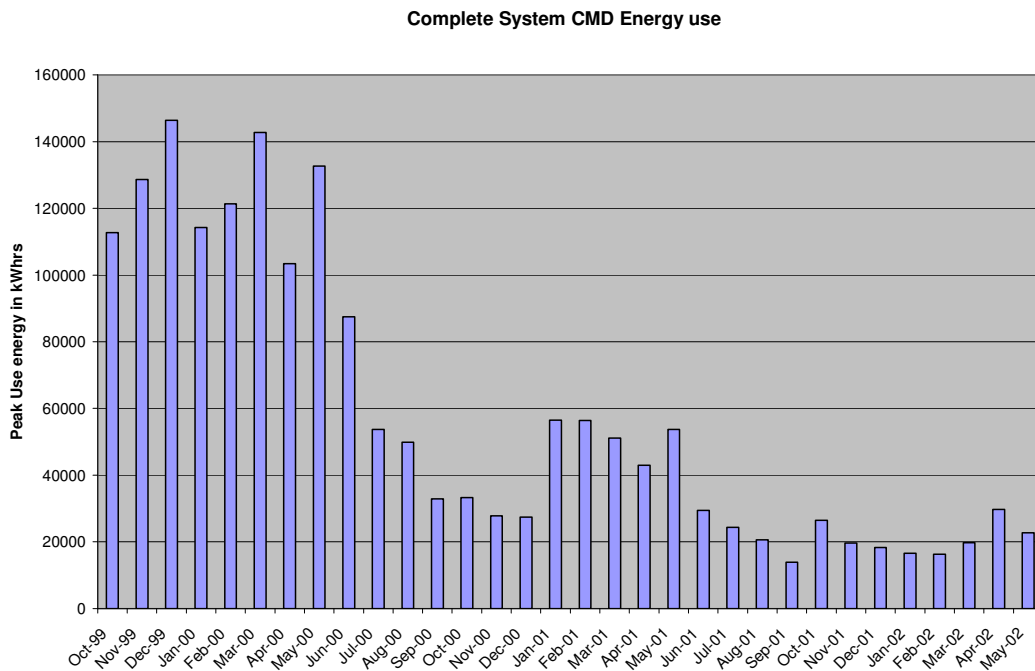
Currently Wainuiomata WTP marginal production costs per cubic metre are on average approximately two cents more than that of Waterloo WTP. For operational reasons Wainuiomata must always operate above a minimum flow when suitable source water is available. Waterloo WTP's lower cost means that Waterloo supplies Wellington in preference to Wainuiomata, except when Waterloo has insufficient capacity or it is cheaper to supply from Wainuiomata during the CMD periods.

Prior to commissioning the optimiser, the Wainuiomata WTP operated at constant flows as set by operators each day. Chemical cost savings achieved by supplying water from Waterloo rather than Wainuiomata for the nine months since full commissioning are approximately \$20,000.

2.4.4 ENVIRONMENTAL BENEFITS

The Water Group is committed to sustainable environmental management and has implemented an Environmental Management System (EMS). The EMS objective of “4.2.3: Reduce power use during coincident charge hours” with regard to the environmental policy “Recognise and operate within the natural limits of natural resources, particularly water and conserve non-renewable resources such as fuels, energy and materials” was achieved with the operation of the optimiser. Peak period energy use during the CMD periods has been reduced by up to 80 percent since full commissioning of the optimiser. The reduction is shown on the graph in *Figure 4 Wainui Waterloo System Peak Energy Use**. (*Note figure updated 8/07/2002)

Figure 4 Wainui Waterloo System Peak Energy Use.



2.4.5 OTHER BENEFITS

Implementation of Derceto has brought about other benefits including:

- Ability to schedule sources and pumping stations
- Calibration of pumping equipment, pressure transducers and reservoir level instrumentation
- Demand prediction capability through use of the customer’s demand meters
- Improved capability to focus on cost savings
- Certainty that least cost energy is being used
- Certainty that best use is being made of lowest cost water
- A review of pumping equipment
- Ability to reflect possible future energy cost tariffs and source costs in system operation
- Reduced operator intervention

In addition the scheduling of maintenance shut-downs are timed to take advantage of low tariff periods, while letting Derceto automatically maintain safe reservoir levels. Operators can immediately see the projected impact of different duration shut-downs on reservoir level and energy costs, and interactively schedule for the most suitable period during the day.

3. CONCLUSIONS

Overall the implementation of optimisation has produced a significant change in our ability to schedule plant production while maintaining levels of service to our customers. Environmental benefits include reduced energy consumption during peak power usage periods. Assessed economic benefits for the nine months since operation can be summarised as:

Energy saving	\$40,000
Savings in network charges	\$35,000
Savings in chemical costs	<u>\$20,000</u>
Total (nine months)	<u>\$95,000</u>

These savings suggest an annual return of \$130,000 and that the investment in Derceto would be recovered within three years.

Water distribution systems have a natural capacity to take advantage of peak energy tariff systems, as reservoirs allow water to be stored for use during peak periods. As more countries turn to efficient time-of-use metering systems it is likely that optimisation systems like Derceto will become commonplace.

ACKNOWLEDGEMENTS

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