# MEASURING PUMP STATION PERFORMANCE


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## ABSTRACT

With the increased focus on reducing operating costs and minimizing greenhouse emissions, it is now more important than ever to understand how well pumping stations are performing. Most pump stations are now monitored by SCADA systems, and may have PLC control systems, and these can provide the data required to develop useful information to ensure performance of the stations is optimised.

Focusing on pump efficiency is only part of the answer, and it is necessary to look at the performance of the whole system to ensure best performance is realized. This paper demonstrates Melbourne Water's development of standard performance measurements that apply to all stations, on both the water supply and sewerage systems.

## KEYWORDS

Energy, Efficiency, Optimisation, Pumping.

## 1.0 INTRODUCTION

Melbourne Water (MWC) manages water supply catchments, treats and supplies drinking water and recycled water, removes and treats most of Melbourne's sewage, and manages waterways and major drainage systems in the Port Phillip and Westernport region. Service delivery is based on efficient resource use, and by 2018 Melbourne Water will achieve zero net greenhouse gas emissions and meet all its energy needs from renewable resources.

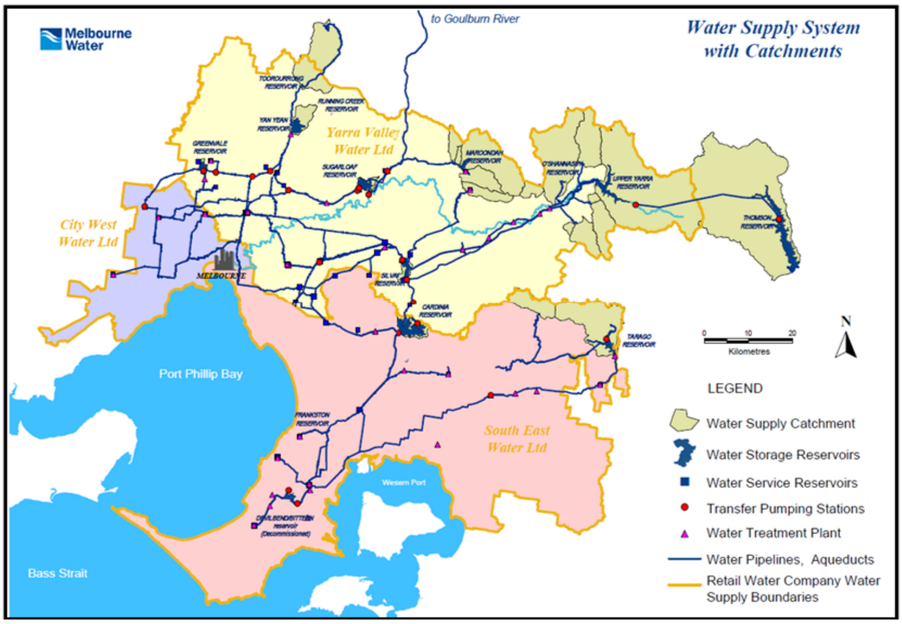


**Figure 1:** ***Melbourne Water – water supply system***

Pump operation is Melbourne Water's major use of electricity, with annual consumption for water supply of 100GWh with 40GWh sourced from mini hydros, and sewage 200GWh with 100GWh sourced from biogas generation. Electricity costs are in excess of $15M per annum.

Monitoring and analysis of pump systems to ensure they are operated and maintained efficiently is of critical importance to the business, and improved monitoring has been implemented at Melbourne Water for this task. Getting optimum performance from these assets, even those performing poorly is critical, as it has proven difficult to justify capital projects solely aimed at improving pumping efficiency on NPV evaluation.

This paper is focussed on the water supply system, but the learnings are also being applied to the sewage and recycled water systems.

## 2.0 DISCUSSION

### 2.1 Pump Efficiency

From the mid 1980's the MWC SCADA system has been providing flow, pressure and power information from major pump stations (typically with motors rated at over 1MW), and the opportunity was taken to add real-time efficiency calculations for each pump at these sites.

Smaller sites typically had flow and pressure information, but power monitoring was not available. This was addressed on a site by site basis by recording power usage at different operating heads, and developing a default power curve to use with SCADA data to enable efficiency to be calculated to a reasonable accuracy at these smaller stations. More recently, all upgrades at these stations have included power supply monitoring.

Key learnings from efficiency monitoring have been:

- All installed pumps perform noticeably below the pump factory test results, as the operating pressure readings are taken at the station header, thus including the losses in the connections to each pump.
- Many pumps were working at low efficiency, as the efficient operating range did not coincide with the actual operating range. Many of these problems were due to errors in the design system curves. One notable problem was due to a cut and paste error when the station operating manual was produced, the result being this variable speed pump was only operated at up to 60% of its design flow.
- Many of the water supply pump stations are fitted with fixed speed pumps, as they basically transfer between storages. Even so, they often have a wide range of operation due to changing system heads and transfer main losses. As shown below, even with a variable speed solution, the results were often disappointing.
- Newer stations are now more likely to have variable speed drives. This is mostly due to tighter requirements from the power supply companies requiring smoother start up of the pumps to limit impacts on the power network. While allowing hydraulic optimisation, they also waste approximately 3% of the pump input energy. It can also reduce motor and VSD size and improve station performance, especially when lift is higher than the duty point.

But the key learning was that pump efficiency was not telling us whether we were running the system efficiently, and how well energy was being used.

### 2.2 System Performance, a Real Measure

When examining pump efficiency, two major observations warranted further investigation.

1. Efficiency information does not provide real information on the cost of system operation, which ultimately is the most important aspect for the business.
2. Optimising station operation to take advantage of cheap offpeak power and reduce the cost of pumping often improves pump efficiency, but may not be justified due to changing system characteristics. Pump efficiency does not necessarily reflect overall system efficiency. Some pumps were being operated to achieve high efficiency, but this caused increased system losses, and hence increased power consumption. This was often found to be a side-effect of maximised offpeak operation.

These issues are examined by using the power and flow information to calculate the energy in kilowatt hours (kWh) required to deliver each megalitre (ML) of water through the station. SCADA can provide the kWh/ML in real-time, and the effect of multiple pump operation and changes in system pressures can immediately be identified. At larger stations where pump flows are individually monitored, comparative performance of each pump is available. Where only station flow is available, running each pump individually in turn enables the same information to be generated.

The next step with this information is to integrate it with the power tariffs, a simple exercise unless a complicated tariff structure has been implemented. This enables real-time monitoring and logging of the actual cost of operating the pump station at any time, in any configuration.

### 2.3 Benchmarking

The last step taken in this project has been to provide a measure that enables the performance of any pump to be compared against any other pump. Again this can be done in real-time using the system efficiency information already generated.

The rate of energy use to deliver the unit volume is divided by the pump lift, providing a value for the kWh/ML/metre of lift for that pump. This performance measure can then be benchmarked against the same value for all other pumps.

### 2.4 Case Study 1, Somerton Pump Station

This station consists of four 132kW pumpsets, design duty point of the pumps 13ML/day @ x 52m lift. This is the maximum offpeak operating duty point, a single pump typically runs at about 25ML/day @ 25m lift.

Figures 2 and 3 show that reduced flow due to losses in the station pipework has reduced efficiency by 5-10% when compared to the pump test performance results. A quick review of these charts suggests that multi pump offpeak operation should be maximised. But note the high lift that occurs with multi pump operation.

Figure 4 shows performance at Somerton pump station where it operated on single pump mode during peak period, and multi pump mode during off peak. Multi pump off-peak operation seems to run the pumps more efficiently, but uses 50% more power per ML than peak single pump due to system constraints. This was a lower cost option under pre 2010 tariffs. Current tariffs have a smaller premium on peak operation, making off-peak optimisation uneconomic.

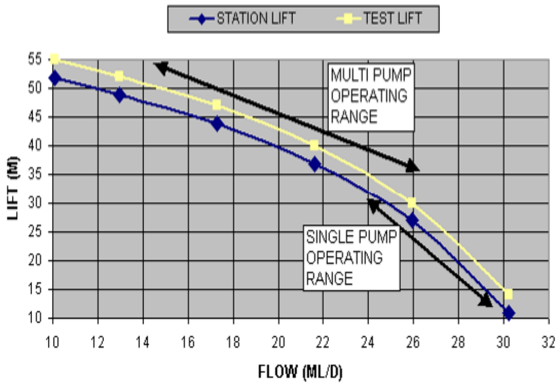


**Figure 2:** ***Somerton PS head vs flow***

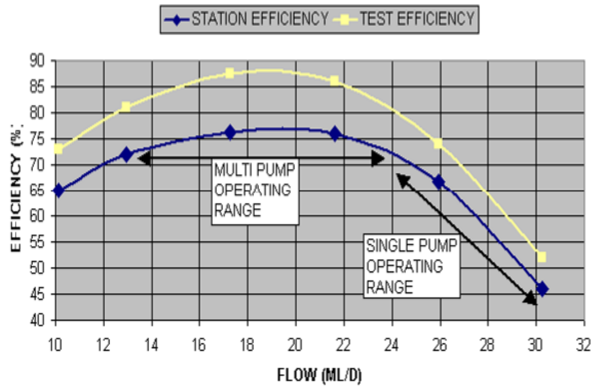


**Figure 3:** ***Somerton PS efficiency vs flow***

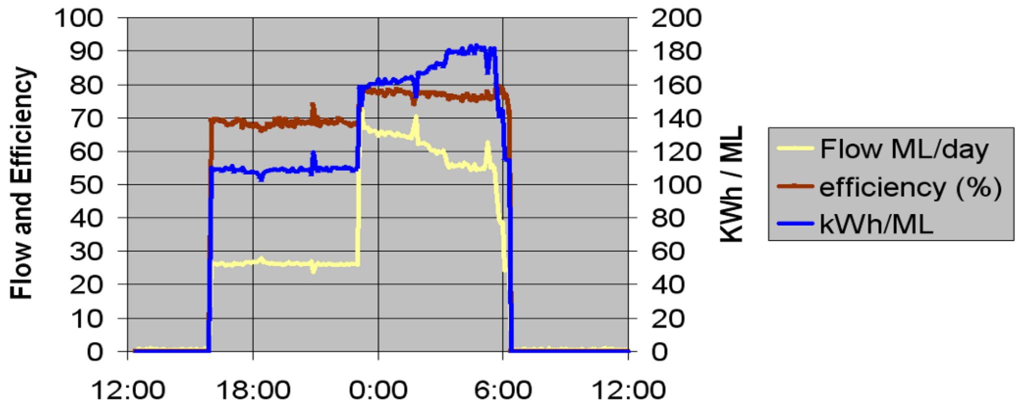


**Figure 4:** ***Somerton PS peak and off-peak performance***

## 2.5 Case Study 2, South Morang Pump Station

South Morang pump station is an example of where the design operating head was very different from actual conditions. The station was running at efficiencies around 55%, despite the pumps having design efficiency ranging from 70-85%. Figure 5 shows the design lift range of the station was 15-70 metres, but in practice lift is 15-30m. The variable speed pumps were running off the end of their curves to meet the required flow at low lift with greatly reduced efficiency. The old variable speed drives (VSD) were also found to be operating inefficiently. A renewals project was initiated due to obsolescence issues (lack of spare parts) for the existing VSDs, which provided the opportunity to upgrade the station with smaller fixed speed pumps which run at acceptable efficiency.

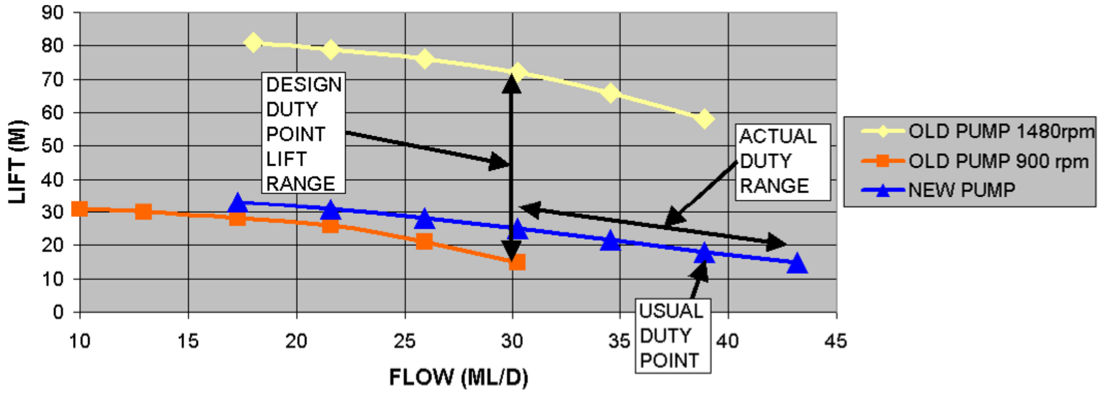


**Figure 5:** ***South Morang 300kW variable speed pump and 110kW fixed speed pump***

## 2.6 Case Study 3, Silvan-Seville Pump Station

This station consists of three (two duty, one standby) 150kW pumpsets, design duty point of the pumps 6.5ML/day @ x 110m lift. The pumps were found to be operating at 50% efficiency, due to two main factors. The pump operating duty point was down the curve from the design duty point, and there were significant losses on the station pipework. The loss in capacity was significant enough to justify remedial action through NPV analysis. Pump 1 was not modified, pump 2 was fitted with new connecting pipework, and pump 3 was replaced with a lower lift pump more suited to the required duty and new connecting pipework.

Table 1 shows the higher flow results in the pumps having to generate more lift, but higher efficiency results in much better performance with the more suitable pumpset. Duty pump selection is now highly biased towards pump 3, and operating levels have been set to maximise single pump offpeak operation, and minimise multiple pump operation.

**Table 1:** ***Comparative performance of Silvan-Seville PS pumpsets***

| PUMP No. | Flow ML/day | Lift (m) | Power (kW) | Efficiency (%) | kWh/ML | kWh/ML/ m lift |
|---|---|---|---|---|---|---|
| 1 | 6.95 | 74 | 114 | 51 | 394 | 5.32 |
| 2 | 7.7 | 77 | 122 | 55 | 380 | 4.94 |
| **3** | **9.55** | **83** | **125** | **71** | **319** | **3.85** |
| 2 & 3 | 11.9 | 100 | 200 | 66 | 420 | 4.20 |
| 1 & 2 | 11.0 | 93 | 206 | 56 | 451 | 4.51 |

## 2.7 Case Study 4, Winneke Reservoir Pump Station and Supplementary Pump Station

Winneke Reservoir PS (RPS) supplies the Winneke Treatment Plant at up to 650ML/day, and has three 1600kW pumpsets. The Supplementary Reservoir PS was built to improve operational flexibility, and allow the RPS to be taken partially off-line for a major upgrade.

The RSPS has three 360kW pumpsets. All pumpsets can be operated in any combination, and a project is underway to use the system performance measurements to enable pump operating regimes to be optimised.

Energy use for the different stations at is shown in Figure 6. Together the two stations use 6000-9000MWh annually, so efficient operation can yield considerable savings.

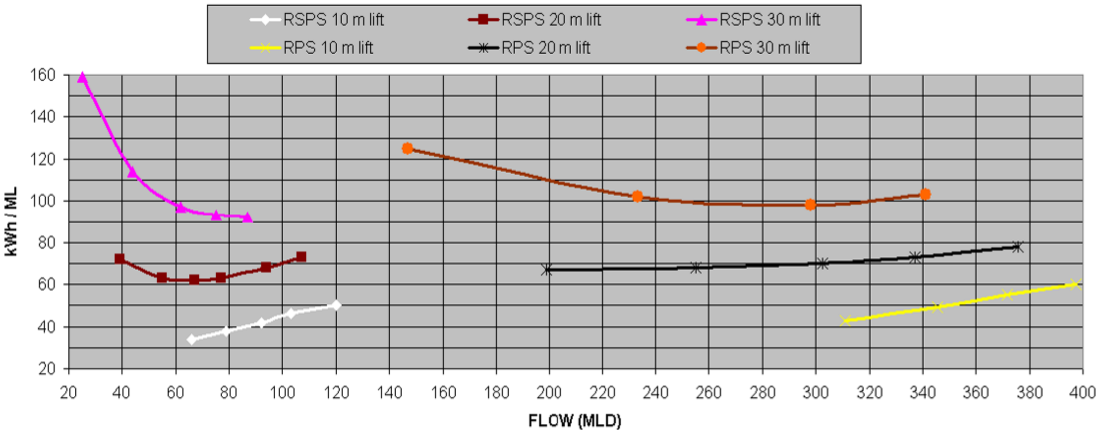


**Figure 6:** ***Winneke RPS and RSPS energy / ML at different pump lifts***

## 2.8 Case Study 5, Cardinia Pump Station

Cardinia PS is a 350ML/day capacity transfer pump station between Cardinia Reservoir and Silvan Reservoir. The station contains three 1500KW pumpsets. The station control system has been designed to provide operators with the choice of whether to run the station to achieve the best energy usage, or when necessary to achieve maximum possible transfer.

Figure 7 shows how the operating speed of the VSD is varied depending on the Cardinia Reservoir level, which affects the lift required at the PS. The capabilities of the VSD were also used to enable the motor and drive size to be reduced from 1800kW to 1500kW. Station performance has been improved by running the pumps overspeed at higher lift to increase flow, and limiting speed when lift is low to keep the pump operating within recommended limits, even with the reduced motor size.

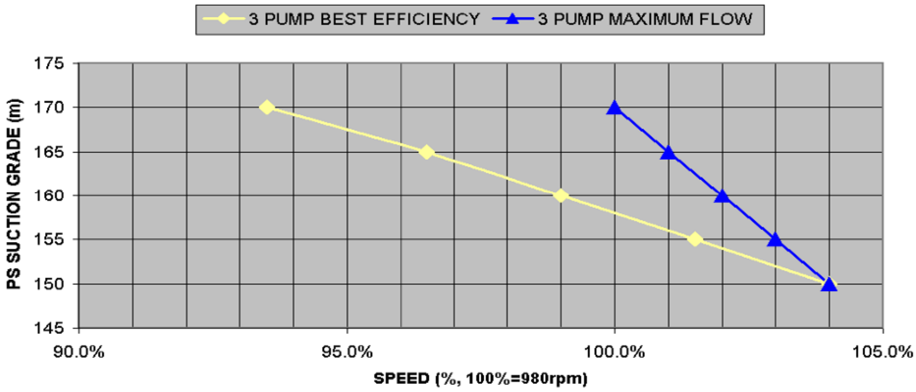


**Figure 7:** ***Cardinia PS, variable pump speed setpoint as suction grade changes***

## 3.0 CONCLUSIONS

The development of these pump system performance measures has greatly improved the understanding of how these stations are performing, by using the Melbourne Water SCADA system to transform data into a range of useful diagnostic information. By using the data available to generate performance measures such as energy per megalitre pumped and energy per megalitre per metre of lift, and having this data available in real-time, together with efficiency and basic station information, Melbourne Water has been able to ensure it is optimising system operation and energy, both from a cost and greenhouse perspective.

Additional benefits have included using the increased understanding of pump performance to optimise maintenance inspection and overhauls, and information to assist with power use forecasting and power contract negotiation.

Being able to produce this information on SCADA in real-time has proven beneficial, as it provides access to all users and can have alarm triggers added to the calculated values. To a large degree, all this information can also be produced periodically from manual site readings using simple Excel spreadsheets when SCADA is not available.


## 4.0 ACKNOWLEDGEMENTS
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