WINNEKE FILTERS
THE ROAD TO BETTER BACKWASH

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ABSTRACT
After almost 30 years of operation, by 2010, the Winneke treatment plant filter media had reached the end of its life with a project initiated for full media replacement in 12 of the plant's 16 rapid sand filters.

In the subsequent years after this project, significant deficiencies were identified that, if not adequately addressed, could have substantial impacts on filtration efficiency resulting in increased risk of pathogen breakthrough.

This paper addresses some of the impacts faced when undertaking such a project without first conducting a robust review of the efficacy of the existing backwash regime.

1.0 INTRODUCTION
The Winneke Treatment Plant is situated in Victoria and provides up to 30% of Melbourne's potable water supply. The plant was constructed in 1980 with a current design capacity of 560 megalitres per day (ML/D) with coagulation and filtration being the two main mechanisms for removal of Protozoa followed by post chlorination for inactivation of virus and bacteria.

Figure 1: ***Winneke Treatment Plant, Clarifiers & Filters***

1.1 Description of the Winneke Filter design;
The Winneke filters are a mono-media design with 3 grades of support gravels and 1 meter depth of filter sand.

They are a closed plenum arrangement with a "D" type floor design with two beds each containing 2200 filter nozzles which protrude into 100 lateral pipes per filter bed. The backwash sequence consists of three minutes of air scour followed by six minutes of washwater.

Backwash Step	Air Scour Blower [Capacity 15L/s at 40 kPa]	Wash water pump(s) [Capacity 470 L/s at 10m head]	Duration
1	Blower - 36.7 m^3/h	Off	3 mins.
2	Off	2 Pumps - 22m^3/m^2/hr (900 L/s)	6 mins.

Media Type	Effective size	Uniformity coefficient	Support Gravels
Silica based sand @ 1000mm depth	0.62mm	< 1.3	3 layers of Quartz pebbles: 75mm of 1.5-3.0mm 75mm of 3.0-6.0mm & 100mm of 6.0-12mm

Table 1: ***Winneke filter backwash process and media specification***

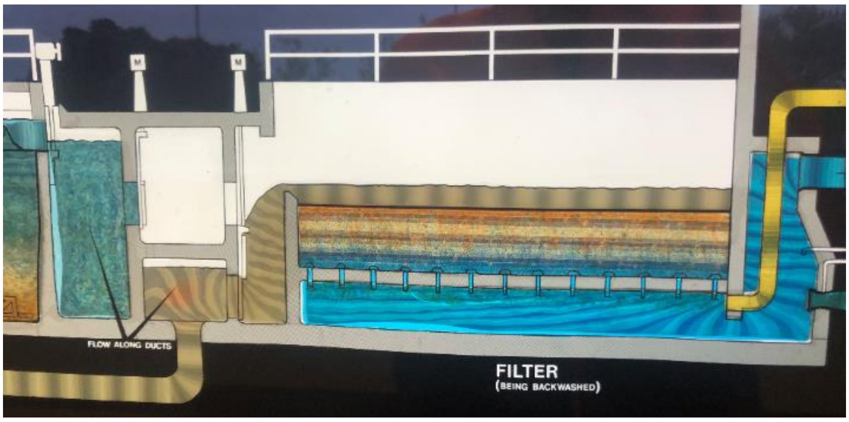

Figure 2: ***Schematic of Winneke filter in backwash mode***

In 2009/10, a project commenced to replace the original filter media in filters 1-12 noting that filters 13-16 had only been in service since 2008. This involved replacement of all filter nozzles, support gravels and sand media as well as raising the height of the backwash launders.
During a subsequent filter inspection program in 2015, operators identified a number of significant deficiencies relating to media appearance and backwashing, including;

- Boiling and displacement of the filter media due to trapped air in the plenum space;
- Media loss into the plenum chamber and backwash launder;
- Media blocking lateral pipework and nozzles leading to high solids retention and media cracking;
- Inadequate washwater flow rates for media fluidisation and expansion;
- Ineffective washwater draw across the filter resulting in poor turbidity profiles and extended backwash times;

Despite these issues, analysis of filter performance showed there was no immediate or impending water quality risk evident. Filtrate turbidity and filter headloss trends continued to show good filter performance with filtrate turbidity often less than 0.1NTU. Backwashing was typically triggered based on a set filter runtime rather than turbidity or headloss limits, with the exception of isolated events.
The Winneke Operations Team were still, however presented with the immediate challenge to improve the efficiency of the backwashing program in order to minimise gravel disruption, improve washing of the media and achieve effective fluidisation and expansion during the washwater cycle.
The main question they faced was what could be done in a short period of time using the existing plant infrastructure to prevent further degradation of the recently replaced filter media.

2.0 DISCUSSION

Throughout the 2015 filter inspection program, the above issues became acutely apparent with deep cracks beginning to form in the filter media increasing the risk of short-circuiting and potential reduction in pathogen log removal. Evidence of mud balls and mud below the filter surface was seen indicating that the filters were not cleaning effectively. Supporting gravel was also found near the surface of the filter media indicating significant disruption to the layering of the support media.
As a result, several projects were identified in an effort to reverse these issues and delay the need to replace the filter media including:

- Introduction of an air scour ‘Pause Timer’ to allow much of the residual air in the plenum space to vent to atmosphere prior to introduction of the washwater.
- Use of Variable Speed Drives (VSDs) to control ramping of the backwash pumps and reduce the volume of air being forced through the filter media.
- Increasing washwater flowrate by changing the existing pump operation improving media fluidisation and expansion.

- Changes to backwash penstock opening sequence resulting in improved solids removal and reduced washwater volumes.

The impact of these issues and the solutions implemented are described below;

2.2 Boiling and displacement of the filter media due to trapped air in the plenum space.

At the completion of the backwash air scour phase a significant volume of air remained trapped within the filter plenum space. Originally, washwater was introduced by two backwash pumps, starting up within 20 seconds of each other, reaching a combined flow rate of 900L/s within less than one minute.

This resulted in the volume of trapped air being forced through the filter media at a rate much higher than that normally delivered during a typical backwash. The high volume air flow resulted in the disruption of supporting gravels and excessive localised boiling leading to media carryover into the backwash launder throughout the washwater cycle.

Figure 3: ***Boiling occurring due to rapid onset of the washwater pumps***

The excessive boiling and disruption of supporting gravels had two major impacts;

Sand media carried over into the backwash launder was deposited in downstream systems such as the washwater recovery tanks, sludge thickeners and centrifuge feed systems. This led to blockages in desludge pipework and accelerated wear on the sludge thickener and centrifuge feed pumps.

Figure 4: ***Sand build up in washwater recovery tank 1***

The disruption of supporting gravels also resulted in sand media washing through, and often blocking, filter nozzles with media being deposited in the filter lateral pipes and filtered water plenum space. This further exacerbated the ineffectiveness of the backwash cycle leading to localised areas of extreme mud deposits throughout the depth of the media. Subsequent filter inspections revealed that the solids retained within these areas after a backwash were often in the range of 30-50% which is far in excess of the recommended value of 5-10% solids retention. This level of mud layering throughout the depth of the media also resulted in significant surface cracking increasing the risk of short circuiting and potential for pathogen breakthrough.

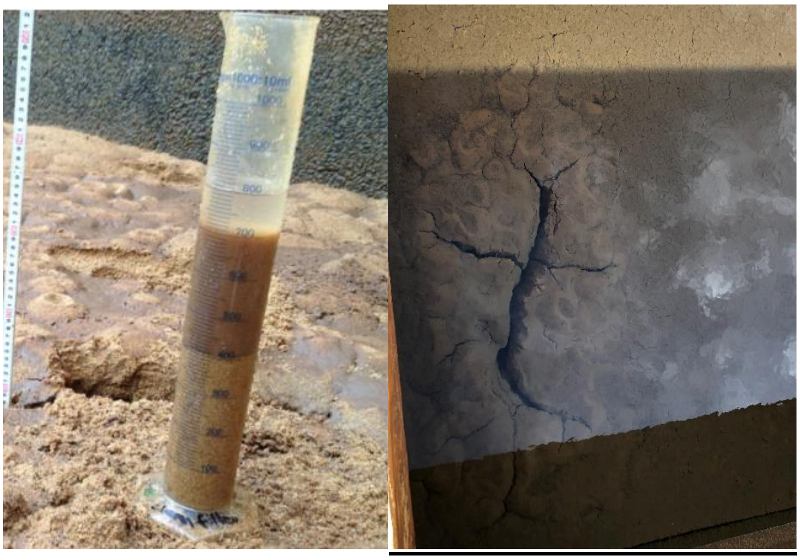

Figure 5: ***Solids retention test & media surface cracking***

Figure 6: ***Blocked filter nozzle and sand build up in lateral pipework***

In order to reduce the impact of excess air being forced through the media, two fundamental changes were made to the backwash programmable logic controller (PLC) program.
Previously, air relief valves relieved excess pressure in the air manifold whilst the filter air inlet valves remained shut. The PLC program was modified to hold the air inlet valves open during the air relief process allowing the trapped air within the filters to equilibrate to atmospheric pressure before washwater is introduced. This then reduced the amount of pressurised air being pushed through the filter during the washwater process therefore reducing the amount of disturbance to the media and subsequent media loss. This change alone has resulted in significant reduction in sand carryover and its impact on downstream recovery systems.
The second PLC change involved optimisation of the existing backwash pump VSDs to progressively ramp up the introduction of washwater thus squeezing the trapped air out through the filter nozzles without over pressurising it. This simple change significantly reduced the boiling effect and subsequent disruption of the support gravels and media loss.

2.3 Inadequate washwater flow rates for media fluidisation and expansion.

The original washwater phase of the backwash cycle consisted of three backwash pumps operating in a Duty/Assist/Standby mode, providing 900 L/s of washwater flow. This equates to a rise rate of around $22m^3/m^2/hr$ which is far lower than the typical minimum of $37m^3/m^2/h$ recommended for rapid sand filters. Whilst bed fluidisation in excess of 90% was being achieved, bed expansion was typically around 7-9% which is much lower than the 20-30% expansion required for effective removal of suspended particles and enabling reclassification of the sand and gravel layers.

It should be noted that the limited walkway access to the filters meant that fluidisation and expansion tests could only be conducted at one location at the inlet end of the filter. Where tests could be conducted at the outlet end, the results showed poor fluidisation at around 50% and expansion typically below 5%.

This situation was marginally improved by modifying the backwash program to operate all three pumps in a Duty/Duty/Assist configuration. The result of this was an increase in washwater flows from 900 to 1200L/s increasing the rise rate from 22 $m^3/m^2/h$ to up to $30m^3/m^2/h$.

Whilst this still falls short of the desired 37 $m^3/m^2/h$, This was the maximum flow achievable given the hydraulic constraints of the existing backwash pumps, concrete ducts and associated valves and pipework.

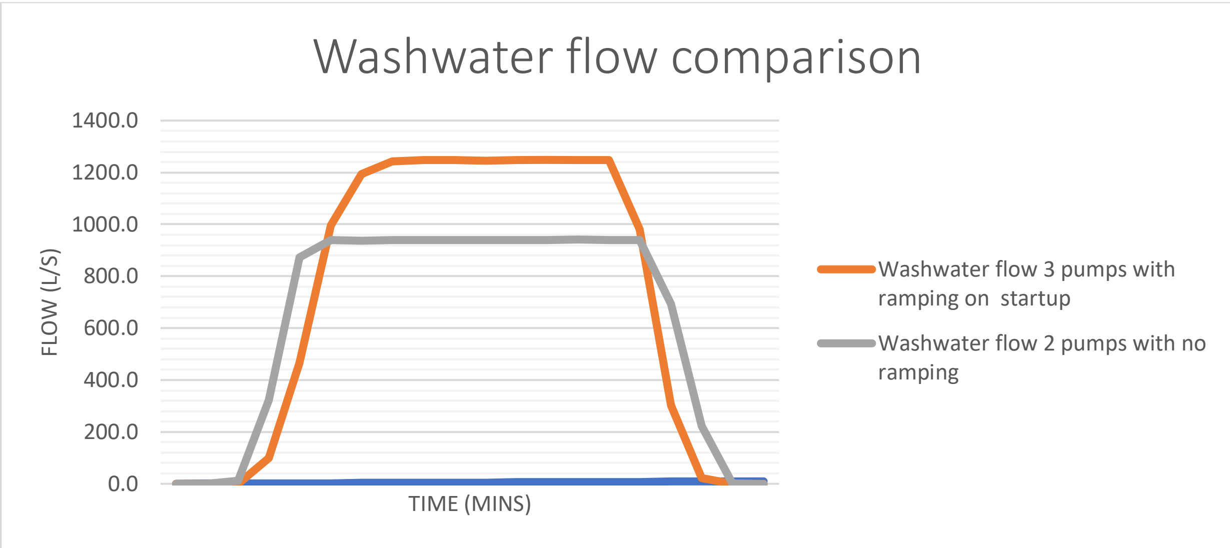

Figure 7: ***Backwash flow data comparing 2 pumps @ 900 L/s with 3 pumps @ 1200 L/s***

2.4 Ineffective washwater draw across the filter;

During the previous filter backwash program the opening of the backwash outlet penstock was delayed to allow the incoming washwater to fill the filter to approximately 300mm above the backwash launder before the penstock begins to open. This practice was thought to have been introduced in an attempt to prevent filter media from washing over the launder. The actual effect of this deferred opening delays the wash over of turbid backwash water into the launder and allows suspended solids to settle back onto the media surface resulting in poor turbidity profiles and extended backwash times. It is much more efficient to allow the washwater to enter an empty launder as soon as it is introduced to the filter.

In order to rectify this issue the backwash PLC program was amended to ensure the backwash outlet penstock opened immediately upon start-up of the backwash pumps. This resulted in a significant reduction in the washwater time required to reach a nominal 10 NTU, of up to two minutes. An opportunity was therefore presented to reduce the washwater phase from six minutes down to four minutes equating to a potential reduction in washwater volumes of up to 30%.

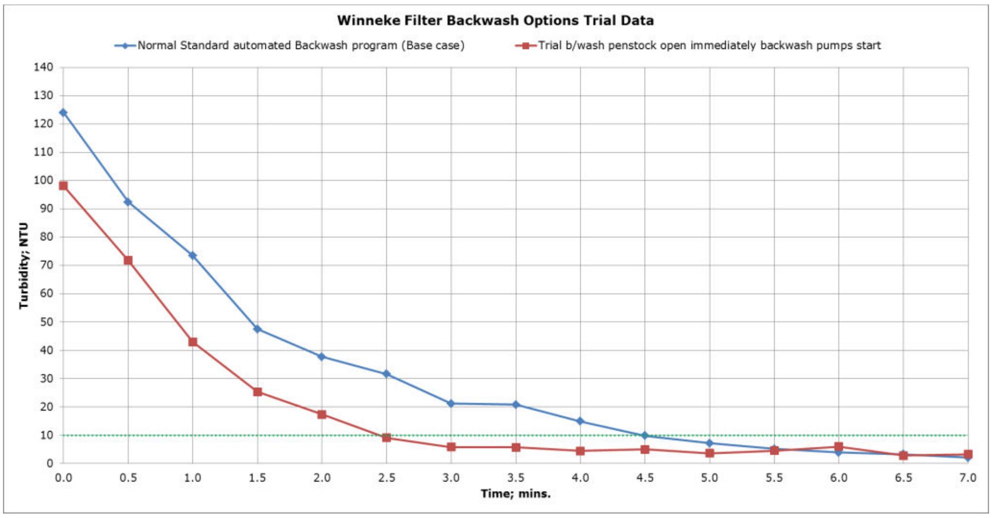

Figure 8: ***Turbidity profile data comparing delayed opening of the backwash penstock with immediate opening on start up of the washwater phase.***

3.0 CONCLUSION

There have been ongoing issues with the performance of the Winneke filters following their renewal in 2010 and a number of changes have been made to the operating regime during this time. These changes have considerably improved the effectiveness of the backwash cycle by reducing the disruption of the filter support layers and volumes of lost media. Unfortunately they have not been completely successful in halting the localised degradation of the filter media, particularly at the outlet end of the filters. This is thought to be largely due to the inability of the current backwash pumps and pipework to provide the required rise rates to ensure sufficient fluidisation and expansion of the current sand media. This results in poor backwash performance and inability to remove embedded mud layers from the filter media.

The other contributing factor is the deficiencies in the original civil design of the filters which results in a localised low pressure zone within the plenum space as the washwater enters the plenum. This low pressure zone together with the insufficient washwater flows results in poor washing of the filter media at the immediate end of the filter where the washwater is introduced.

At the time of publication of this paper, Melbourne Water has embarked on a new project to refurbish the Winneke filters. This project will seek to address a number of key issues including:

- Pilot trials of alternative media combinations to maximise filter run times and ensure effective backwashing within the current limitations of the existing equipment.
- Computational Fluid Dynamics, (CFD) modelling of backwash flows within the filter plenum and lateral pipework.
- Investigation into alternative filter floor designs.
- Enhancement of current backwash program including collapse pulse backwashing.
- Improvements to upstream clarification processes including optimisation of aluminium sulphate and polymer dosing systems.
- Aluminium chlorohydrate dosing trials for reduction of excess polymer within the filters.
- Installation of baffles within the filter plenum to improve flow distribution and address localised low pressure zones.
- Full media replacement for all 16 Winneke Filters.
- Installation of additional walkways to aid in filter inspection & maintenance activities.

4.0 ACKNOWLEDGEMENTS

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5.0 REFERENCES

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