PRODUCING SAFE DRINKING WATER FROM THE DYNAMIC FITZROY RIVER

Paper Presented by:

Jason Plumb

Authors:

Jason Plumb, *Manager Process Operations,*
Paul Wilson, *Manager Process Maintenance,*
Mark Percy, *Process Technical Officer,*
Michael Dalton, *Treatment Plant Supervisor,*

Fitzroy River Water

35th Annual Qld Water Industry Operations Workshop
Community Sports Centre, CQ University, Rockhampton
22 to 24 June, 2010

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ABSTRACT

The Fitzroy Basin is the second largest catchment in Australia. It consists of numerous river systems that drain areas which vary significantly in their geology, land use practice, and rainfall patterns. As a result of this catchment diversity, the origin of flows in the basin has a strong influence on the quantity and quality of water that enters the lower Fitzroy. The Fitzroy River Barrage impoundment serves as the water source for both the Rockhampton and Capricorn Coast Water Supply Schemes. With ever increasing water quality regulation and scrutiny on water service providers, maintaining a safe supply of drinking water from a dynamic river system such as the Fitzroy requires an array of skills and expertise. Specific challenges include, treating raw water turbidity that can vary by more than three orders of magnitude, responding to flood events, and dealing with prolonged cyanobacterial blooms. Here we describe our response to some of these challenges and discuss future issues that will impact the supply of safe drinking water from the Fitzroy River.

KEYWORDS

Catchment, cyanobacteria, turbidity, conductivity, treatment, filter.

1.0 INTRODUCTION

1.1 Fitzroy River Basin

The Fitzroy Basin is the second largest catchment in Australia behind the Murray-Darling system. The basin extends almost 600 km in the north-south direction, more than 450 km in the east-west direction and covers approximately 142 600 km^2. The Fitzroy Basin contains six major sub-catchments: the Isaac/Connors in the north, the Nogoa, Comet and Mackenzie in the west and centre, the Dawson in the south, and the Fitzroy in the east of the catchment. The Fitzroy River delivers flows from across the basin into the ocean at the southern end of the Great Barrier Reef.

Each of the sub-catchments drains areas of the basin that vary in climate, geology, vegetation type and land use. Average annual rainfall across the basin varies between 600 mm in the west, 800 mm in the east and 1000 mm in the north with most rain falling between the months of November and April. River flow patterns through the basin are characterised by extended periods of little or no flow punctuated by short periods of very high flow. On average around 4800 GL flows out of the basin each year, with daily discharge volumes in excess of 250 GL during moderate or major flood events which occur on average every five years.

The basin supports a range of land use activities that include conservation and forestry, grazing and cropping, mining and urban development. These activities and land use practices together with prevailing geology and rainfall patterns determine the quality of water throughout the river systems.

Water quality at different locations within the basin or during flow events from these locations varies accordingly.

1.2 Glenmore Water Treatment Plant

The Fitzroy River Barrage and Glenmore Water Treatment Plant (GWTP) were constructed in 1971 to supply drinking water to Rockhampton and surrounding areas and to provide water for irrigation by rural users. The barrage separates the tidal estuary from the fresh water and provides a total storage volume of 81.3 GL. The GWTP has a conventional process design that includes two parallel process trains of coagulation, flocculation and sedimentation prior to filtration and disinfection. Coagulation and flocculation is achieved through addition of a polyaluminium chlorhydrate coagulant and non-ionic synthetic organic polymer. Coagulation is monitored using measurements of streaming current to enable fine tuning of coagulant dosing and helps to detect significant changes in raw water quality. A coal-based powdered activated carbon is dosed pre-flocculation as required. Clear water is produced by filtration through 10 dual media sand and garnet filters. Following filtration, pH is corrected by addition of lime prior to disinfection using gaseous chlorine. Fluoridation of water commenced at GWTP in December 2009 via the addition of sodium fluorosilicate. GWTP has a design capacity of 140 ML/d and produces approximately 50 ML/d on average.

1.3 Raw Water Quality in the Fitzroy River Barrage

The GWTP produces safe drinking water despite significant variation in raw water quality. The dynamic and highly diverse nature of the Fitzroy Basin leads to dramatic changes in the quality of water that enters the Fitzroy River Barrage storage depending on the origin of flows into the lower Fitzroy and other associated events. Table 1 provides an indication of the changes in raw water quality in the Fitzroy River Barrage following flows from two of the major sub-catchments (Dawson and Isaac/Connors), and following the release in 2008 of mine water from the Ensham mine in Central Queensland. Turbidity, pH and alkalinity vary significantly depending on the source of flows into the lower Fitzroy River. The Dawson River has produced flows with turbidity greater than 1000 NTU on a number of occasions. The volume, timing and rate of flows from different sub-catchments have the potential to cause rapid changes to the quality of raw water entering the GWTP. For example, changes in turbidity of more than 300 NTU within 24 hours have been observed with the arrival of flow fronts in the Fitzroy River Barrage.

Table 1: ***Variation in raw water quality in the Fitzroy River Barrage due to the source of flow events***

	Source of flow		
Parameter	**Dawson River**	**Isaac/Connors Rivers**	**Ensham Mine**
pH	7.0-7.6	7.1-7.8	8.0-8.4
Turbidity (NTU)	> 800	150-400	<20
E.C. (µS/cm)	100-250	150-300	> 800
Alkalinity (mg/L $CaCO_3$)	40-60	60-100	140

The discharge of around 138 GL of water from the Ensham Mine in 2008 was a unique

event which led to significant changes in water quality throughout parts of the basin.
Of particular concern was the elevated level of dissolved salts which led to electrical conductivity values in excess of 1000 μS/cm in some locations, and had a significant negative effect on water aesthetics. In the absence of follow-up rainfall and river flows, the poor water quality caused by the Ensham event extended for several months in late 2008 until flows in early 2009 flushed this water from the basin.

The Fitzroy River Barrage is an unprotected surface water storage. Local land use activities including cattle grazing contribute to the input of nutrients and potential pathogens and contaminating substances into the storage. Typically the barrage storage experiences annually an extended period where raw water quality is impacted by the growth of algae and cyanobacteria. As raw water turbidity decreases during extended periods of no flow, sufficient levels of nutrients and fine calm weather create ideal conditions for the development of algal blooms that can last for more than 6 months. Numerous species of green algae and cyanobacteria proliferate and cause changes to raw water quality. These changes include increases in pH, production of undesirable tastes and odours and the potential formation of cyanobacterial toxins by species of *Anabaena* and *Cylindrospermopsis*. Each of these changes tests the effectiveness of the GWTP to produce high quality safe drinking water.

The following information discusses two recent process upgrades that have been made to improve the effectiveness of the GWTP in order to ensure production of high quality safe drinking water and provides comment on the likely future requirements for treatment process upgrades.

2.0 DISCUSSION

2.1 Addition Of Filter-To-Waste Functionality

The original design of the filters in the GWTP made no specific provision for optimising the return to filter production following backwashing. As a result the quality of water produced by individual filters following backwashing often exceeded 1 NTU for periods in excess of 30 minutes until filter ripening occurred to the extent required to reduce outlet turbidity to target levels. An outlet turbidity setpoint of 0.8 NTU had been used to initiate filter backwashing or the filter reduced flow function in order to overcome the reduction in filter performance. The poor quality water produced by each filter following backwashing led to the initiation of a project to install filter-to-waste functionality to each of the 10 filters.

Pneumatically-actuated filter-to-waste valves and associated pipework was installed to permit the diversion of filter outlet flows into the backwash waste drain. The valves were connected to the existing plant programmable logic controller (PLC) to enable the operation of the filter-to-waste valves to be incorporated into the existing filter backwash cycle. A number of individual steps were incorporated into the filter backwash cycle to control the wasting of the initial water produced by each filter following the backwash rinse cycle until a selectable turbidity setpoint is achieved, Once this turbidity target is achieved the filter-to-waste valves are closed and the outlet valves are opened to resume production of water through the filter. Measures were taken to allow for gradual opening and closing of valves to prevent hydraulic shocks that would cause disturbances to the filter ripening process. Selectable time settings were included to vary the amount of time for each individual step and to allow for short-lived elevated turbidity readings.

The filter water quality performance targets in the USEPA Long Term 2 Enhanced Surface Water Treatment Rule, (2006) have been adopted for filters at the GWTP. The USEPA rule states that no individual filter should have a measured turbidity level greater than 0.3 NTU in two consecutive measurements taken 15 minutes apart. The USEPA adopted this turbidity target following extensive research to define "safe" turbidity thresholds beneath which the presence of key potential pathogens such as *Giardia* and *Cryptosporidium* spp. is minimised. Through the addition of the filter-to-waste functionality at the GWTP, individual filters are now able to meet this USEPA turbidity performance target. Individual filters consistently produce water with turbidity less than 0.3 NTU, and often less than 0.1 NTU when returned to service. It is expected that the improvements in the quality of water produced by each filter following backwashing have reduced the penetration of chlorine resistant pathogens such as *Giardia* and *Cryptosporidium* through to the final water. This is likely to become an important consideration as stricter water quality guidelines are adopted in years to come.

2.2 Upgrade Of Filter Media For Improved Performance

The presence of high numbers of cyanobacteria in raw water tests the ability of the GWTP to continuously produce high quality drinking water. The pre-treatment of cyanobacteria using algicides or disinfectants is no longer the preferred option at many treatment plants, due possible release of cyanobacterial toxins upon cell death. Optimising the addition of coagulants and flocculant aids is a reasonably effective means of removing algae and cynaobacteria during via the sedimentation process, although diurnal or more frequent changes in the abundance and diversity of cyanobacteria in raw water due to the formation of surface scums or vertical movement of cyanobacteria through the water column are not easy to predict. In conventional treatment plants without membrane filtration one option is to improve the effectiveness of the existing filters to enable removal of cells such as cyanobacteria and similarly sized microbial cells.

Historically at GWTP, raw water containing cyanobacteria at >20,000 cells/mL led to final water cyanobacterial counts of >1000 cells/mL. During severe cyanobacterial bloom events, raw water counts are known to exceed 100,000 cells/mL, with proportionately higher final water counts. While there is currently no guideline value for numbers of cyanobacteria in drinking water, failure to remove cyanobacteria from final water has the potential to lead to taste and odour problems and may cause the release of toxins from cyanobacteria during the disinfection process. Small cells such as cyanobacteria penetrate though coarse filter media especially when turbidity is low and filter pore spaces remain clear. *Cylindrospermopsis raciborskii* appears to be especially adept at penetrating sand filters. This is probably due to the relatively small, slender cell morphotype that this species possesses. In recent years many treatment plant operators have opted for filter media of increased effective size (ES) that allow greater water production capacity to meet growing demand. The change to filter media of increased ES generally reduces the ability of filter media to remove fine particle sizes within the 10-30 μm and a number of studies show this to be the case. Filters at GWTP contained an 800 mm depth of sand with an ES of 0.9-1.0 mm placed on top of three layers of silica gravel (combined depth of 300 mm) of appropriate size.

A decision was made to install fine media with a smaller ES to improve the ability of the filters to remove cyanobacteria and other small particles. This upgrade was achieved by installing a 200 mm depth of fine garnet media (ES = 0.3-0.4 mm) beneath a 600 mm depth of the existing sand.

The existing sand was retained as it generally performs well during periods when raw water contains no cyanobacteria. In order to provide a suitable support for the fine garnet layer, three layers of garnet gravel were installed to replace the existing silica gravel. The garnet gravel layers consisted of 100 mm depths of each of 0.6-1.2 mm, 1.2-2.4 mm and 2.4-4.8 mm size fractions. The new filter media configuration is shown in Figure 1. Garnet has a specific gravity of 3.8 compared to that of 2.65 for sand. This promotes the settling and retention of the garnet gravel and fine garnet layer respectively beneath the silica sand media. Garnet is an extremely hard material and although expensive, it is expected that the garnet media will last a very long time before needing to be replaced. Removal of all sand and gravel layers from each filter was achieved using a combination of a venturi-style sand pump and a vacuum truck. New garnet media was added to the filters using a concrete pump and covered with sand media using the sand pump.

Sand ES = 0.9-1.0 mm 600 mm depth
Fine Garnet ES = 0.3-0.4 mm 200 mm depth
Garnet Gravel ES=0.6-1.2 mm 100 mm depth
Garnet Gravel ES=1.2-2.4 mm 100 mm depth
Garnet Gravel ES=2.4-4.8 mm 100 mm depth

Figure 1: ***New filter media configuration at Glenmore Water Treatment Plant.***

The upgraded filters showed a considerable improvement in performance during the cyanobacteria season that extended throughout the second half of 2009. Penetration of the filters by *Cylindrospermopsis raciborskii* was observed in only one out of more than 10 sampling events, with less than 100 cells/mL detected. The improved filtration in the upgraded filters is reflected by an increased rate of loss of head when treating raw water containing cyanobacteria. No significant loss of production capacity has been observed due to the upgrade of filter media with the plant still able to achieve design capacity.

3.0 CONCLUSIONS

Although now middle aged, the GWTP is capable of producing safe drinking water from what is often a highly variable Fitzroy River. Recent process upgrades have increased the ability of the GWTP to continuously produce safe drinking water. It is hoped that these upgrades will enable to meet the anticipated introduction of stricter guidelines for turbidity and log removal of potential pathogens following the current revision of the Australian Drinking Water Guidelines. While recent upgrades improve the ability to treat raw water with increased abundance of cyanobacteria or similar microbial cells, the removal of elevated levels of dissolved salts from the raw water is not possible using the current process design. The management of water quality throughout the Fitzroy Basin is therefore an important part of ensuring the long term effectiveness of the GWTP.

4.0 ACKNOWLEDGEMENTS

The authors acknowledge the excellent work of the Process Operations and Process Maintenance team at Fitzroy River Water to deliver the upgrade projects described above.