Banana SHIRE
SHIRE OF OPPORTUNITY

Theodore WTP

Planning Report

July 2010

CITY WATER TECHNOLOGY PTY LTD
Water and Environmental Specialists

Quality System
Quality Endorsed Company

Banana Shire Council
Theodore WTP Planning Report

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Overview

This report outlines the investigations undertaken by City Water Technology on the Theodore WTP. Issues and outcomes from the study are summarised below.

WTP Flow Rate and Demand Issues

The design flow rate of Theodore WTP is 27 L/s. Because of raw water pump capacity limitations the WTP normally operates at 18 – 24 L/s, which is sufficient to meet current maximum daily water demands.

Very high river levels in early 2010 allowed the WTP to run at 27 L/s for several days. Adequate process performance was reported at 27 L/s, although further extended trials could be undertaken to confirm performance under various conditions.

Council expects some future development in Theodore, which may result in moderate increases in water demand. The full WTP design flow rate of 27 L/s is expected to be well able to meet likely future demands.

Water Quality Issues

A review of the raw water and WTP treated water quality found that:

- Raw water issues include very high turbidity and colour from river flow events, periodic high manganese levels and taste and odours. Herbicides are known to be present. Algal toxins are a potential risk;
- WTP treated water typically meets target values, with periodic excursions on treated water turbidity and true colour. The chlorine residual measured after the clear water tanks is highly variable and low residuals may sometimes compromise disinfection. Manganese targets are occasionally exceeded;
- *E.Coli* has been detected in several samples from the reticulation system, which indicates disinfection failure and/ or faecal contamination and the potential for consumers to be exposed pathogens;
- Herbicides have been present in treated water, sometimes at levels exceeding the ADWG recommended level;
- From modelling of corrosivity potentials, the typical treated water is likely to be only mildly corrosive except under worst case conditions.

WTP Process, Chemical Systems and Operational Issues

A review of the WTP treatment processes and chemical dosing systems found that:

- Most of the plant components are sized to achieve the design flow of 27 L/s. The raw water pumps limit the achievable flow rate, particularly at low river levels.
- Of the chemical dosing systems, the capacity of the pre- and post-chlorine dosing systems and the lime system would need to be upgraded to allow the expected range of doses at WTP design flow rates of 27 L/s.
- Plant control and automation, safety and maintenance issues were also reviewed, with various recommendations identified in section 7 of this report.

Recommended Actions

The recommended high priority and capacity upgrade actions are listed in the following table, with indicative budget costs given where appropriate. Refer to Section 7 of this report for further details.

High Priority and Capacity Upgrade Actions and Indicative Budget Costs

Action	Budget Cost	Notes
High Priority		
Re-enable critical callout alarms to provide out-of-hours indication of faults	Council to carry out internally, with assistance if required	-
Follow up any further *E.Coli* detections urgently to identify and address any issues leading to inadequate disinfection and/or faecal contamination of the treated water		
Online chlorine residual meter purchase, installation, connection to SCADA system, commissioning and set up of alarms	$10,000	Estimate
WTP Capacity Upgrade		
New raw water pumps to deliver 27 L/s under all likely river water levels – 2 new (duty/ standby pumps) plus control panel, linked to SCADA, supply, installation, commissioning	$50,000	Allowance
Upgraded chlorine system capacity – Larger rotameters and/ or modification of drawoff from cylinders and/ or room heating	$5,000	Allowance
Upgraded lime system capacity – Larger dosing pump, supply, installation, commissioning	$5,000	Allowance

Further recommended medium and lower priority actions are outlined in Section 7 of this report. Medium and low priority upgrade requirements have not been costed, although it is noted that the action with the most significant cost implications would be the addition of a system such as PAC automatic dosing or a full ozone BAC process to improve the removal of herbicides from the water.

It is recommended that Council pursue all recommended upgrade options, with the high priority, short timeframe actions to be undertaken immediately or as soon as possible.

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1. Introduction and Objectives

Banana Shire Council engaged City Water Technology to conduct a detailed review of the Shire's water treatment plants (WTPs), reviewing the treatment plant capacity and addressing planning issues for current and future upgrade requirements. Plant capacity was then compared to future demands and other requirements, determined with the assistance of Council. This planning report outlines the findings from the above investigations for the Theodore WTP and sets out options for addressing the upgrade requirements.

The objectives of the review and planning report for each WTP are to:

- Review treatment requirements based on raw water quality and treated water requirements;
- Review the capacity of each plant and each unit process, identifying capacity restraints or any available excess capacity;
- Identify issues and process upgrade requirements for current and future demand scenarios;
- Identify options to achieve the required upgrades and improvements.

2. Plant Flow Rates and Water Demand Issues

2.1 Annual Raw Water Extraction Allocations

Theodore's water is sourced 100% from the Dawson River. Current allocation from the river is 250 ML/yr.

Water Source	Source %	Allocation (ML/yr)
Dawson River	100	250

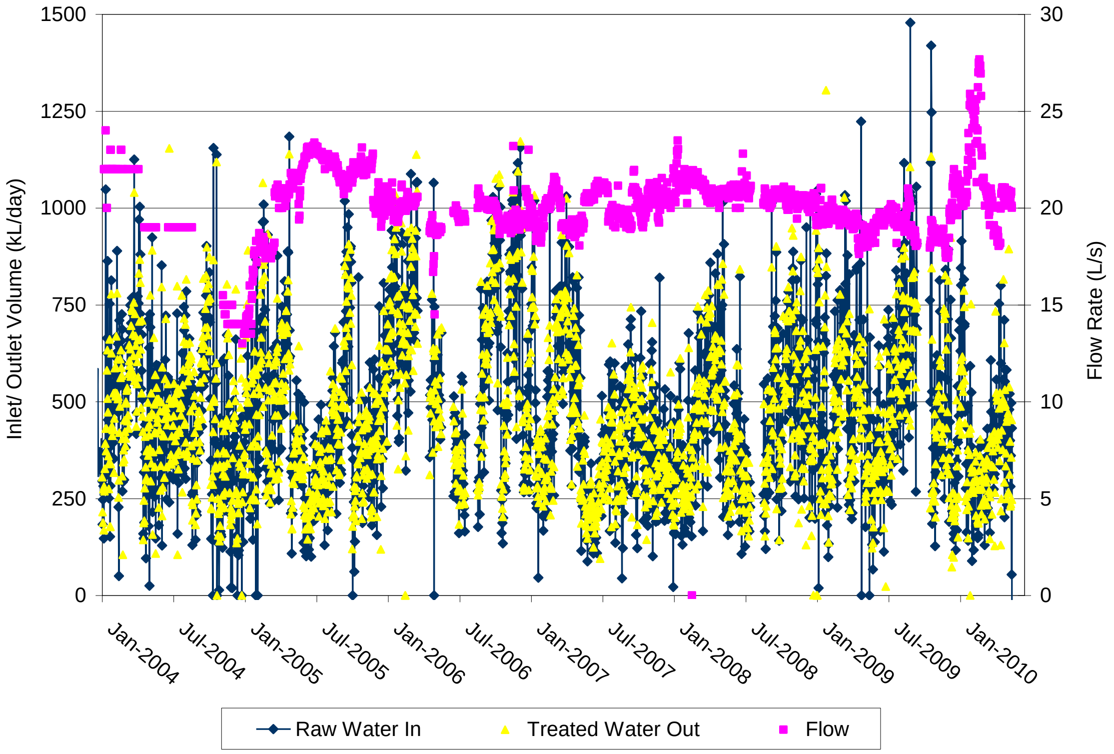
2.2 Plant Flow Rates

2.2.1 Design Flow Rate

Based on the original operating manual supplied with the plant, the design flow for the plant was 27 L/s. The operators advise that the plant has been run at 27 L/s only for brief periods for the purpose of testing the raw water pumps, and that this required running the two (duty/ standby) raw pumps together.

2.2.2 Operating Flow Rates and Production Data

Available plant data for plant flow rates, daily raw and treated water volumes available electronically for the period 2004 to 2010 is shown in the graph below.



Graph of Plant Flow Rates and Water Production

From the graph it can be seen that the plant flow rate has been mostly in the range 18 to 24 L/s, but in extremes has varied between 13 and 27 L/s. The operators report that the variation in pumping rate corresponds roughly to changes in the river level, with the very low rates in January 2005 associated with a very low river level and high rates in March

2010 associated with very high (significant flood flow) river levels. Sudden changes in flow rate are attributed to changeover of raw water pump duties and/ or blockages or other conditions affecting the pumps.

The reported raw water volume treated per day varies between < 100 kL/day up to around 1480 kL/day. Typical values are 200 – 800 kL/day. The maximum treated water volume recorded is around 1,300 kL/day.

The plant typically runs for 2.5 – 15 hours per day, although it has occasionally operated for up to 24 hours on individual days. There is generally capacity to run the plant for more hours per day to produce higher water production if required. The maximum daily run hours will be limited by the time required for backwashing and maintenance tasks, which are required to be done when the plant is off-line.

The operators report that the WTP may have up to 5 starts per day, depending on the start/ stop trigger level settings. Ideally, the number of WTP startups should be minimised by adjusting trigger level settings if possible, to enable stable operation which generally aids process performance.

2.3 WTP Treated Water Production Capacity

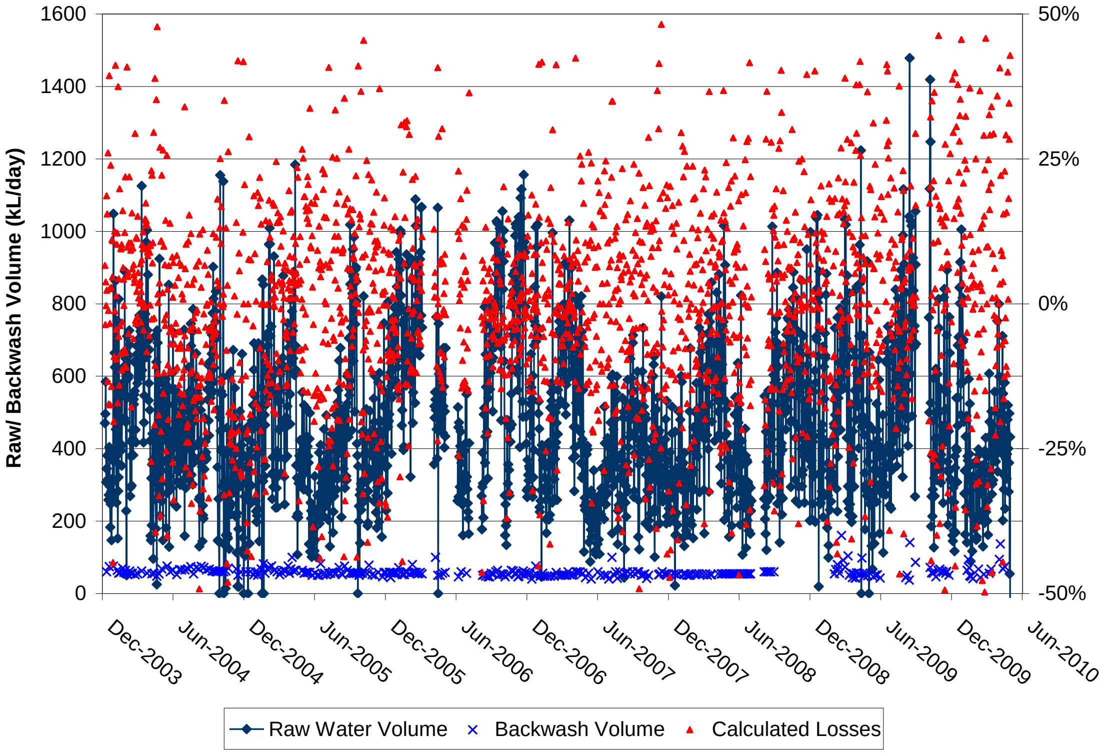
2.3.1 Flow Rate Variation Through WTP Process

The plant flow rate set point is the raw water inlet flow to the WTP. The actual flow rate will vary through the WTP process as water flow is removed as follows:

- ‘Plant flow rate’ measured on raw water flow meter at inlet to plant;
- Flow removed periodically from clarifier during desludges;
- Flow removed periodically from rising main after treated water pumps for filter backwashing;
- ‘Consumption’ flow measured after treated water pumps and after backwash water takeoff point.

Recycling of the wastewater streams back to the head of the plant has reportedly been done in a rough fashion in the past however there is currently no recycling of sludge lagoon supernatant and any wastewater flows removed are thus permanently removed from production.

Plant data comparing the inflow and outflow volumes was used to prepare the following graph of water losses through the process. The ‘water loss’ was calculated as the raw water minus treated water daily volume as a percentage of the raw water inflow, with negative losses attributed to storage within the clear water tank between various days. Water losses, daily raw water flow volumes and recorded backwash flow volumes are shown in the graph.



Graph of Plant Flow Rates and Water Losses

As seen in the graph, there is wide variation in the calculated water losses through the process. The median value of the losses is around zero and the average around -5%, which is not expected to reflect the true conditions. Average water losses should be a positive value because water is removed for clarifier blowdown and filter backwashing between the inlet and the outlet of the WTP. It is suspected that either the raw or the treated water flow meter is reading inaccurately. The operators report that the flow meters were calibrated in early 2010, however the comparative trends did not change as a result of the calibration. In order to confirm the true WTP capacity and water demands, the discrepancies between the **raw and treated water flow meters should be further investigated and corrected.** Because of the question over the meter readings, it is not possible to calculate accurate water losses through the process based on these meters.

The water volume removed during clarifier desludges is not measured. The filter backwash volumes are recorded manually based on a totaliser reading on this line. Backwash is typically carried out every 2 to 7 days. As seen in the graph above, recorded backwash volumes have varied from zero to 160 kL/day and are generally around 60 kL on days when backwashing is undertaken, representing around 10-15% of the typical raw water inlet volumes of 400-600 kL /day. Together with the clarifier desludge, it is assumed that overall plant losses would typically be between 5 and 20% of the raw water inflow. Losses of 5 – 10% are reasonable for a typical conventional treatment plant, with higher losses expected during periods of dirty raw water due to increased desludge and backwashing.

2.3.2 Daily Water Production Capacity for Various WTP Flow Rates

The table below summarises the potential maximum daily water output for various WTP inlet flows. Calculations are based on up to 20 hours WTP operation per day and process water losses of 5-10% and a worst case of 20%.

Estimated Water Production at Various WTP Flow Rates

WTP Inlet Flow Rate (L/s)	Estimated Treated Water Output (kL/d) with 20 h/day Operation	
	5-10% Water Loss	20% Water Loss
13	840 - 890	750
15	970 – 1,030	860
18	1,170 – 1,230	1,040
20	1,300 – 1,370	1,150
23	1,490 – 1,570	1320
25	1,620 – 1,710	1,440
27	1,750 – 1,850	1,560

As seen in the table above, the current average plant flow rate of 20 L/s can produce 1,200 to 1,400 kL/d in 20 hours operation. The potential maximum flow rate of 27 L/s can produce 1,600 to 1,800 kL/d. The lowest recorded flow rate of around 13 L/s would only produce 750 - 900 kL/d.

2.4 Current and Future Water Demand

Demand for water produced at Theodore WTP includes the town demands and supply to trucks filling at the WTP standpipe. In the past, mines in the area have taken significant amounts of water, reportedly up to 0.5 ML/day.

As seen in sub-section 2.3.2 above, the historical maximum treated water demand of around 1,300 kL/ day can be met by plant flows of 20 - 23 L/s with 20 hours operation per day.

It is understood that marginal growth is predicted in Theodore in future. There has been a recent subdivision with 27 new lots and may be a second subdivision, potentially adding growth to the town population. Permanent water restrictions may reduce the impact of population growth on water demands, although the effect of potential water restrictions has not yet been quantified.

Council use the Queensland DNRM rule of thumb to size WTPs, based on the maximum WTP output meeting the mean day max month (MDMM) demand. The MDMM for Theodore has not been calculated, however from flow trends discussed above it could be expected to be around 800 kL/day or lower. The WTP design flow rate of 27 L/s can produce 1,560 – 1,850 kL/d, which is around 200% of the estimated current MDMM and 20 - 40% greater than the historical maximum daily demand. Thus, if the current WTP maximum design flow can be maintained under all conditions, the existing WTP is expected to be well able to meet moderate demand increases from future development.

3. Water Quality Issues

3.1 River Source and Catchment Land Uses

Theodore WTP draws water from the Dawson River, which also feeds the Moura and Baralaba WTPs. Theodore is many kilometres upstream of the Moura and Baralaba draw-off points. The Theodore WTP raw water draw-off is about 1 km upstream of the Theodore weir. There are four weirs upstream of the Theodore raw water drawoff point. The upstream weirs are used for irrigation water removal.

The Theodore region has a large amount of cotton, sorghum and beef farming. Irrigated crops are required to have catch ponds to take runoff from the irrigated area, i.e. to have zero runoff back to the river, however it is expected that this regulation may not always be adhered to and/ or catch dams may overflow in times of heavy rains. The water-borne protozoan parasites *Giardia* and *Cryptosporidium* may be present in the faeces of cattle and other livestock. Because of the surrounding agricultural areas, the raw water is likely to contain some of these protozoan parasites and may also contain pesticides/ herbicides.

High raw water manganese levels are reported to occur when land in the catchment is cleared and sediments wash into the river.

The WTP raw water pumps are located in the Sunwater Pump Station, which also houses several other much larger irrigation pumps. The water drawoff point is around 1 km upstream from the Theodore weir. The river depth at the Theodore weir is around 8.5 to 11 m. The operators reported that stratification/ turnover in the water body behind the weir was not known to be a problem.

3.2 Water Quality Monitoring Data

Raw water quality is monitored daily at the WTP. Records for the period 2004 to 2010 were reviewed.

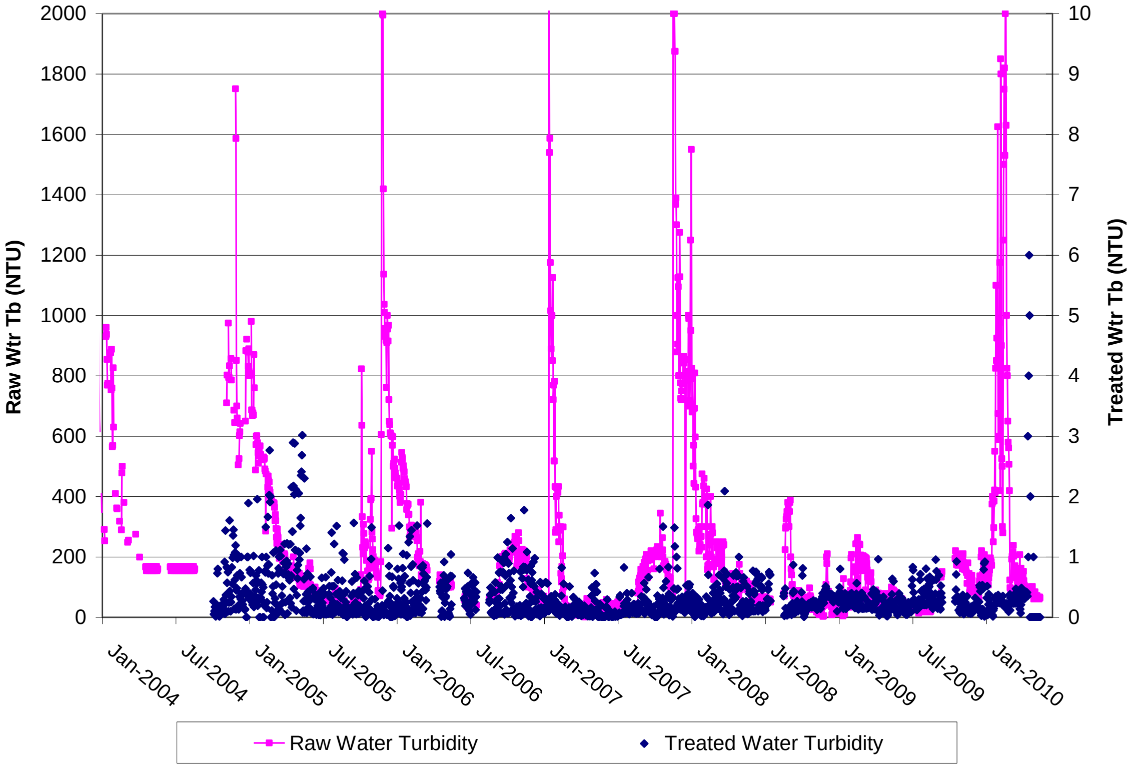
Raw and treated water samples have also been taken for external laboratory analyses, and the available data from this source has been summarised in Appendix A of this report.

Water quality results are discussed below for each relevant water quality parameter.

3.3 WTP Raw and Treated Water Quality

3.3.1 Turbidity

Raw and treated water turbidity trends, based on WTP log sheet data, are shown in the following graph. Treated water turbidity is analysed for a sample taken from the treated water sample tap in the WTP laboratory. It is noted that this sample comes from a point after post-chlorine and lime dosing to the filtered water.



Graph of Raw and Treated Water Turbidity

As seen in the graph, raw water turbidity varies seasonally with turbidity peaks seen in December-January of most years associated with river flow conditions. The maximum recorded turbidity is 2500 NTU and there have been several peaks over 2000 NTU during river flood conditions. Raw water turbidity is generally lower and more stable during the winter months. It is noted that the significant and sometimes rapid changes in turbidity will require the operator to be vigilant in re-optimising the coagulant dose.

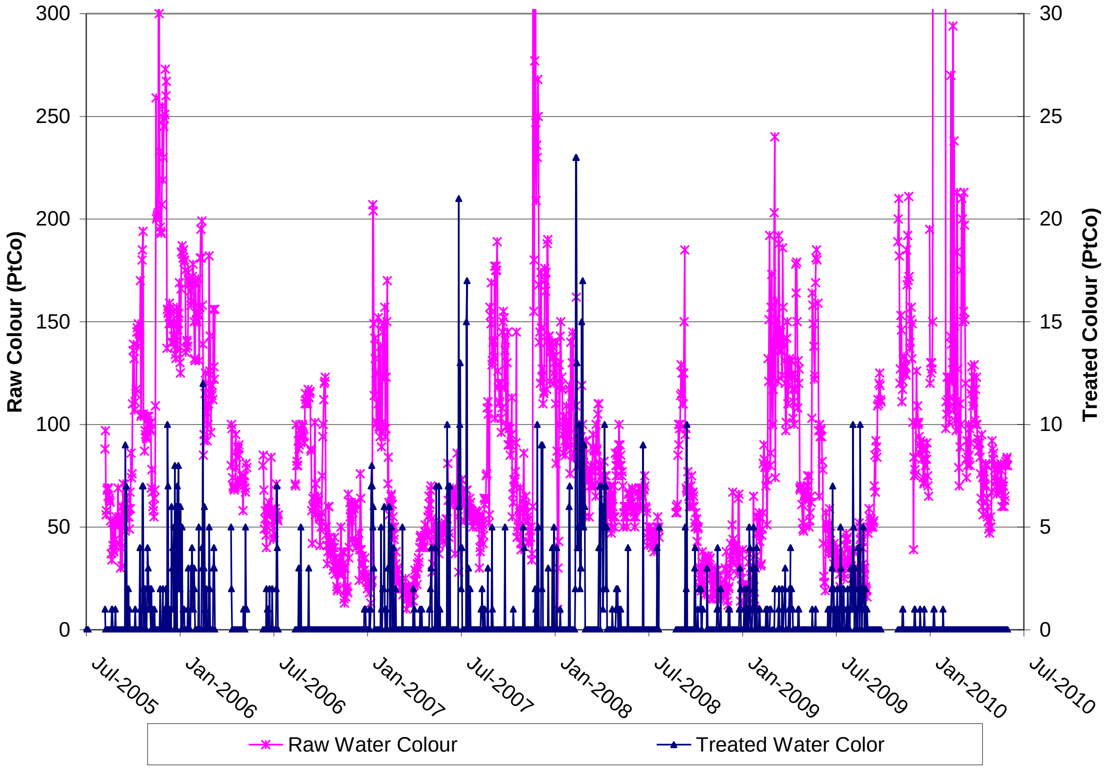
Treated water turbidity is typically around 0.3 NTU, however values are often >1 NTU, and some readings have been as high as 6 NTU. The treated water laboratory analyses tabulated in Appendix A show final water turbidities of <1 to 8 NTU. One period of particularly poor final water turbidities occurred from 1 – 15 May 2010, reportedly associated with repeated failure of the coagulant dosing pump and thus ineffective coagulation. It is noted that because the turbidity sample is taken downstream of the post-filtration lime dose, some of the high turbidities shown in the graph may be due to impurities in the lime.

An online turbidity meter is connected to the filtered water sample line, drawing water from the filter outlet manifold before post-filtration lime and chlorine is dosed. This turbidimeter is connected to the SCADA trending system. Data trends were not available for review as part of this report, however the filtered water turbidity is understood to follow similar trends to the final water, as expected.

High treated water turbidities in the filtered water are likely to be associated with poor coagulation and/or poor filter performance and turbidities of less than 0.3 NTU should be targeted to minimise potential pathogen breakthrough. Disinfection is likely tot be compromised at turbidities above 1 NTU.

3.3.2 Colour

Raw and treated water true colour levels, based on WTP log sheet data, are shown in the following graph. The measurement of ‘true colour’ requires the filtration of the sample to remove turbidity before colour analysis. This filtration step has been performed since mid-2005, when a suitable filtration flask was obtained for the WTP laboratory.



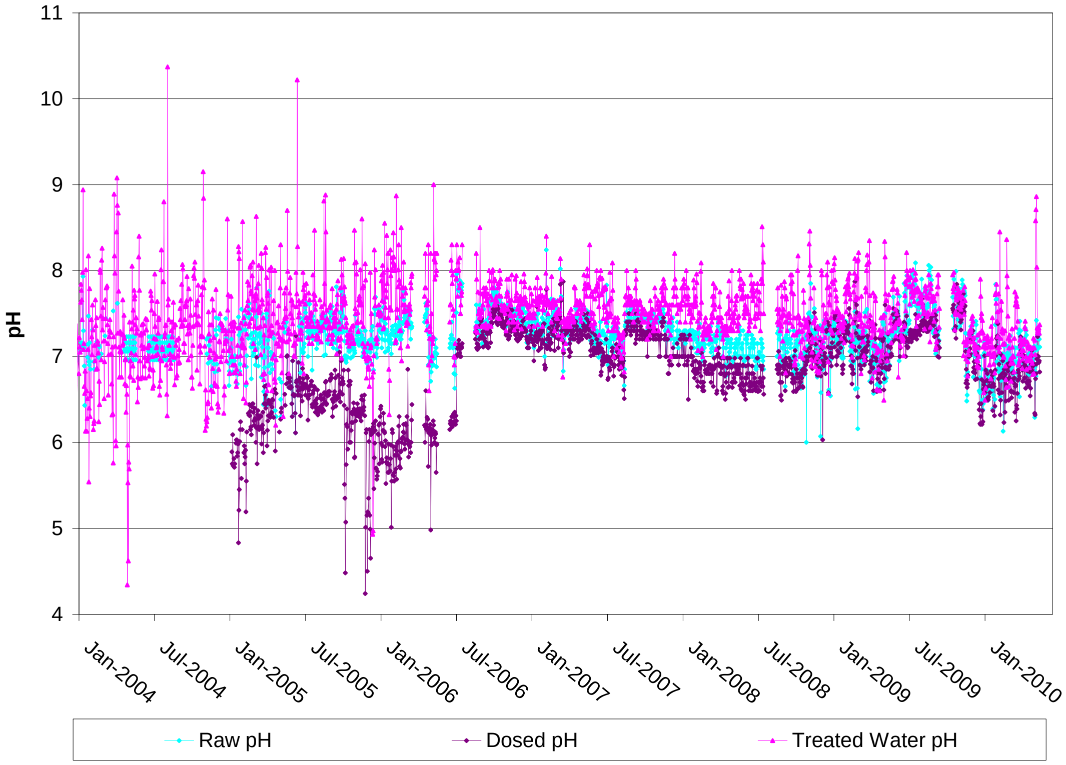
Graph of Raw and Treated Water Colour

Raw water true colour measurements have ranged between 12 and 1200 Pt-Co, with most values between 12 and 200 Pt-Co as seen in the graph. The highest value true colour of 1200 Pt-Co occurred in January 2010 associated with a large flood event. True colour tends to vary seasonally in a similar manner to turbidity.

Treated water colour has typically been < 5 Pt-Co, although there have been occasional spikes up to a 15 Pt-Co or higher. High treated water colour results can be an indication that coagulation is not fully optimised.

3.3.3 pH and Alkalinity

Raw, dosed and treated water pH levels, based on available WTP log sheet data, are shown in the following graph.



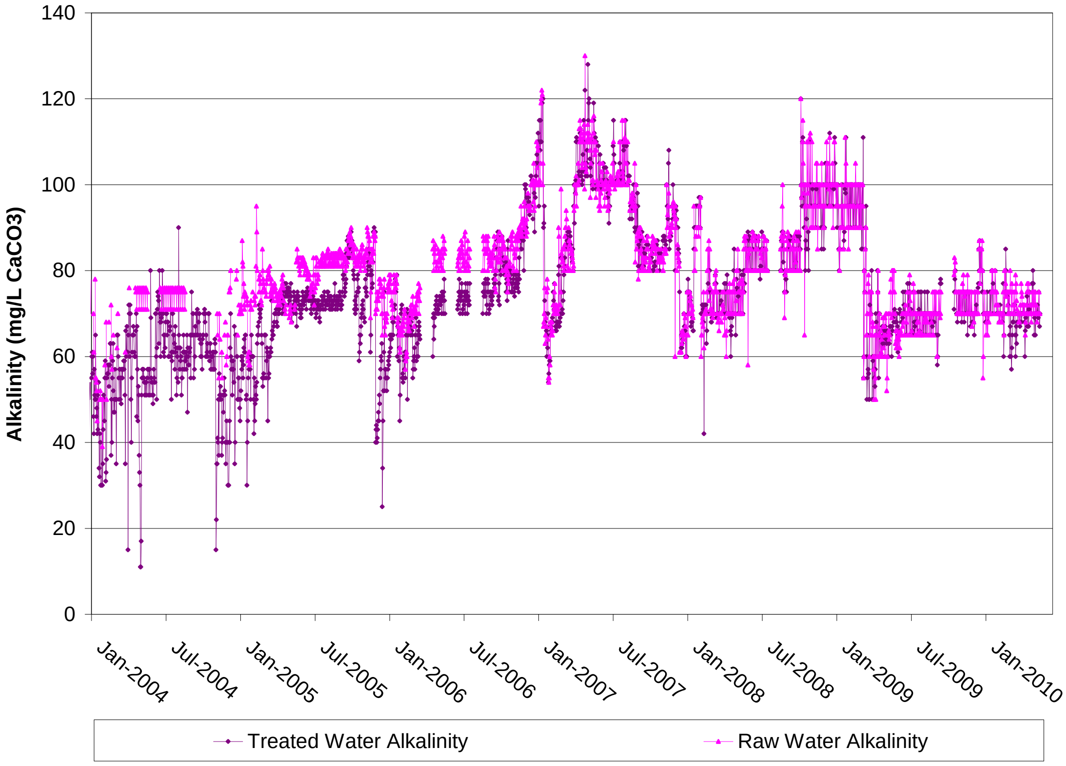
Graph of Raw, Dosed and Treated Water pH

As seen in the graph, the raw water pH is relatively stable, with measurements between 6.0 and 8.2.

The dosed water pH has been significantly higher since the coagulant was changed from alum to Nalco coagulant in 2006, and is now generally similar to the raw water pH. The lowest dosed water pHs were associated with high raw water turbidity and high alum doses.

The treated water pH has been maintained between 6.5 and 8.5 since Nalco coagulant dosing was commenced. The average treated water pH has been around 7.5, close to the current target of pH 7.6, although significant oscillations occur from day to day. The lowest treated water pH of 4.3 in 2005 probably occurred when the coagulant dose was high and post-filtration lime dosing failed. The spikes of pH > 8 indicate occasional lime overdosing.

Alkalinity levels, based on available WTP log sheet data, are shown in the following graph.



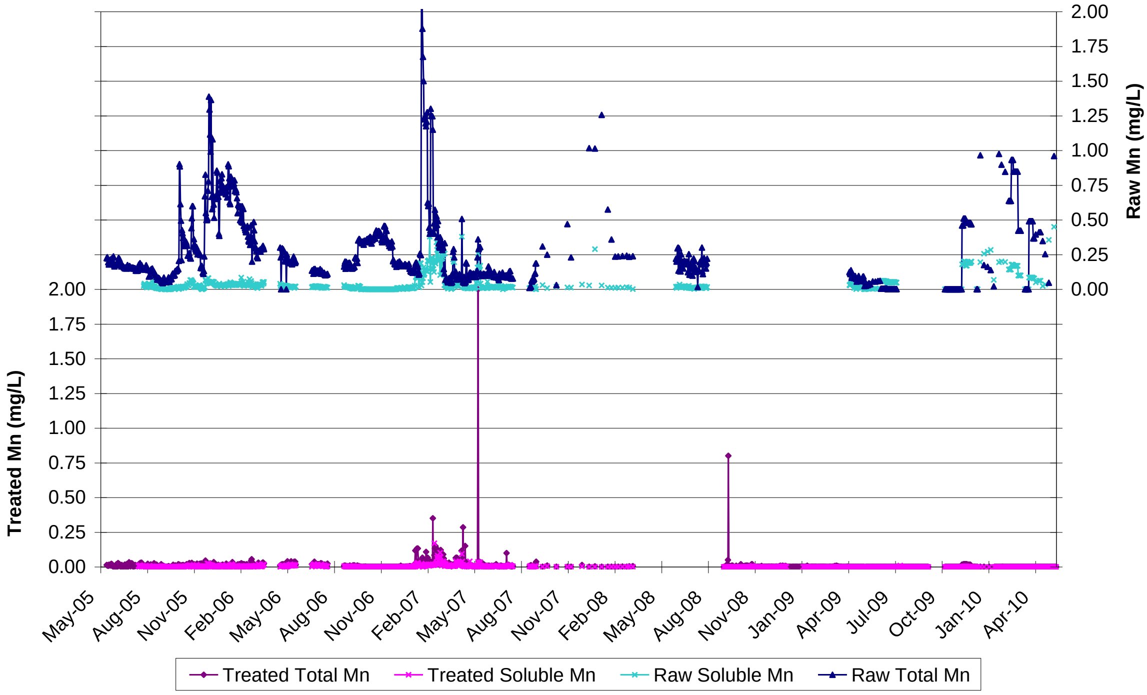
Graph of Raw and Treated Water Alkalinity

Raw water alkalinity has ranged between 50 and 130 mg/L. Treated water alkalinity has ranged from 15 to 128 mg/L. The treated water alkalinity trend shows that significantly more alkalinity was consumed with alum as the coagulant compared to the use of Nalco coagulant from 2006.

The pH and alkalinity variations shown in the data are reasonable, considering that the post-filtration lime dosing is manually adjusted. **Automatic lime dose adjustment for pH correction would be possible if an on-line pH analyser were to be installed. Such as system would lessen the requirements on the operators and is expected to give less variation in final water pH.**

3.3.4 Manganese

Raw and treated water manganese levels, based on WTP log sheet data, are shown in the following graph. Data was not available for all months shown.



Graph of Raw and Treated Water Manganese

As seen in the graph and the data above, manganese is present in the raw water at Theodore at quite high levels, with several episodes of total manganese > 1 mg/L. The manganese is mostly present in the particulate form, probably associated with sediments either washed into the river or resuspended by turbulent flow. Raw water soluble manganese levels have generally been < 0.05 mg/L, with a period of elevated levels during 2007.

Treated water manganese levels are generally < 0.05 mg/L, however levels were elevated to around 0.1 mg/L at the same time as high raw water soluble manganese levels during 2007. There have also been a number of short term spikes up to 2 mg/L.

The data indicates that the particulate manganese present has been mostly removed. Soluble manganese is more likely to pass though the WTP process.

The 2004 Australian Drinking Water Guidelines set an aesthetic guideline of 0.1 mg/L (100 µg/L) and a guideline health value of 0.5 mg/L. However it has been found that significant numbers of dirty water complaints are usually received when treated water manganese concentrations exceed 0.02 mg/L and targets as low as 0.01 mg/L have been set in some WTPs with manganese problems. Manganese can also accumulate in the reticulation system to emerge from taps later causing more complaints.

3.3.5 Pesticides and Herbicides

The data available on raw water pesticide and herbicide analyses is shown in the table below.

Pesticide and Herbicide Analysis Results for Raw Water

Parameter	Units	6/11/02	7/11/05	WTP 11/7/06	Weir 28/11/06	Weir 16/5/07	Weir 12/11/07
OC Pesticides	µg/L	<0.10	< Detection limit	<0.3	<0.3	<0.3	<0.3
OP Pesticides	µg/L	<0.1	<0.01	<0.10	<0.10	<0.10	<0.10

Parameter	Units	6/11/02	7/11/05	WTP 11/7/06	Weir 28/11/06	Weir 16/5/07	Weir 12/11/07
Herbicide Atrazine	µg/L	<0.02	0.03	0.34	0.11	0.09	0.44
Herbicide Desethyl Atrazine	µg/L	-	-	0.04	0.01	<0.01	0.11
Herbicide Desisopropyl Atrazine	µg/L	-	-	<0.01	<0.01	<0.01	0.03
Herbicide Diuron	µg/L	<0.01	<0.01	0.02	0.02	0.03	<0.01
Herbicide Hexazinone	µg/L	-	0.01	<0.01	0.02	<0.01	<0.01
Herbicide Simazine	µg/L	-	<0.01	<0.01	<0.01	<0.01	0.03
Herbicide Tebuthiuron	µg/L	-	0.47	0.03	0.02	0.10	0.03
Herbicide Fluometuron	µg/L	-	0.02	<0.01	0.06	<0.01	0.07
Herbicide Prometryn	µg/L	-	-	-	0.02	<0.01	<0.01

As seen in the table above, pesticides were below the detectable levels in the samples taken, however a number of herbicides were found to be present.

Treated water herbicide and pesticide analyses available are shown in the table below.

Pesticide and Herbicide Analysis Results for Treated Water

Parameter	Units	WTP Treated Water 7/11/02	Distribution System (Theodore Hospital) 27/9/05	WTP Treated Water 21/12/09	ADWG Recom-mended Value	Value Where Risk to Human Health *
OC Pesticides	µg/L	<0.10	< Detection limit	< Detection limit	-	-
OP Pesticides	µg/L	<0.10	<0.1	<0.1	-	-
Herbicide Atrazine	µg/L	0.03	0.12	0.07	<0.1	40
Herbicide Diuron	µg/L	<0.01	0.03	0.01	-	30
Herbicide Hexazinone	µg/L	<0.10	<0.01	0.01	<2	300
Herbicide Simazine	µg/L	-	<0.01	<0.01	-	50
Herbicide Tebuthiuron	µg/L	-	<0.01	0.02		
Herbicide Fluometuron	µg/L	<0.01	<0.01	<0.01		

* As listed in ADWG, based on 10% of acceptable daily intake

As seen in the table, the herbicides Atrazine and Diuron were detected in the treated water, with the Atrazine level in one sample above the ADWG recommended level but less than the ADWG level associated with human health risks.

The presence of herbicides in the treated water is not desirable. The existing WTP process includes PAC dosing, which may adsorb some chemicals, however the current arrangement may not effectively remove such organic contaminants. Ideally **the operation and/ or design of the WTP treatment system should be improved with the aim of effectively removing pesticides and herbicides from the water.** PAC dosing or ozone/ BAC are commonly employed treatment systems.

As herbicides have been detected, **pesticides and herbicides should continue to be monitored regularly in the raw water and these contaminants should be considered in any incident management procedures developed for raw water contamination events.**

3.3.6 Algae and Algal Toxins

Blue green algal blooms have been reported to occur in the river from time to time, especially when the river level is low and the water becomes stagnant. The WTP operators conduct regular visual checks of algal levels at the river. Algal analyses undertaken in November 2008 are summarised in the table below.

WTP Raw and Treated Water Algal Analysis

Organism	**River Water 12/11/08 (cells/mL)**	**Raw Water 12/11/08 (cells/mL)**	**Treated Water 12/11/08 (cells/mL)**
CYANOPHYTES (blue-green algae)			
Nostocales			
Anabaena spp.(coiled)		n.s.	n.s.
Anabaenopsis spp.		n.s.	n.s.
Cylindrospermopsis raciborskii		n.s.	n.s.
Total (Nostocales)		n.s.	n.s.
Oscillatoriales			
Planktolyngbya minor	510	n.s.	n.s.
Planktolyngbya subtilis		n.s.	n.s.
Pseudanabaena limnetica		n.s.	n.s.
Pseudanabaena galeata		n.s.	n.s.
Spirulina laxissima		n.s.	n.s.
Unidentified Oscillatoriales		n.s.	n.s.
Total (Oscillatoriales)	510	n.s.	n.s.
Chroococcales			
Aphanocapsa spp.		n.s.	n.s.
Aphanothece spp.	493	n.s.	n.s.
Chroococcus minumus		n.s.	n.s.
Cyanodictyon spp.	8525	n.s.	n.s.
Cyanogranis liberia	1972	153.	n.s.
Cyanocatena spp.	1054	n.s.	n.s.
Merismopedia spp.	1156	n.s.	n.s.
Myxobaktron spp.		n.s.	n.s.
Rhabdoderma spp.		n.s.	n.s.
Snowella spp.		340.	n.s.
Synechococcus spp.		n.s.	n.s.
Unidentified Chroococcales		374.	n.s.
Total (Chroococcales)	17300	876	n.s.
Total (CYANOPHYTES)	17900	876	n.s.
TOTAL CELLS PER ML	**17900**	**876**	**n.s.**

n.s. = not sighted

The analysis above shows a high level of algal cells in the river, much lower levels in the WTP raw water and no cells passing through into the WTP treated water. Of the species present in the river, some Oscillatoria species are associated with taste and odour compounds and algal toxins but other species present are not known to produce these compounds.

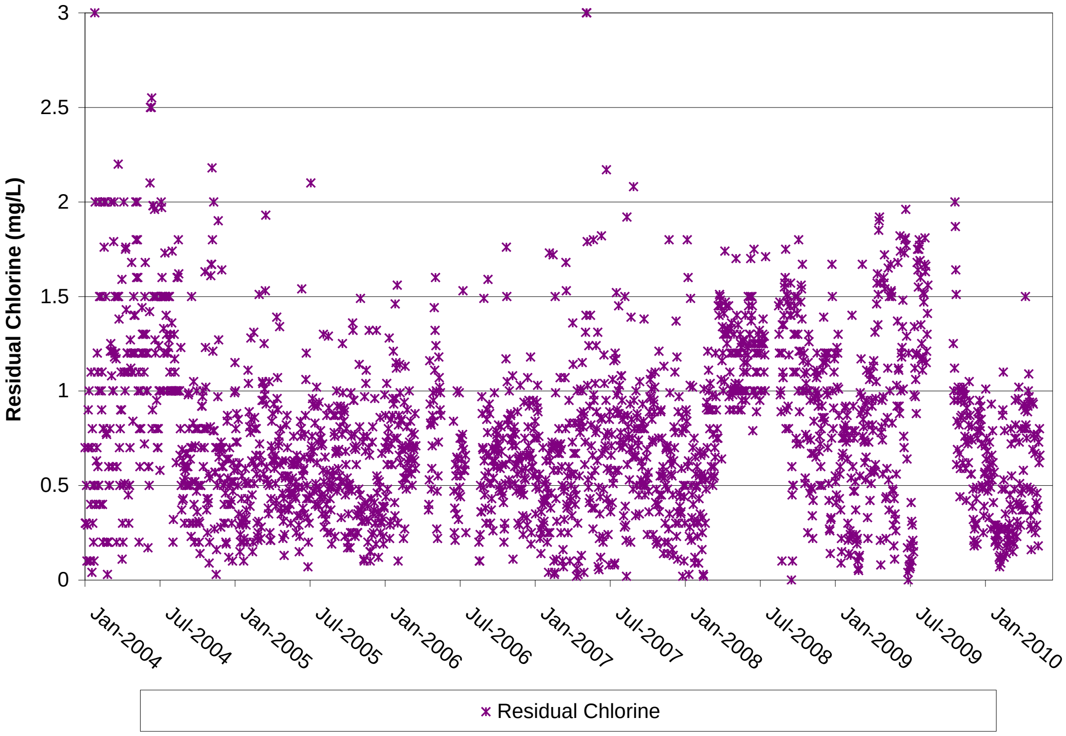
It is understood that ongoing algal monitoring is undertaken by Sunwater. **Council should ideally formalise a system for reviewing the algal analyses available from Sunwater.**

The operators report that tastes and odours can be a problem at the plant at times, however there is no data available to show which taste and odour compounds were present.

Algae and taste and odour compound analyses should be carried out when these contaminants are likely to be present in the river water.

3.3.7 Chlorine Residual

Treated water chlorine residual levels, based on available WTP log sheet data, are shown in the following graph.



Graph of Chlorine Residuals

As seen above, chlorine residuals have ranged between 0.02 and 3 mg/L. There has been quite significant variation in day to day values. On days where the chlorine residual was significantly lower than the target value, there may be a risk of ineffective disinfection.

In the graph it can be noted that in the first half of 2004 the median residual was around 1 mg/L, which matches the chlorine target at this time. During late 2004 the chlorine target was reduced to 0.7 mg/L because of complaints about a chlorine taste and odour in the treated water and between 2004 and 2005 the average chlorine residual was around 0.7 mg/L. In 2008/09 the chlorine residual target was again raised to 1 – 1.5 mg/L to ensure effective disinfection. Median chlorine residuals have been around 1 mg/L during 2008 and 2009.

3.3.8 Aluminium

WTP and external laboratory data indicates that total aluminium levels are typically < 0.1 mg/L. High readings of up to 0.34 mg/L were seen around December 2005. This period of high aluminium levels appeared to correlate with particularly low dosed water pHs (with alum used as the coagulant), which would lead to poor coagulation.

3.3.9 Microbiological Parameters

Data on total coliforms and *E.Coli* for samples taken at the WTP and in the distribution system (mostly at Theodore Hospital) is shown in the table below. It is assumed that all samples are on treated water, although prior to 2009 records describing the WTP sampling point were not always clear.

Theodore Coliforms Analyses

Date	No. of samples tested	Parameters			
		Theodore WTP		Theodore Hospital/ Reticulation	
		Coliforms MPN per 100mL	E.Coli MPN per 100mL	Coliforms MPN per 100mL	E.Coli MPN per 100mL
03/03/08	1	ND	ND	**29**	ND
31/03/08	1	ND	ND	ND	ND
28/04/08	1	ND	ND	ND	ND
26/05/08	1	ND	ND	ND	ND
23/06/08	1	ND	ND	ND	ND
21/07/08	1	ND	ND	ND	ND
18/08/08	1	ND	ND	ND	ND
29/09/08	1	**>200**	**32**	**170**	**19**
18/11/08	1	ND	ND	ND	ND
16/12/08	1	ND	ND	ND	ND
Jan 2009	1	-	-	-	ND
Feb 2009	1	-	-	-	ND
Mar 2009	1	-	-	-	**1**
Apr 2009	1	-	-	-	ND
May 2009	1	-	-	-	ND
Jun 2009	1	-	-	-	ND
Jul 2009 a	1	-	-	-	**1**
Jul 2009 b	1	-	-	-	**1**
Aug 2009	2	-	-	-	ND
Sep 2009	2	-	-	-	ND

Date	**No. of samples tested**	**Parameters**			
		Theodore WTP		**Theodore Hospital/ Reticulation**	
		Coliforms **MPN per 100mL**	**E.Coli** **MPN per 100mL**	**Coliforms** **MPN per 100mL**	**E.Coli** **MPN per 100mL**
Oct 2009	2	-	-	-	ND
Dec 2009	2	-	-	-	ND
Jan 2010	2	-	-	-	ND
Feb 2010	1	-	-	-	ND
Apr 2010	2	-	-	-	ND
Jun 2010	2	-	-	-	ND

ND = Not Detected

As seen in the table, coliforms and *E.Coli* are generally below detectable limits. However two samples had detectable levels of total coliforms and samples in September 2008 and March and July 2009 had detectable levels of *E.Coli* at the WTP and/ or the reticulation system. The *E.Coli* detection in March 2009 was attributed to a post-chlorine dosing failure due to a split chlorine dosing hose. The presence of *E.Coli* in a number of treated water samples is of particular concern as it indicates possible recurring failure to adequately disinfect the water and/or faecal contamination which could expose consumers to pathogens. The ADWG recommend that *E.Coli* should not be detected in drinking water.

E.Coli should continue to be monitored regularly and **any further *E.Coli* detections should be followed up urgently to identify and address any issues leading to inadequate disinfection and/or faecal contamination of the treated water.**

Due to the agricultural landuses in the dam catchment, it is suggested that **the raw and treated water could be analysed for *Cryptosporidium* and *Giardia* on occasion to check background levels of these pathogens,** particularly after heavy rain.

3.3.10 WTP Raw and Treated Water Quality Summary

The range and typical values for significant water quality parameters in the WTP raw and treated waters are summarised in the table below.

WTP Raw and Treated Water Quality Parameters Summary

Parameter	**Units**	**WTP Raw Water**		**WTP Treated Water**	
		Range	**Typical**	**Range**	**Typical**
Turbidity	NTU	25 – 2500	Summer: > 300 Winter: 100	0.0 – 3.0	0.3
True Colour	Pt-Co	12 – 500	Summer: 150 Winter: 50	< 1 - 23	< 5
pH	-	6.0 – 8.2	7.3	4.3 – 10.3	7.5
Manganese (total)	mg/L	0.0 – 2.35	0.35	0.0 – 2.0	0.02

Parameter	Units	WTP Raw Water		WTP Treated Water	
		Range	Typical	Range	Typical
Manganese (soluble)	mg/L	0.000 – 0.38	0.03	0.0 – 0.17	0.01
Alkalinity	mg/L $CaCO_3$	50 - 130	80	15 - 128	80
Chlorine	mg/L	-	-	0.02 – 3.00	0.7
Total coliforms		Not tested		Detected in some samples	
E.coli	MPN/100ml	Not tested		Detected in some samples	
Pesticides	-	Not detected		Not detected	
Herbicides	-	Detected		Detected. One sample > ADWG recom. level	
Blue Green Algae	-	Blooms known to occur		Blooms known to occur	
B-G Algal Toxins	-	Not tested		Not tested	
Taste and odour compounds	-	Reported to occur		Reported to occur	

3.4 Water Corrosivity Issues

3.4.1 Problems Caused By Corrosive Waters

Waters may be potentially corrosive due to various combinations of parameters such as low pH, low alkalinity, or low hardness. Problems commonly experienced in a water supply as a result of aggressive water include:

- reduced disinfection efficiency at elevated pH levels;
- pitting corrosion, high copper levels and blue water in copper pipes within buildings;
- elevated iron levels associated with iron or steel pipes;
- meringue dezincification of brass fittings at pHs of 8.5 or higher;
- high pH values throughout the reticulation due to the dissolution of various compounds from concrete and cement within the system.

These problems can lead to increased health risk to consumers and deterioration of service pipes and fittings in water supply schemes.

Water quality is considered the main contributing factor to corrosion of infrastructure in water supply systems. Other factors contributing to corrosion may include micro-organisms on pipe walls; reticulation design and layout; materials used; and water use characteristics.

3.4.2 Corrosivity Indices

Indices which reflect the corrosion potential or “aggressiveness” of water can be modelled using water quality data. These indices are useful in estimating the likely corrosion potential of waters, although they do not necessarily apply to all types of waters. They include:

- the Calcium Carbonate Precipitation Potential (CCPP);

- the Langelier Index; and
- the Larson Index.

The CCPP and Langelier Index are indicators of whether a water is likely to be aggressive or scale forming. Negative values indicate that waters are likely to be corrosive while positive values indicate the water is likely to form calcium carbonate scale.

If the CCPP is zero then the water is saturated in terms of calcium carbonate. If the CCPP is positive then the water is over-saturated and likely to precipitate a film, predominantly of $CaCO_3$, onto pipes and other water supply infrastructure in contact with the water. If the CCPP is negative then the water is under-saturated and is likely to be corrosive. Various studies have shown CCPP to be an accurate indicator of corrosiveness of concrete and cement linings.

The Langelier Index (LI) has also been found to be an accurate indicator of water scaling and hence corrosivity under most circumstances. It is the difference between the saturated pH and the water's actual pH, and is therefore on a logarithmic scale. Again a negative value indicates that the water is likely to be corrosive and a positive value shows it to be over-saturated and therefore likely to be scale forming.

The Larson Index is an indicator of the potential aggressiveness of water in relation to the effect on oxide film formation on metals such as iron or mild steel. The Larson index is calculated as the ratio of chlorides and sulphides to alkalinity with all levels expressed in equivalents per million.

3.4.3 Water Quality Targets for the Prevention of Corrosion

The water quality targets outlined in the table below are generally recommended to minimise potential corrosivity in treated waters, based on industry experience.

Typical Target Water Quality Parameters for Corrosion Control

Parameter	Units	Target	Guideline Range
pH	pH units	7.8 to 8	7.6 to 8.2
Alkalinity	mg/L as $CaCO_3$	45 to 55	> 40
Ca Hardness	mg/L as $CaCO_3$	> 40	> 40
CCPP	mg/L	- 3	- 6 to 0
Langelier Index	pH units	- 0.3	- 0.6 to 0
Larsen Index	ratio	< 0.8	< 1.2

The pH of the water should be above 7.6 for waters leaving the WTP but should not exceed 8.3 as dezincification can occur at pHs of around 8.5 and above. At pHs above 7.0, the effectiveness of chlorine disinfection is reduced.

A free chlorine residual of around 0.2 mg/L in the extremities of the reticulation system is usually recommended to minimise the possibility of microbiologically-induced corrosion.

3.4.4 Theodore Corrosion Indicators

Corrosivity indices were modelled for Theodore WTP raw and treated water using proprietary software. The data used as input to calculations and the calculated indices are set out in the table below.

Corrosivity Indices for Theodore Raw and Treated Water

Parameter	**Units**	**Raw water Typical**	**Treated Water Typical**	**Treated Water Worst Case**
Temperature	° C	22	22	22
TDS	mg/L	130	190	150
Alkalinity	mg/L as $CaCO_3$	80	80	15
Calcium hardness	mg/L as $CaCO_3$	32.5	75	40
pH	-	7.3	7.5	4.3
Chloride	mg/L	20	30	40
Sulphate	mg/L	4.8	55	60
CCPP	**mg/L**	**- 15.3**	**- 6.2**	**- 682**
LI	**-**	**- 0.7**	**- 0.3**	**- 1.7**
Larsen Index	**-**	**0.41**	**1.2**	**7.9**

The results of the modelling for the raw water show that it is likely to be corrosive in terms of CCPP and LI, but not in terms of the Larsen Index. It is noted that corrosion has occurred on steel fittings on the raw water pumps offtake, as discussed in the next chapter.

The results for the typical treated water show that the water is just outside the recommended range for CCPP, LI and Larsen Index, and therefore may be moderately corrosive.

The worst case treated water quality very likely to be corrosive, however it is noted that this type of quality would occur rarely and for short periods of time. The use of Nalco coagulant instead of alum will also decrease the risk of very low treated water pH and alkalinity occurring.

No particular corrosion problems have been reported within the Theodore water reticulation system.

3.5 Treated Water Quality Targets

The treated water quality target levels recommended in the Australian Drinking Water Quality Guidelines (NHMRC, 2004) are shown in the table, with common targets based on industry experience and other water treatment plants around Australia and the current targets used at the Theodore WTP.

Treated Water Quality Targets & Guideline Values

Parameter	Units	ADWG		Common Industry Treated Water Targets	Current Moura Treated Water Target
		Health	Aesthetic		
Turbidity	NTU	1	5	< 0.1	< 0.3
Colour	HU		15	≤ 5	≤ 5
pH			6.5 – 8.5	7.5 – 8.3	7.6
Chlorine	mg/L	5		Depends on system	1 – 1.5 (previously 0.7)
Total Aluminium	mg/L	0.2		≤ 0.2	-
Total Manganese	mg/L		0.1	≤ 0.05	-
Total Iron	mg/L		0.3	≤ 0.3	-
Total Alkalinity	mg/L as $CaCO_3$			≥ 40	-
Total Dissolved Solids (TDS)	mg/L		< 500	< 500	-
CCPP				-1 to -5	-
Total Trihalomethanes	mg/L	0.25		≤ 0.15	-

The targets adopted at the WTP are reasonable compared to the ADWG and industry values. It is noted from the analysis of water quality above that the targets are not always met.

4. WTP Process Description and Capacities

4.1 Process Overview

Theodore WTP is a conventional treatment process, comprising the following main unit processes:

- Coagulation
- Flocculation
- Settling
- Filtration
- Disinfection
- pH adjustment

A diagram of the plant process is shown below.

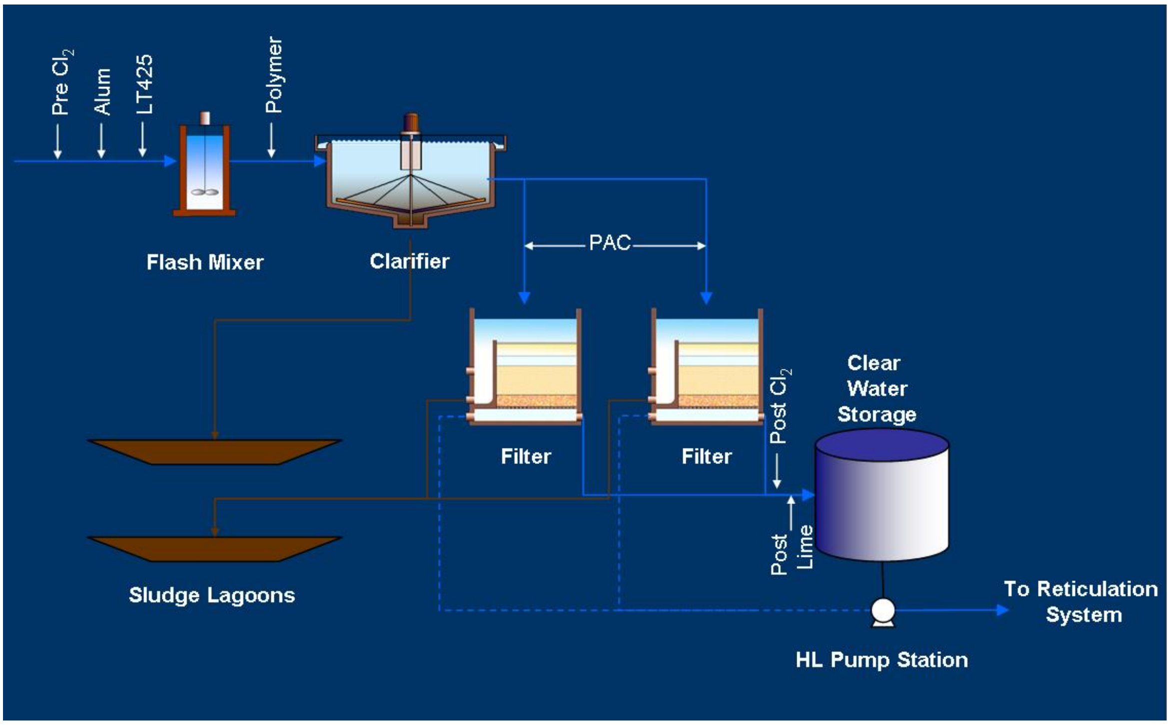


Diagram of Theodore WTP Treatment Process

4.2 Raw Water Pumps and Plant Inlet

Raw water is drawn from the Dawson River in the Theodore Weir impoundment, around 1km upstream of the weir.

The raw water pumps are mounted in the Sunwater Irrigation Pump Station on the right bank of the river. The raw water pumps are powered and controlled from the raw water pump switchboard in the Sunwater Irrigation pump station. Much larger irrigation pumps are housed in the same Sun Water pump station, drawing water from the same point in the river.

Photo of Floating Drawoff at River

The raw water pumps are two (duty/standby) centrifugal pumps, each rated at 27 L/s according to the original plant operating manual. As the pumps are the original pumps installed with the WTP in 1987, in their current condition it is reported that the pumps only have a capacity of 20 to 22 L/s with the river full (overflowing at the weir), and less at lower river levels. However in early 2010 during very high river water levels associated with local flooding, data shows that the pumps did produce 27 L/s for several days.

The main parameters of the raw water pumps and plant inlet are given in the table below.

Raw Water Pumps and Plant Inlet

Component	Parameter (Units)	Design Criteria	Comments
Dawson River Pumps	Intake type	Floating draw-off	Noted that foot valve replaced approx. 12 months ago
	No. and Capacity each (L/s)	2 (duty/ standby) x approx 22 L/s (13 – 27 L/s depending on river level)	Noted that pumps have no speed adjustment capability
	Pumping elevation to WTP	Approx 12 m	Weir crest 133.82 AHD, Plant inlet TWL 146.1 AHD (from Council's data)
Plant Inlet	Max hydraulic capacity	27 L/s assumed	Designed for 27 L/s as per old manual Not stated in old manual

During a CWT site visit in March 2006 it was noted that the raw water pump control panel at the pump station was also aging and the duty selection switch was not working.

The pumps take water from a floating drawoff in the river, designed to rise and fall with the river and to avoid drawing in the sediments near the bottom of the river. It has been noted by the operators that the foot valves on the floating draw offs for the pumps are prone to deteriorate due to corrosion. It is understood that new polymer foot valves have been ordered to replace the steel vales previously used. During a CWT site visit in March 2006, one of the pump intake lines was offline due to problems with its foot valve. Later it was reported that corrosion was also becoming a problem in the drawoff pipes. **The current foot valve and draw off pipe corrosion problems should be addressed by maintenance and/or replacement with corrosion-resistant materials.**

The operators also noted that the operation of lifting and replacing or clearing each foot valve was not simple. A small pontoon was used last time, along with a borrowed boat. The pontoon is apparently not easy to work on due to limited space and stability concerns. **An improved pontoon would make the maintenance of the intake foot valves job easier and safer.**

The raw water is pumped 500m to the WTP site via an asbestos cement rising main.

The inlet main at the WTP before the Flash Mixing Tank contains a non return valve, the raw water sample point (for sample to the laboratory), the magflow raw water flow meter, dosing points for pre-chlorine and coagulants (described below) and a manual isolation valve. The magflow flow meter records to a chart recorder in the WTP laboratory and from there to the SCADA system.

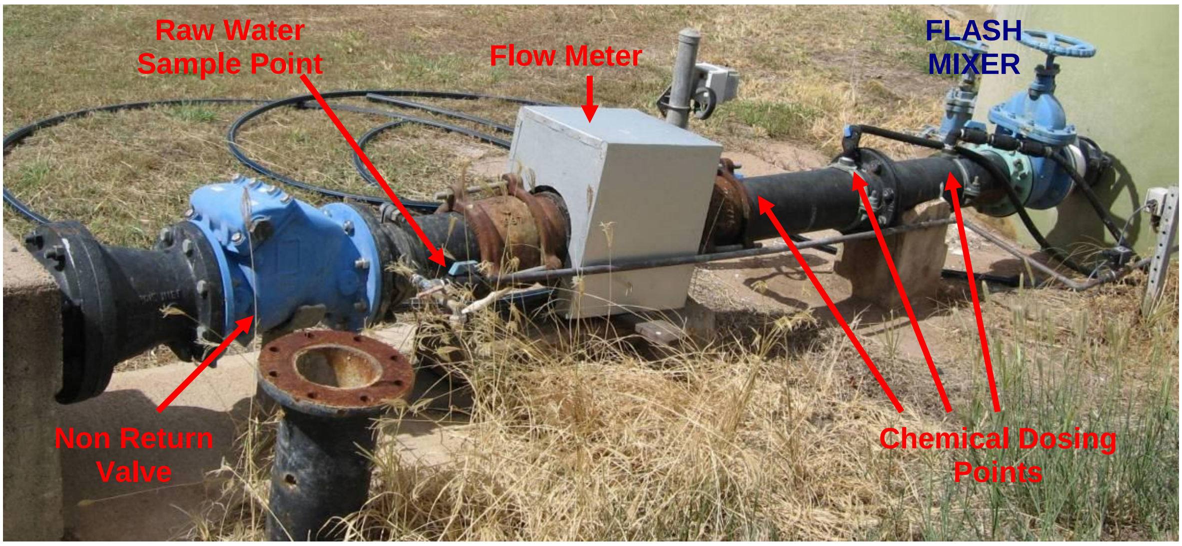


Photo of Raw Water Inlet Main at WTP

4.3 Pre-Filtration Chemical Dosing

4.3.1 Chemical Dosing Locations

The chemicals currently dosed for pre-treatment and coagulation are:

- Pre-coagulation chlorine (oxidant) dosed into the main at the plant inlet;
- Nalco coagulant dosed into the main at the plant inlet;
- Polyacrylamide, product name Magnafloc LT20 (flocculant aid) dosed into the pipe between the flash mixer and the clarifier.

Until 2006, alum and cationic polyDADMAC (LT425) were used as the coagulants instead of Nalco Coagulant.

The dosing points for these chemicals are shown in the figures below.

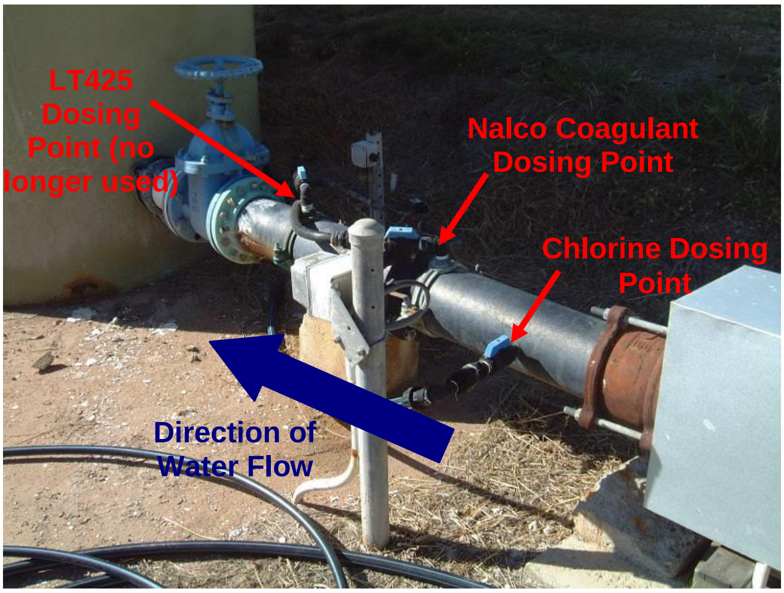


Photo of Pre-Chlorine and Coagulant Dosing Points

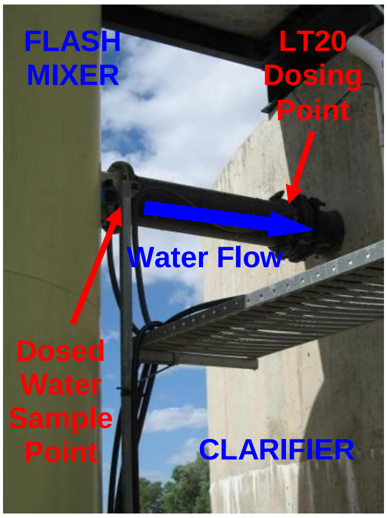


Photo of Polyacrylamide Dosing Point

4.3.2 Pre-Coagulation Chlorine Dosing

Chlorine is dosed in to the raw water main before the coagulants. It is noted, based on the WTP original operating manual, that pre-coagulation chlorine dosing was not included in the original plant design but has been added to the process subsequently.

Pre-coagulation chlorination ('pre-chlorine') is generally used to oxidise soluble metals and organic compounds (including taste and odour compounds). Chlorine dosing can also assist by enhancing the coagulation process. It is understood that pre-chlorine is dosed mainly for oxidation of taste and odour compounds at Theodore WTP.

One of the risks with pre-coagulation chlorination is that there is more chance that chlorine will react with the high levels of organic substances in the water to produce undesirable by-products such as trihalomethanes (THMs). If blue-green algal cells are present, chlorination may also lyse the cells, potentially releasing any algal toxins into the water.

The chlorine dose is reportedly adjusted to achieve a residual of around 0.1 to 0.2 mg/L (measured by grab sample from the settling zone of the clarifier). The actual dose required depends on the raw water quality parameters, particularly turbidity and colour.

Chemical doses used and chlorine storage and dosing system capacities are discussed in the next chapter of this report.

4.3.3 Pre-Coagulation Alkali Dosing

Pre-coagulation alkali dosing is not currently used at the plant. This dosing would sometimes be beneficial for maintaining a suitable pH for coagulation, especially if alum was used as the main coagulant again. Nalco coagulant consumes less alkalinity than alum, therefore there is less likelihood that pre-lime will be needed if this coagulant continues to be used.

If required, there is potential capacity to dose pre-coagulation lime (‘pre-lime) as there are two lime dosing tanks (currently used as duty/ standby for post-lime). Dosing pre-lime would require the installation of another lime dosing pump. The spare polyDADMAC dosing point in the raw water main could be used for dosing.

4.3.4 Nalco Coagulant Dosing

The proprietary coagulant produced by Nalco, product number DVS1 C001-D245, has been implemented as the main coagulant (to replace both alum and polyDADMAC) since 2006. It was noted during discussions with Nalco, that the last part of the product number usually used on site to name the product, D245, is in fact a reference to the container size and is common to many other Nalco chemicals. **The Nalco coagulant product should therefore more correctly be referred to using the first part of the number, DVS C001, in discussions with Nalco at least.** As no other Nalco coagulants have been used at the Banana Shire plants, the chemical is referred to as ‘Nalco coagulant’ in this report.

The Nalco coagulant is understood to be a polymerised aluminium chemical product, of the type often called aluminium chlorohydrate (ACH) or polyaluminium chloride (PACl), although the actual chemical composition of the product is protected by Nalco as proprietary information. Such products can be effective at lower doses than alum and generally cause less of a drop in pH, therefore reducing the need for pre-coagulation alkali dosing.

4.3.5 Flocculant Aid Polyacrylamide (LT20) Dosing

The polyacrylamide, Ciba product Magnafloc LT20, is dosed as a flocculation aid at the pipe carrying water between the flash mixer and the clarifier. Magnafloc LT20 is a non-ionic polyacrylamide. It is understood that the polyacrylamide product LT25 has also been dosed as a flocculant aid in the past.

Anionic or nonionic polyacrylamides (also known as polyelectrolytes) are used as flocculation aids to assist in binding particles together during coagulation and flocculation. These long-chain polymers influence the bonding between floc particles and help to form larger and/or denser floc.

The dosing location after the flash mixer allows contact time and mixing of the coagulant chemicals before contact with the polyacrylamide. Flocculation aid polymers are best dosed downstream of the primary coagulant dosing point, allowing a suitable contact time for the coagulant, as well as adequate mixing and initial floc development before the polymer is added.

Chemical doses used and polyacrylamide storage and dosing system capacities are discussed in the next chapter of this report.

4.4 Flash Mixing Tank

The flash mixing tank comes directly after the dosing of coagulant and essentially provides mixing and chemical contact time for floc formation. The main parameters for the flash mixing tank are given in the table below.

Flash Mixing Tank

Component	Parameter (Units)	Design Criteria	Comments
Flash Mixing Tank	Dimensions: diameter, depth (m), volume (m^3)	1.8 m, 5 m, approx 12 kL	From original operating manual
	Detention time	7 min at 27 L/s 8.5 min at 22 L/s	Time for 27 L/s from original operating manual
	Flash mixing	Hydraulic only	

It is noted that only hydraulic mixing is provided to blend the coagulants into the water. Poor mixing can typically lead to overdosing of coagulant and high aluminium levels in the treated water. Based on available results coagulation appears to be reasonable, however a mechanical or inline static mixers could be employed, if required, to optimise coagulant mixing with the raw water. If these options were pursued, it is noted that the effect of the additional headloss on the capacity of the raw water pumps would need to be considered.

The maximum capacity of the flash mixer is taken to be the design flow rate of 27 L/s, although plant trials would be recommended to test this rate (or higher rates) to prove that adequate mixing and detention time can be provided at the new rate.

4.5 Clarifier

The clarifier is a solids contact upflow design. It was originally designed to treat a flow of 27 L/s. Inflow into the clarifier is into the central flocculation zone, where hydraulic mixing assists in the formation and development of floc particles. The water then flows under the skirt and upwards in the outer settling zone, where floc settle out and clarified supernatant is collected in the radial arms and flows on to the filters.

The clarifier flocculation zone has a stirring paddle, however the operators report that this paddle is usually turned off as it was decided at some time in the past (prior to 2006) that floc formation was better without mechanical mixing. This point was unable to be confirmed while on site, although floc formation looked reasonable at the time, but **the issue of flocculation mixing could be re-checked by conducting plant trials with the mixer off and on at various speeds**.

Photo of Clarifier Showing Central Flocculation Well and Settling Zone

There is a sludge rake in the settling zone of the clarifier which operates when the plant is on to scrape the sludge to the centre of the conical floor. Settled sludge is periodically removed from the bottom cone of the clarifier by operation of the automatic desludge valve.

The main parameters for the clarifier are given in the table below.

Clarifier (Flocculation and Settling Zones)

Component	**Parameter (Units)**	**Design Criteria**	**Comments**
Flocculation	Type	Flocculation occurs in central flocculation zone of clarifier	
	Dimensions: depth (m), volume (m^3)	4.5, 24.6 m^3	From original operating manual
	Flocculation time	15 min at 27 L/s 18 min at 22 L/s	Time for 27 L/s from original operating manual
	Flocculation mixing	Hydraulic only	Paddle (normally off, per operator), has 1:6 speed turndown, per original operating manual
Clarification	Clarifier type	Upflow sludge blanket clarifier	
	Dimensions: diameter, depth (m)	Internal diameter 10 m, 4.5m deep	
	Settling zone surface area (m^2)	66 m^2	
	Surface rating (m/h)	1.47 m/h at 27 L/s 1.20 m/h at 22 L/s	Rate for 27 L/s from original operating manual
	Sludge scraping	Sludge rake, 3 m/min rake tip speed	
	Sludge drawoff system	Automatic desludge from bottom of clarifier cone	

Component	Parameter (Units)	Design Criteria	Comments
	Tank drainage facilities	Manual sludge bleed/ scour line	
	Typical sludge removal frequency, duration (sec), volume	Frequency 10 min, duration 1 min, volume not measured	Desludge on and off times are operator adjustment at filter control panel

The design flocculation time of 15 minutes (at 27 L/s) is reasonable based on the expected warm water temperatures and additional floc formation time available in the flash mixer. However some conditions may require longer flocculation times. Jar testing trials could be carried out to look at the minimum flocculation time required to form suitable floc, if required.

The design settling surface rating of 1.47 m/h (at 27 L/s) is considered to be a reasonable rate for an upflow clarifier. Higher surface ratings may be achievable, however plant trials would be recommended to prove that adequate settling could be achieved if higher rates were applied.

The clarifier is understood to run well at flow rates of 18-22 L/s and reportedly performed adequately when the raw water flow rate reached 27 L/s for several days during flood conditions in early 2010. Thus the maximum capacity of the clarifier is taken to be the design flow rate of 27 L/s, noting that performance at this flow rate could be further confirmed over a longer period of stable operation.

4.6 Filtration and Backwashing

4.6.1 Filter Design and Condition

The two filters are located in cylindrical tanks next to the clarifier. The filters are designed to treat a flow of 27 L/s, according to the original operating manual. The filters contain sand media of effective size 0.5 to 0.6 mm.

It is understood that some of the sand media has been lost and as evidence some sand was visible in the backwashing trough of Filter 1 on filter draindown. There was insufficient information to determine the depth of the media in its original condition. **The sand media level should be topped up to the original design depth by adding the required amount of 0.5 – 0.6 mm sand of a consistent uniformity coefficient (U.C.).**

It was observed that the backwash trough of Filter 1 (the filter closest to the plant building) slopes back away from the filter outlet, which may cause incomplete removal of particles washed out of the filter bed. **The slope of the trough should be corrected if possible to slope towards the outlet.**

Photo of Filter 1 Showing Trough, PAC Dosing Tube and Media Surface

During CWT's site visit in March 2006 it was noted that the inlet valve for Filter 2 could not be closed due to failure and needed to be repaired or replaced. The inlet valve for the other filter had been replaced recently. **The failed inlet valve should be replaced or repaired as soon as practical.**

The main parameters for the filters are given in the table below.

Filters Summary

Component	Parameter (Units)	Design Criteria	Comments
Filter Beds	Maximum flowrate for filtration stage (L/s)	27	Based on original manual
	Type	Sand mono-media	
	Number of filters	2	
	Filter vessel: diameter, height (m)	2.58 m, 5 m	Based on original manual
	Area per Filter (m^2)	5.3 m^2	
	Total Filter Area (m^2)	10.6 m^2	
	Filtration Rate (m/h): Both filters operating One filter off-line	 9.2 (at 27 L/s flow rate) 18.4 (at 27 L/s flow rate)	Filters are usually backwashed while plant is off, so not common to have only one filter on line
Filter Media	Filter sand: size (mm), U.C., depth (mm)	0.5 – 0.6 mm, 1.4 – 1.7, Depth not known	From original manual. Reported that some sand media has washed out during backwashing

Component	Parameter (Units)	Design Criteria		Comments
	Coarse sand and gravel	Size (mm)	Depth (mm)	
		0.5 – 1	900	
		2 – 3	100	
		3 – 5	75	
		5 – 12	75	
		12 - 20	100	
	Underdrains	PVC header and laterals cast into concrete. Plastic nozzles		From original manual
	Available Headloss (m)	At least 2.5 m		Headloss displayed on chart recorder in laboratory

The filters are normally run for around a week between backwashes. Backwashes may be initiated on run time, headloss or increases in the combined filtered water turbidity (outlined in the Filter Backwashing System section below).

Based on the filtration rates in the table above, a typical filtration rate of 9.2 m/h is in the rage generally acceptable for sand media filters. However, if only one filter was on-line when the plant was running, the resulting filtration rate (18.4 m/h for 27 L/s) would be excessive for the filter design. Based on this, it would appear that the plant was designed to have both filters on-line at all times when running. Therefore the normal procedure should be to conduct backwashing, filter maintenance etc only when the plant is off instead of letting one filter take the full plant flow, as is currently carried out.

Based on available data, the filters appear to operate adequately at the current flow rates of 18 – 22 L/s. The filters reportedly performed well when the raw water flow rate reached 27 L/s for several days during flood conditions in early 2010. Thus, the maximum capacity of the filters is taken to be the design flow rate of 27 L/s, although performance at this flow rate could be further confirmed over a longer period of stable operation.

4.6.2 PAC Dosing to Filters

PAC is dosed manually into the filters, added to the clean filter bed after each backwash. The PAC is mixed with water in a bucket and then poured down the PVC tube to the surface of the media. Either a hose or turbulence from the filter inflow is used to distribute the PAC over the filter surface.

Photo of PAC Dosing to Filter Bed

The PAC is reportedly dosed every filter run under normal operation, whether or not taste and odour problems are known to be associated with the raw water. The compounds adsorbed onto the PAC would generally be removed with the carbon particles as part of the waste backwash water.

The general purpose of PAC dosing is to adsorb organic compounds, such as taste and odour compounds and algal toxins. There are different types of PAC product, each good for adsorbing certain compounds. The PAC used at Theodore is James Cumming and Sons (C&S) product No. MDW 3545CB. This is a coal based PAC with a high iodine no. of 1050. It is an appropriate choice for general algal toxin and taste and odours.

In many water treatment processes, PAC is dosed to the raw water and settled out in the clarifier, providing a reasonably long contact time and removing most of the additional solids before the filtration stage. Dosing PAC once at the start of the filtration run, as done at Theodore WTP, gives the PAC a long contact time, although the adsorption of the PAC dosed may be exhausted before the end of the filter run and doses must be limited to significantly lower doses than could be applied to the raw water. There is also a risk that the uncoagulated PAC fines may overload or pass through the filters.

PAC doses and system parameters are discussed further in the next chapter of this report.

4.6.3 Filter Backwashing System

The purpose of backwashing is to remove the floc and other solids from the filter media at the end of a filter run. Air scour is often used before water washing to loosen the floc from the media grains. The air scour and water washing rates should be carefully designed and controlled to provide adequate washing without disturbing the media bed or washing filter media into the wastewater collection troughs.

At Theodore WTP, the backwashing sequence includes an air scour phase followed by a water wash. Air scour is provided by an air blower, located in a small shed on the outside wall of the main chemical building. Backwash water flow and pressure is provided by the (dual purpose) clear water pumps. Backwashing is a fully manual procedure. The filter inlet, outlet and backwashing valves are hydraulically controlled, and a tap inside the filter control cabinet needs to be manually turned on before operating the valves to provide fluid to the controls. The valves must then be operated individually to configure the filter for each backwashing phase.

Photo of Filter Control Panel

The backwash water is drawn off from the treated water main downstream of the clear water pumps. The clear water pumps normally operate in response to level signals in the elevated town reservoir. If they are operating automatically at the time of backwashing, the operator need only open the backwash inlet valve for the water wash phase. If the clear water pumps are off when the backwash is being performed, the automatic controls can be overridden to start the pumps from the filter control panel, however the operator must remember to turn the pumps back to automatic control when the backwash is finished because with the controls overridden the pumps will not stop when the high level in the reservoir is reached. Reservoir overflows have reportedly occurred because of operator error in forgetting to return the pumps to automatic control.

An automated backwash system (with the capacity to allow manual backwashing when required) would reduce the operator time spent on this task and reduce the likelihood of operational mistakes. As an interim, **a countdown timer or other arrangement could be linked to the clear water pump controls at the filter control panel so that the pumps will return to automatic control after backwashing, removing the need for the operator to remember to switch them back to automatic control.**

Filter backwashing component capacities and settings are outlined in the table below.

Filter Backwashing

Component	Parameter (Units)	Design Criteria	Comments
Backwashing Parameters	Backwash control	Manual operation of valves and pumps	Backwashing can only be done manually.
	Backwash phases	Procedure (manually controlled): • Air scour (typically 2 min) • Water wash (typically 10 min or until clean)	Filter valves are hydraulically operated from local control panel.
	Backwash triggers	Manual backwash performed when: • Filtered water turbidity > 0.6 NTU • Headloss > 2.5 m • Run time > 1 week	
	Backwash frequency (hours)	Filters are normally backwashed once per week	The two filters are normally washed on the same day
	Air scour rate (m/h, L/s)	42 m/h	From original manual
	Air scour blower: capacity (m^3/min)	3.4 m^3/min	From original manual
	Water scour rate (m/h, L/s)	Design: 24 – 42 m/h, 35 – 62 L/s Current: 13.6 – 15 m/h, 20 - 22 L/s	Rate (m/h) per original manual Flow of 20 - 22 L/s per operator

Component	Parameter (Units)	Design Criteria	Comments
	Backwash pumps capacity	Clear water (high lift) pumps are used to provide backwash flow. Flowrate around 20 - 22 L/s	Per operator Noted that flow *volumes* reported indicate rate of *30 – 50 L/s* (assuming 10 min washes)

The air scour time and rate shown in the table above are fairly typical. The air scour rate quoted was taken from the original operating manual, and it could be confirmed that the blower still has this capacity by measuring the flow rate. On observation of the air scour at the surface of the media during CWT's site visit in March 2006, the air scour appeared to provide enough agitation of the media.

The backwash time of 10 minutes or more is considered to be adequate. The water flow rate quoted by the operator of 20 – 22 L/s, is significantly less than the design backwash rate and very low compared to typical backwashing rates for sand media. In contradiction, the reported backwash flow volumes indicate a rate of 30 – 50 L/s if washes are 10 minutes long, which is within the original design range. Observations during CWT's site visit in March 2006 showed that media was only slowly lifted out of the media bed but that the backwash troughs were relatively close to the top of the expanded filter media. As media has reportedly been lost during backwashing in the past, the current backwash rate may be the maximum rate which can be applied. Ideally, **the backwash water flow capacity and optimum rate should be further investigated to check they are appropriate for effective backwashing.**

Photo of Air Scour Blower

Photo of Backwash Water and Air Inlet Pipework

4.7 Post-Filtration Chemical Dosing

4.7.1 Chemical Dosing Locations

The chemicals dosed after filtration are:

- Post-filtration chlorine (disinfectant);
- Post-filtration lime (alkali for pH correction).

Both chemicals are dosed into the filtered water pipe at the inlet to the clear water tank. The dosing points for these chemicals are shown in the figure below.

Photo of Post-Filtration Chemical Dosing Points

4.7.2 Post-Filtration Chlorine Dosing

Post-filtration chlorine ('post-chlorine') is dosed for the purpose of disinfection, and to contribute a residual chlorine concentration to the water leaving the plant to prevent the regrowth of biofilms in the reticulation pipes.

The post-chlorine dose is manually adjusted to meet the final water chlorine residual target.

Chemical doses used and chlorine storage and dosing system capacities are discussed in the next chapter of this report.

4.7.3 Post-Filtration Lime Dosing

Post-filtration lime ('post-lime') is dosed to correct the pH of the water after coagulation and filtration to a level suitable for release into the distribution system. Soda ash was originally used as the alkali for both pre-coagulation and post-filtration dosing, and was reportedly replaced by the alternative alkali lime in 1996.

It was noted that the actual lime dosing rate is not regularly recorded in normal plant operation. Instead the dosing pump is adjusted up or down based on the measured pH in relation to the pH target. **Automatic dose trimming coupled with planned online pH measurement could be considered, as discussed in the water quality section of this report.**

It is noted that there is no static or mechanical mixer where the lime is dosed into the filtered water pipe. Online pH measurement will indicate by trend stability whether the hydraulic mixing in the pipe and clear water tank is adequately mixing the lime into the water to give a stable pH reading. An inline static mixer, if possible with the available headloss in the pipe, could be considered if mixing problems are identified, although headloss over the static mixer must be considered.

Chemical doses used and lime storage and dosing system capacities are discussed in the next chapter of this report.

4.8 Clear Water Storage

The final treated water is stored in the clear water tank, from where it is pumped to the elevated town reservoir by the clear water pumps. A standpipe connected to the treated water rising main, located just outside the WTP site, is used to fill water trucks.

The main parameters of the clear water system are shown in the table below.

Treated Water Systems

Component	Parameter (Units)	Design Criteria	Comments
Clear Water Storage Tank	Type	Round, concrete tank	
	Diameter, depth (m)	20.6, 3 m deep	
	Total Capacity CWT (ML)	1.0	Based on data sheet supplied by operator
	Detention time	10.3 hours at 27 L/s 12.6 hours at 22 L/s	Assuming no short circuiting
Clear Water Pumps	No. and Capacity each (L/s)	2 (duty/ standby), Capacity: 28 – 35 L/s filling to elevated town reservoir 42 L/s to WTP standpipe for truck filling	Rates given by operator Original manual gives capacity as 54 L/s at 38m head Council data gives capacity as 40 L/s
Elevated Town Reservoir	Capacity (ML)	0.227	Based on data sheet supplied by operator

The contact time in the clear water tank is extensive if the full 1 ML volume is used. However it was noted that the inlet and outlet to the clear water tank are close together and not separated by a baffle, thus short circuiting is likely to occur and the full contact time of the tank will not be used. Adequate contact time in the clear water tank is critical as water is pumped out of this tank directly into the distribution system. Ideally **a baffle arrangement should be installed to ensure that the water does not short circuit through the clear water tank.**

Photo of Clear Water Tank and Clear Water Pumps

The clear water pumps are centrifugal pumps which pump water through the town system and into the elevated reservoir in town and also supply flow and pressure for backwashing the filters. There is some discrepancy in the data available on pump capacities. The capacity of the clear water pumps is taken to be 28 to 35 L/s when filling to the town system and elevated town reservoir. The capacity will vary due to changing pressures within the town distribution system and varying levels in the reservoir.

Components on the treated water rising main after the clear water pumps (located where the main passes through an access pit) include the tee for backwash water supply, the treated water magflow flow meter, a non-return valve and an isolation valve, as shown in the following figure. The treated water flow meter records to the chart recorder in the laboratory and from there sends a signal to the SCADA system.

Photo of Pit on Treated Water Rising Main

An offtake off the treated water rising main goes to the truck filling standpipe, just outside the WTP fence. When this standpipe is open, the capacity of the clear water pumps rises to around 42 L/s due to the comparatively low back-pressure.

The elevated town reservoir reportedly holds around 230 kL of water. The water flows to the elevated town reservoir through the reticulation when the WTP clear water pumps are on, and back-feeds out of the reservoir into the system when the clear water pumps are off.

Council report that reticulation water mains generally consist of 100mm and 150mm AC mains. Water services generally consist of 20mm polyethylene pipes. All domestic services are fitted with metric positive displacement meters with helical rotor meters for larger installations.

4.9 Wastewater System

Waste clarifier sludge and filter backwash water is normally directed into one of the two sludge lagoons via a flow splitting manhole. The manhole originally contained stopboards to isolate each lagoon, however these have deteriorated and the lagoons are now isolated by fitting a pipe cover onto the end of the inlet pipe into the lagoon.

The main parameters of the wastewater system are summarised in the table below.

Wastewater System

Component	Parameter (Units)	Design Criteria	Comments
Sludge Lagoons	No. of, dimensions	2 lagoons, each 70m x 52m	Dimensions based on original operating manual
	Typical maximum fill level	700 mm sludge depth	Based on original operating manual
	Sludge capacity (m^3)	2,550 m^3 each (assuming 700 mm depth)	Lagoons appear to be adequate for current sludge production as operators report that suitable drying is achieved

Component	**Parameter (Units)**	**Design Criteria**	**Comments**
	Supernatant collection	Originally used supernatant collection weirs with adjustable stopboards. However weirs have been blocked off – i.e. currently no supernatant removal	Major water discharge is by evaporation
	Underdrains	Underdrains located under sand layer. Underdrain isolation valves are located at discharge points on fence line.	Underdrainage discharges into paddock next door to WTP. Underdrains usually closed while lagoon being filled
Supernatant Recycling	Facilities	No facility for recycling supernatant from lagoons	

As noted above, the supernatant collection weirs have been blocked off and there is no other supernatant removal facility in the lagoons. Evaporation appears to adequately remove water from the lagoons to dewater the sludge.

The lagoons are fitted with underdrains, which can be opened or closed as required. The isolation valves for the underdrains are on the outlet of the discharge pipes, on the WTP fenceline. When opened, the underdrains discharge the subnatant into the neighbouring paddock, with the permission of the land owner. The underdrains are reportedly kept closed while the lagoon is being filled and then opened when the lagoon is in drying phase.

The lagoons reportedly have plenty of capacity for the wastewater levels produced and dry effectively, even with no removal of supernatant. It is likely they are oversized for the level of wastewater produced.

The disposal of subnatant into the neighbouring paddock may become an environmental issue in the future, in which case a method of collection and recycling or disposal will need to be implemented.

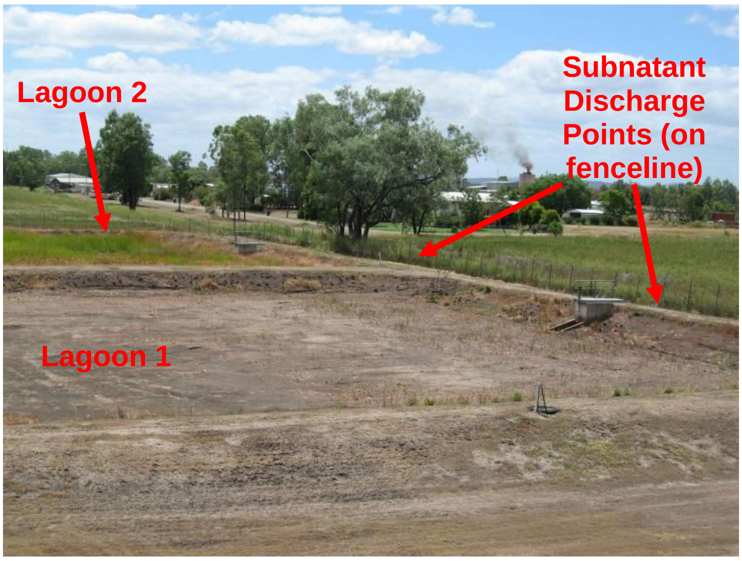


Photo of Sludge Lagoons

4.10 Plant Components Capacity Summary

The current capacities of the main WTP unit processes were estimated, based on the review of components outlined above. These values are shown in the table below, along with notes on the main capacity-limiting factor for each unit process, and options which could be undertaken to increase the capacity of that unit process, if required.

Chemical system capacities are addressed in the next chapter of the report.

Process Components Capacity Summary

Component	Main Limiting Factor(s)	Estimated Maximum Capacity	Options to Increase Capacity (if Required)
Raw Water Pumps	Pump condition/ capacity, river level	22 L/s (full river) Less if river is low	Refurbish/ upgrade pumps, add more pumps
Plant Inlet and Flash Mixer	Hydraulic design	27 L/s	Upgrade design
Clarifier	Flocculation time, surface loading rate	27 L/s	Increase surface loading rating, add another clarifier
Filters	Filtration rate	27 L/s (through both filters)	Add more filters
Clear water tank	Detention time	> 27 L/s	Prevent short circuiting
Clear Water Pumps	Pump capacity	28 - 35 L/s (pumping to elevated town reservoir)	Upgrade, add more pumps
Sludge Lagoons	Lagoon volume and drying time required	Not limited for current operations	Refurbish, add supernatant removal and recycling

From the summary above, it appears that **the capacity of the raw water pumps is currently the most limiting factor for the overall plant capacity**, particularly retarding flow rates when the river is at low level.

5. Chemical System Descriptions, Doses and Capacities

5.1 Chemical System Descriptions

5.1.1 Nalco Coagulant (DVS1 C001-D245)

The Nalco coagulant has been used as the main coagulant since 2006. Nalco Coagulant is delivered in bulky boxes and transferred using an air operated transfer pump into the coagulant solution tank (previously used as polyDADMAC dosing tank) for dosing. Dosing is achieved with a single dosing pump which has a calibration tube for drop tests to check the dosing rate.

The main details for the Nalco coagulant dosing system are given in the table below.

Nalco Coagulant System

Component	Parameter (Units)	Design Criteria	Comments
Nalco Coagulant System	Chemical product and Strength (%)	Nalco DVS1 C001-D245,	Chemical composition is proprietary information
	Batching system	Dosed undiluted	Product density is 1260 g/L
	Storage space (bulky box)	Typically 1 x 1000 L bulky box stored in chemical shed	
	Dosing tank size	500 L	
	Dosing pumps: No. of, Capacity (L/h)	1 x 27 L/h	Available data refers to 27 L/h capacity pump but capacity unable to be confirmed

There is only one Nalco coagulant dosing pump, however it was reported that suitable spare pumps are kept in the storeroom. **A pump failure alarm and an installed standby dosing pump would improve process reliability by allowing plant operation to continue with minimal interruption on the event of pump failure.**

5.1.2 Alum

Alum was previously used as the main coagulant but was replaced by Nalco coagulant. The existing alum system is reviewed below in case it is needed in the future.

Alum is supplied as granular alum in 25 kg bags. It is batched manually into a standard concentration dosing solution. The dosing solution is delivered to the dosing point by a single metering pump.

The main details for the alum makeup and dosing system are given in the table below.

Alum System

Component	Parameter (Units)	Design Criteria	Comments
Alum System	Chemical product and Strength (%)	Powdered alum	
	Storage capacity (25kg bags)	1 – 2 pallets stored in chemical shed	

Component	**Parameter (Units)**	**Design Criteria**	**Comments**
	Makeup and dosing system components	Bag unloading chute Solution mixing tank Dosing pump	Unloading system has a dust collector common to alum and lime
	Number of makeup systems	2 solution tanks, used as duty/ standby	When one tank is empty, standby tank is brought on line and the empty tank refilled
	Batching system	Manual addition of product and dilution with treated water	
	Batching concentration (g/L)	100g/L	8 x 25kg bags (200 kg) alum per 2000 L tank
	Solution tank capacity (L)	2000 L	
	Dosing pumps: No. of, Capacity (L/h)	1 x 250 L/h. Wallace and Tiernan	Spare uninstalled pump capacity 275 L/h (Wallace and Tiernan) is kept in store room
	Dilution water ratio	No dilution water	

The alum batching system is simple and reportedly runs well with minimal maintenance problems, but requires manual handling by the operators in lifting the bags onto the unloading platform and emptying them into the solution tanks. If used again, manual handling and contact with the chemical would ideally be minimised in any planned alum system improvements.

It is noted that there is only one alum dosing pump, however a suitable spare pump is kept in the storeroom. The alum pump has a calibration cylinder, and when used, drop tests were performed weekly to check the pumping rate in relation to the required dose.

Photo of Alum Batching Tanks and Dosing Pump

5.1.3 Cationic PolyDADMAC (LT425)

Cationic polyDADMAC was previously used as the secondary coagulant with alum before Nalco coagulant was introduced to the plant. The chemical system is reviewed below in case it is needed in the future.

Cationic polyDADMAC was supplied as a liquid product in bulky boxes and then diluted with water in the dosing tank which is now used for Nalco coagulant dosing. The dosing solution was delivered to the dosing point by a single metering pump.

No batching or dosing concerns were reported for the polyDADMAC system. There is only one polyDADMAC dosing pump, however it was reported that suitable spare pumps are kept in the storeroom. If the chemical is used again, an installed standby dosing pump could be considered to improve process reliability.

5.1.4 Polyacrylamide (LT20)

The polyacrylamide LT20 is supplied as a powder and batched manually in a combined batching/ dosing tank. A funnel fed eductor is used to wet up the polymer powder as it is added to the water during batching. The main details for the polyacrylamide makeup and dosing system are given in the table below.

Polyacrylamide System

Component	Parameter (Units)	Design Criteria	Comments
Polyacrylamide System	Chemical product and Strength (%)	Ciba Magnafloc LT20, supplied as powder	
	Storage space (bags)	Up to 10 bags stored in chemical dosing shed.	
	Batching system	Manual feed into batching/ dosing tank via eductor	
	Batching concentration (g/L)	1 g/L	500 g into 500 L
	Dosing tank size	500 L	
	Dosing pumps: No. of, Capacity (L/h)	1x 53 L/h	Capacity per pump nameplate. Dosing pump model is TECO/ US Filter Encore 100

Photo of Polyacrylamide Batching and Dosing System

No batching or dosing concerns were noted for the polyacrylamide system, provided correct maintenance procedures were followed.

5.1.5 PAC

PAC is dosed manually to the filters. The main details of the PAC storage facilities are shown in the table below.

PAC System

Component	Parameter (Units)	Design Criteria	Comments
PAC System	Chemical product and strength (%)	Powdered carbon C&S brand product No. MDW 3545 CB	
	Storage space (PAC bags)	1 pallet of 20 kg bags stored in chemical shed	
	Dosing mechanism	Dosed by hand to filters	PAC dose added after backwash

5.1.6 Chlorine

The chlorine room is a separate room in the chemical dosing shed, accessed from the outside of the shed. The chlorine room houses up to six cylinders (two on-line cylinders plus standby cylinders) and the pre-chlorine and post-chlorine chlorinators.

The chlorine booster pump is housed inside the chemical dosing shed, next to the polyacrylamide batching tank.

The main details for the pre- and post-chlorine dosing systems are given in the table below.

Chlorine Systems

Component	Parameter (Units)	Design Criteria	Comments
Chlorine System	Chemical product	Chlorine gas (70 kg cylinders)	
	Chlorine room capacity (cylinders)	4 to 6 x 70 kg cylinders	2 duty (1 x pre and 1 x post), remaining cylinders unconnected standbys
	Ejectors: No. of, Type, Capacity (g/h)	2 (1 x pre and 1 x post dosing), S10k Rotameters, Capacity: Pre: 100 - 2000 g/h * Post: 20 - 400 g/h	Ejector capacity based on rotameter scales. * Note that design maximum gas discharge rate from a 70 kg cylinder is: 1200 g/h at 15 deg C 700 g/h at 10 deg C Thus pre-chlorine likely to be limited to approx. 1200 g/h in winter
	Booster water pumps: No. of, Capacity (L/s)	1 common to both pre and post dosing. Type Grundfos CR-4.	No installed standby

Component	Parameter (Units)	Design Criteria	Comments
	Load cells capacity	No load cells	Pressure switches show when empty and cylinders manually changed over
	Service water supply	Supplied from treated water rising main	
	Chlorine leak detector: Type	Acutec 35	

The chlorine dosing systems do not have auto changeover when a cylinder is empty. Pressure switches on the duty cylinders indicate when a cylinder is empty and the operators say they can see the rotameter oscillating when the pressure in the cylinder is getting low. The systems require the operator to be aware when a cylinder is empty and manually change over to a new cylinder. There are no alarms to remind the operator to change over cylinders; therefore continued chlorination depends on the competency and attendance of the operator.

The continued dosing of post-chlorine is critical for disinfection of the final water. It is understood that the installation of an online chlorine residual meter is planned. **The online residual meter should be installed as soon as possible and should be connected to the SCADA system, with an associated dial out alarm to reduce the potential response time if a chlorine cylinder should run out when the plant is unattended.**

It is noted that there is only one chlorine booster pump, common to both the chlorine systems. A standby pump should at least be kept in stock in case the booster pump fails. **Ideally, an installed standby chlorine booster pump should be provided to lessen the potential down time of the critical post-chlorine dosing system.**

Photo Showing Chlorine Room Door

Chlorine Room Showing Cylinders and Chlorinators

The design of the chlorine systems and the chlorine room is compared to some of the requirements of the Australian Standard for chlorine installations (AS/NZS 2927: 2001) in the table below.

Australian Standard Requirements for Chlorine Installations

Clause	**Reqts Met?**	**Comments**
Cladding or lining of any indoor installation shall be incombustible. Floor shall be of concrete (Clause 3.5.1)	N	Wooden panelling may not be suitable (potentially combustible)
At least one sign prominently displayed at eye level, visible when door is open. Where kept with other dangerous goods, chlorine storage area shall be clearly delineated and marked with signs (Clause 3.5.1)	Y	Chlorine sign displayed outside door, visible when door open
Pits, sumps and machinery wells enclosed or below the level of the chlorine installation shall have no unsealed openings into the chlorine storage or chlorinator areas or areas traversed by pipes carrying chlorine (Clause 3.5.1)	N	Chlorine may be able to leak under walls into pipe channels inside chemical storage shed and laboratory. Noted that if chlorine enters laboratory area, it may damage electrical equipment main control panel
Personnel doors shall open outwards and be fitted with devices to hold the door open (Clause 3.5.2)	Y	Door opens outwards and latch supplied
A sign, indicating that the door is to be kept open whenever personnel are inside, shall be fitted outside the door and shall be visible when the door is open (Clause 3.5.2)	N	Appropriate sign not visible when door open
Natural ventilation required for areas where chlorine stored or < 2000 kg connected to withdrawal system. Natural ventilation requires at least 0.1 m^2 for each 2 m of external wall, near to floor level in opposite walls to create a cross-draught (Clause 3.5.3)	N	Significant ventilation high in wall. Low ventilation in door (one wall only).
Mechanical ventilation required for areas where > 2000 kg chlorine connected to withdrawal system (Clause 3.5.3)	n/a	Max total of 140 kg chlorine connected to withdrawal system
Leak detectors shall be installed where chlorine is stored in tanks or where liquid chlorine is withdrawn. Leak detectors shall be tested each week (Clause 4.8.1)	N	Leak detector installed but not tested each week
Wind direction indicators shall be installed where chlorine is stored in tanks or where liquid chlorine is withdrawn (Clause 4.8.5)	N	No wind direction equipment

As seen above, the installation does not meet some of the requirements of the Standards. **Ideally, the chlorine installation should be improved to meet the Australian Standards, as outlined in the table above.**

5.1.7 Lime

Lime is supplied in 20 kg bags. It is batched manually into a standard concentration dosing solution. The dosing solution is delivered to the dosing point by a single metering pump.

The main details for the lime makeup and dosing system are given in the table below.

Lime System

Component	Parameter (Units)	Design Criteria	Comments
Lime System	Chemical product and strength (%)	Hydrated lime. Various suppliers. Varying purity	Poor quality lime implicated in pump and line blockages
	Makeup and dosing system components	Bag unloading chute Solution mixing tank Dosing pump	Manual loading into tank
	Number of makeup systems	2 solution tanks, used as duty/ standby	When one tank is empty, standby tank is brought on line and the empty tank refilled
	Storage capacity	1 -2 pallets of lime in 20 kg bags	
	Bag unloading arrangement	Bags manually unloaded into solution tank	Dust extraction system available
	Batching concentration (g/L)	Approx 23.5 g/L (2.35%)	2 x 20 kg bags (40 kg) lime per 1700 L tank
	Solution tank capacity (L)	Approx 1700 L	Per original manual. Note that operators gave tank capacity as 1700 L and other data as 1840 L
	Dosing pumps: No. of, Capacity (L/h)	1 pump, 275 L/h	Spare pumps kept on site as standby. A pump and dosing point tapping for pre-lime could be added if required
	Dose adjustment method	Change pump stroke rate	
	Service water supply	Supplied from treated water rising main	

The lime batching system reportedly runs well most of the time, although blockages occur occasionally. The operator’s feeling is that they are usually associated with poor quality lime product and that blockages are much less frequent when good quality lime is used. Good quality lime products should therefore be specified when chemicals are purchased.

The lime system is set up to automatically flush the pump and dosing line with service water both periodically during operation (with operator-adjustable duration and frequency) and on plant shutdown (with operator-adjustable duration).

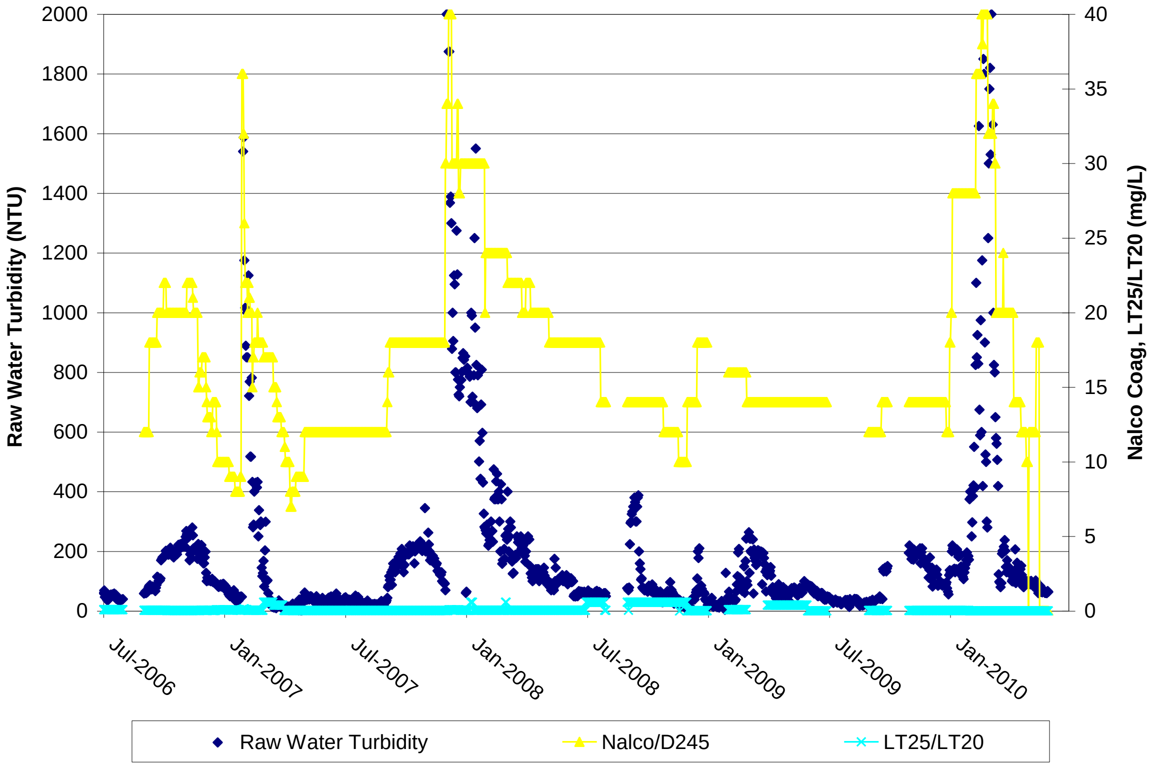
It is noted that there is only one lime dosing pump, however, suitable spare pumps are kept in the storeroom.

Lime requires manual handling by the operators in lifting the bags onto the unloading platform and emptying them into the solution tanks. **Manual handling and contact with the chemical would ideally be minimised in any planned lime system improvements.**

5.2 Chemical Doses Used

5.2.1 Nalco Coagulant (DVS1 C001-D245)

The doses of Nalco coagulant used since this coagulant was implemented in 2006, as reported in operational data, are shown on the graph below. Polyacrylamide doses (as reported) are also shown in the graph. It is understood that jar testing is performed regularly and the coagulant doses are adjusted accordingly. The doses shown in the graph are the numbers reported as 'Setting' on the WTP data sheets. It is understood that these settings represent the actual dose rate as determined in jar tests. **Coagulant dose rates and maximum pump capacity should ideally be confirmed by further testing.**



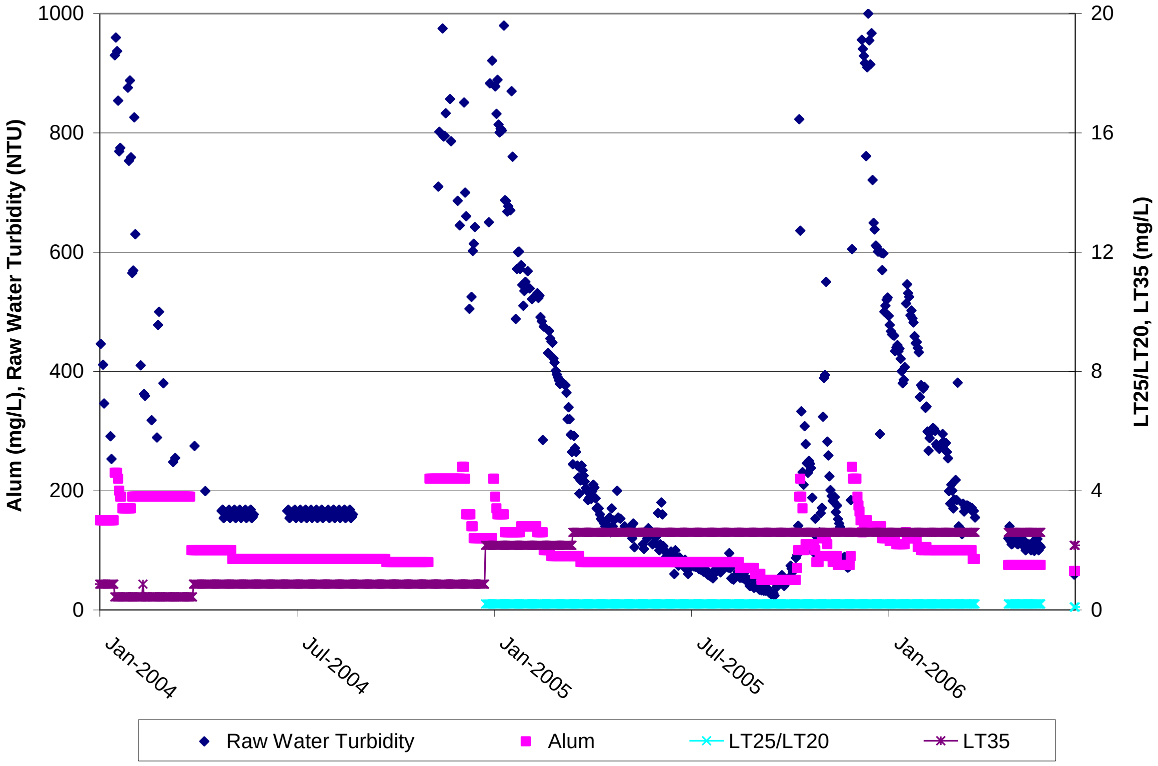
Graph of Chemical Dose Levels for Nalco Coagulant and Polyacrylamide

As seen in the graph, Nalco coagulant doses of 7 – 40 mg/L have been used. Typical doses are 10 – 20 mg/L. Higher doses correspond to higher raw water turbidity, as would be expected.

5.2.2 Alum and Cationic PolyDADMAC (LT425)

The doses of alum and cationic polyDADMAC used up to 2006, as reported in operational data, are shown on the graph below. Polyacrylamide doses (as reported) are also shown in the graph.

When polyDADMAC (LT425) was used as a secondary coagulant with alum, the dose was rarely changed. The basis of the reported dose was uncertain, therefore the dose shown in the graph below was recalculated on the basis of 'as supplied chemical product' using data from drop tests performed by the operator and monthly chemical use and raw water volume summaries. A dose reported as "0.6 mg/L" was estimated to be around 2.6 mg/L as supplied chemical product, with other reported doses converted to this basis based on their ratio to the reported "0.6 mg/L" dose.



Graph of Chemical Dose Levels for Alum, Cationic PolyDADMAC (LT425) and Polyacrylamide

As expected, the alum dose is increased when the raw water turbidity peaks are seen. Doses of up to 240 mg/L are used. Such high doses are likely to reduce the pH of the water significantly, and it was noted from available data that when peak doses were used on 20/10/05 and 7/12/05, the reported dosed water pH was 4.5 or less. **If alum dosing was again used as the coagulant, the installation of components to allow pre-coagulation alkali dosing would be recommended so that the coagulation pH can be controlled to be in the most effective range when large alum doses are required.**

The graph shows that the cationic polyDADMAC dose was turned up in steps to 2.6 mg/L, where it was then constant since early 2005. It is noted that the polyDADMAC dose may be able to be adjusted in various water quality situations to optimise the relationship between this chemical and alum.

5.2.3 Polyacrylamide (LT20)

The reported polyacrylamide dose, based on available operational data and shown on the graphs above, was 0.2 mg/L from January 2005 to May 2006. After the commencement of Nalco coagulant dosing in 2006, reported polyacrylamide doses have ranged from 0.02 – 0.6 mg/L. It is noted that a dose of 0.6 mg/L is at the high end of doses normally applied as flocculant aids, and could possibly be optimised further.

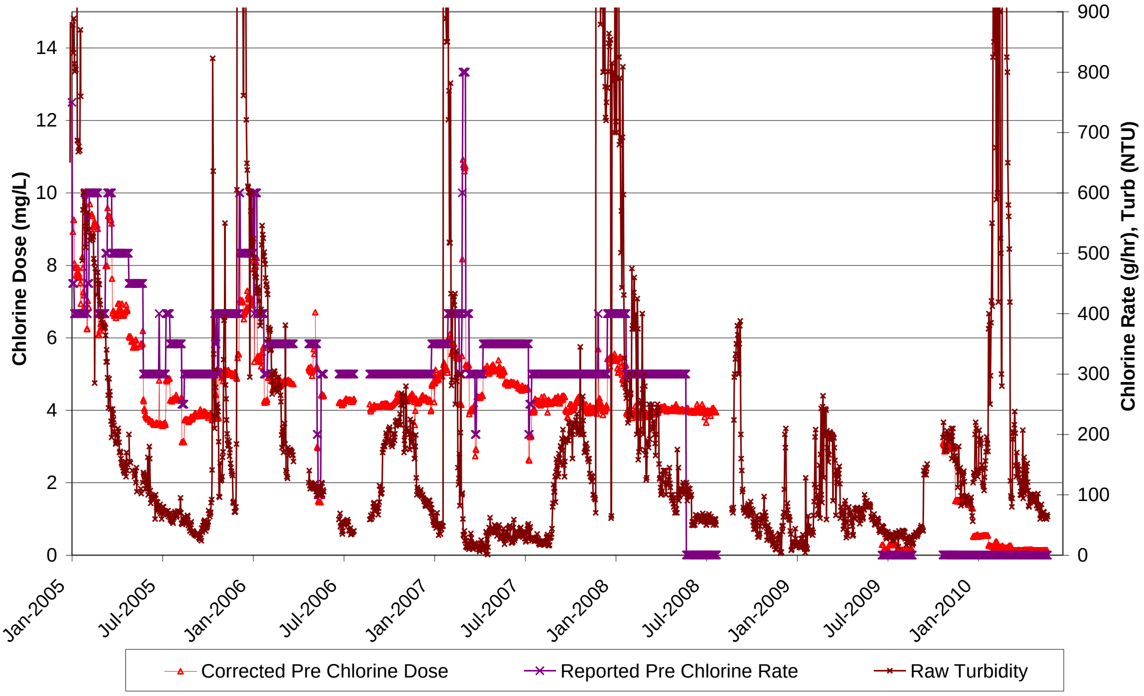
It is noted that the dosing range from 0.02 up to 0.6 mg/L shows a wide variation in dose rates. As an alternative explanation it may be possible that the dose has been reported differently in some months (e.g. 0.02 instead of 0.2 mg/L).

5.2.4 PAC

The PAC dose is reportedly around 0.5 L per filter per run, added manually to the surface of the filter after backwashing.

5.2.5 Pre-Coagulation Chlorine

The graph below shows the pre-chlorine dosing rate (g/h) as reported in available operational data and the chlorine dose (mg/L) calculated based on the reported chlorine dosing rate and raw water flow rate. In available data for 2009 and 2010, the chlorine dosing rate has been reported differently, possibly due to a different rotameter being fitted. The basis of this discrepancy was unable to be confirmed, however based on values before and after the change, the calculated doses shown for this period have been corrected to account for this difference on the basis that the new reporting units are 1000 x g/h.



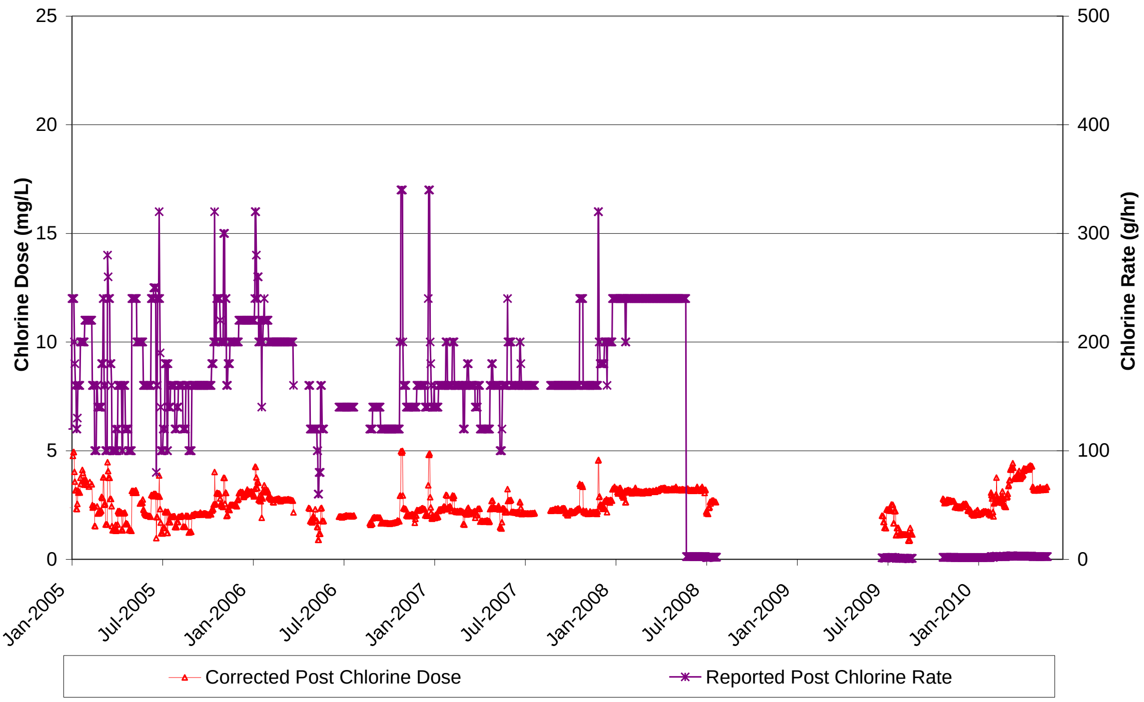
Graph of Pre-Chlorine Dose Compared to Raw Water Turbidity

As seen in the graph, the pre-chlorine dose has varied mainly between 1 and 11 mg/L, indicating that the raw water can have a chlorine demand of up to 10 mg/L. The chlorine demand appears to vary as expected with the raw water turbidity, with the highest dose required in the summer periods with the dirtiest water.

The available data for 2009 – 2010 is limited and does not fit the previous trend. This difference is attributed to a different recording basis rather than a significant change in the doses applied. **The current basis of recording the chlorine dosing rate should be confirmed and the operational records sheet formulae amended to correctly calculate the dose in mg/L**.

5.2.6 Post-Filtration Chlorine

The graph below shows the post-chlorine dosing rate (g/h) as reported in available operational data and the chlorine dose (mg/L) calculated based on the reported chlorine dosing rate and raw water flow rate. In available data for 2009 and 2010, the method of reporting the chlorine dosing rate was changed from the previous system. Based on values before and after the change, the calculated doses shown for this period have been corrected to account for this difference, on the basis that the new reporting units are 100 x g/h.



Graph of Post-Filtration Chlorine Dose Parameters

As seen in the graph, the post chlorine dose has a fairly narrow range between 1 and 5 mg/L and is typically in the range 2 to 4 mg/L.

5.2.7 Post-Filtration Lime

The average lime doses were calculated for each month based on monthly summaries of lime used and water treated (lime doses are not recorded daily as for other chemicals). The lime dosing figures calculated from the monthly totals were in the range 25 to 86 mg/L, although daily dose extreme values for would be expected to have an even wider range. The typical value for lime dosing was around 40 mg/L.

5.3 Chemical Dose and System Capacity Summary

5.3.1 Calculated System Dosing Capacities

The current capacities of the chemical systems in mg/L for various plant flow rates were calculated, based on the review of systems outlined above and data shown in the following table. The capacity values are shown in the table, along with options for increasing the capacity of each system.

Chemical Dosing Capacities (Calculated from Available Data)

Chemical	**System Parameters**		**Calculated Dose Capacity (mg/L)**		**Batch Tank/ Cylinder Usage Time**		**Options to Increase Capacity (if Required)**
	Dosing capacty (L/h)	**Dosing Soln (g/L)**	**22 L/s Plant Flow**	**27 L/s Plant Flow**	**Vessel volume (L)**	**Time to Empty (h)**	
Alum	250	100	**320**	**260**	2000	8	Stronger solution, larger pump
Polydad-mac (LT425)	27	109	**37**	**30**	500	18	Stronger solution, larger pump
Nalco coagulant	27	1260	**430**	**350**	500	18	Larger pump
Polyacr-ylamide (LT20)	53	1	**0.7**	**0.6**	500	9	Stronger solution, larger pump
Pre-chlorine	1200 g/h	n/a	**15**	**12**	70 kg	58	Upgrade dosing system
Post-chlorine	400 g/h	n/a	**5**	**4**	70 kg	175	Upgrade dosing system
Post-lime	275	23.5	**82**	**66**	1700	6	Stronger solution, larger pump

5.3.2 Chemical Dose Summary and Comparison with Capacities

The actual chemical doses, as discussed above, are summarised in the table below, with the estimated system capacity for 22 and 27 L/s plant flow repeated for comparison purposes.

Actual Doses Used (Estimated from Available Data)

Chemical	**Actual Doses Used (mg/L)**		**Capacity at 22 L/s Plant Flow (mg/L)**	**Capacity at 27 L/s Plant Flow (mg/L)**
	Range	**Typical**		
Alum	50 - 240	Summer: 140 Winter: 80	320	260
Cationic polydadmac (LT425)	0.9 – 2.6	2.0	37	30
Nalco coagulant	7 - 40	10 - 20	430	350
Polyacrylamide (LT20)	0.02 – 0.6	0.05	0.7	0.6
PAC	0.25 – 1 L per filter	0.5 L to each filter	n/a	n/a
Pre-chlorine	3 - 16	5	15	12
Post-chlorine	1.0 – 5.0	2.5	5	4
Post-lime	25 - 86	40	82	66

From the capacity and dose values estimated it appears that:

- The Nalco coagulant dosing system appears to have plenty of capacity for the expected doses, however it is noted that the reported capacity of this dosing pump was unable to be confirmed;
- The polyacrylamide system will just reach the maximum expected dose at a plant flow of 27 L/s;
- The pre- and post-chlorine and lime systems will be at or slightly over their maximum limit for maximum doses at a plant flow of 22 L/s. Upgrade of these systems will be required if plant flow rates higher 22 L/s are to be used, to ensure they can achieve the expected highest chemical dose demands.

6. WTP Operational Issues

6.1 Plant Control and Automation Issues

6.1.1 General Observations

It was observed that the plant control system generally has a low level of automation, with no flow pacing or automatic dose adjustment and fully manual backwashing. The existing system is relatively simple, but requires greater operator input than more automated systems.

If automation improvements are made, it would be beneficial and preferred by the operators that the capacity to run systems in manual mode is still retained to give operational flexibility.

6.1.2 SCADA System

A RADTEL brand SCADA system common to all Council WTPs has been implemented over recent years. The Theodore SCADA pages show the water supply and distribution system and some parameters for the WTP.

It was noted that the SCADA system is subject to ongoing development. The SCADA system will potentially be useful in terms of adjusting setpoints, logging online data, remote plant observation/ operation and callout alarms.

It was noted that operational staff are still learning about the the SCADA system. The trending of on-line information will be a particularly good tool for WTP operators to use as input for operational decisions. **Ongoing training of the operators and other staff on the various SCADA capabilities would be beneficial.**

6.1.3 Control of Plant Startup and Shutdown

The plant is automatically started and stopped based on water demand via the following control loops:

- High Lift Pump Control: The elevated town reservoir level signal is used to generate a start/stop signal to the WTP high left (treated water) pumps via the SCADA. The start/stop signals can be set on the SCADA system;
- Raw Water Pump Control: The WTP clear water tank level signal is used to generate a starts/stop signal to the raw water pumps via telemetry;
- Chemical Dosing Systems Control: A level switch installed in the flash mixing tank is used to generate a start/stop signal to the WTP chemical dosing systems. The chemical dosing systems start when the operating water level is reached in the flash mixer/ clarifier.

It is noted that all valves on the flow path through the WTP remain open when the plant is off. The filter inlet and outlet valves are manually operated only.

The chemical dosing start-up trigger is currently based on a level switch sensing the water level in the flash mixing tank. In the past, the chemical dosing trigger was based on a flow switch in the raw water main, however the control arrangement was reportedly changed because it caused overdosing of post-lime and post-chlorine if there was raw water flow into the plant but no flow out of the filters (e.g. because the level in the flash mixer and clarifier had dropped while the plant was off line).

With the current chemical dosing start-up control system, there is a risk that if the clarifier level has drained down (e.g. due to desludging) then the coagulant chemical dosing will not start as soon as raw water starts entering the plant and a significant amount of uncoagulated water may enter the clarifier, as has reportedly happened in the past. The problem is currently avoided by the operators being aware of the level in the clarifier and, when necessary, running the pre-chlorine and coagulant chemical systems in manual mode until the trigger level in the flash mixer is reached. However this system relies on the operators remembering to start and stop the chemical systems, and can lead to more problems if the dosing systems are not switched back to automatic operation again when the plant is running normally.

The problems associated with the chemical dosing start-up controls could theoretically be overcome by having two separate chemical dosing system start-up triggers:

- Raw water flow triggers the pre chlorine, coagulant and coagulant aid polymer dosing systems to start up;
- Level in clarifier triggers the post dosing chlorine and lime chemicals.

This separation of the pre- and post- chemical dosing start-up controls should be investigated and implemented if possible to make the plant easier to operate with varying flash mixer/ clarifier levels.

6.1.4 Process Impacts of Plant Start-up

It is noted that clarifier and chemical dosing systems generally run more smoothly with continuous rather than start/stop operation. Flow changes due to plant start-up may disturb settling in clarifiers and/or lead to periods of over/ under dosing due to delays in chemical dosing system starts and stops.

The operators feel that flow changes at the Theodore WTP due to starting and stopping are not a great problem in terms of process stability and water quality achieved. They reported that start-up can cause the sludge blanket to lift, particularly in the mornings when the river water may be around 10 ºC warmer than the water in the clarifier, however it generally does not lead to significant floc carryover.

It is noted that if the impact of start-ups is seen to be limiting further optimisation of the plant process in future, the number of start-ups per day could be potentially reduced by:

- **altering the start and stop levels in the clear water tank and elevated reservoir; and/ or**
- **fitting VSDs to the raw water pumps and making chemicals flow paced.**

6.1.5 Filter Backwashing Automation

As discussed in the previous section on Filter Backwashing, the backwashing system should be improved to make operation easier and reduce the chance of operator error in terms of:

- **Upgraded control of filter valves and provision for an automated backwash sequence;**
- **Upgraded control of clear water pumps (used for backwashing), so that they will return to automatic operation after being used for backwash.**

6.1.6 Online Monitoring

The existing and planned online monitoring facilities for the WTP are summarised in the table below.

Online Monitoring Meters Summary

Component	**Parameter (Units)**	**Design Criteria**	**Comments**
Turbidity	Type	HACH	Logged to SCADA. Local display shown on instruments panel inside lab High turbidity alarm set to 2 NTU
	Sampling location	From filtered water sample line (drawing from tapping in common filter outlet pipe)	
pH	Type	**Planned, but not yet installed**	To be logged to SCADA
	Sampling location	Final water - **Not yet installed**	
Chlorine Residual	Type	**Planned, but not yet installed**	To be logged to SCADA
	Sampling location	Final water - **Not yet installed**	
Raw Water Flow	Type	ABB magflow meter	Logged to SCADA (through chart recorder)
	Sensor location	Raw water main (under metal cover)	Noted flow meter not recording properly March 06
Treated Water Flow	Type	ABB magflow meter	Logged to SCADA (through chart recorder)
	Sensor location	Treated water rising mains (in open valve pit under metal cover)	
Clear Water Tank Level	Type	'Platypus' pressure sensor plus Hi/ Lo level float switches	Level sensor logged to SCADA Hi/ Lo float switches trigger alarms on SCADA
	Sensor location	Clear water tank	
Elevated (Town) Reservoir Level	Type	'Platypus' pressure sensor plus Hi/ Lo level float switches	Level sensor logged to SCADA Hi/ Lo float switches trigger alarms on SCADA
	Sensor location	Reservoir	
Filter Headloss	Type	Kent differential pressure sensors	Logged to chart recorder
	Sensor location	Filters 1 and 2	

As seen in the table, flow rates, filtered water turbidity, critical tank levels and filter headloss are monitored by on-line instruments. Most of these signals are connected to the SCADA system and thus are understood to be able to be trended.

It is understood that the provision of on-line instruments for measuring treated water chlorine residual and pH is budgeted and that these instruments would also be connected to the SCADA system. As mentioned in the Water Quality and Chemical System sections above, automatic dose adjustment for lime and post-chlorine could be considered as a long term improvements, once the respective online meters have been installed. To allow for these further chemical dosing automation improvements, if considered desirable, the on-line chlorine and pH instruments selected should be suitable for use in chemical dosing trim control loops.

The provision of an additional online turbidity meter to monitor the raw water turbidity level could be considered in future, with alarm limits able to be set to warn operators of a sudden deterioration in the water quality in the river.

6.1.7 SCADA Callout Alarms

During CWT's site visit in March 2006, it was noted that none of the SCADA callout alarms were enabled. As it is understood that the SCADA callout alarms have replaced previous dial out systems, this meant that there were no alarm signals configured to call the operator out, and the system therefore relied on operator observation to notice any alarms. **Critical callout alarms should be re-enabled as soon as possible to provide out-of-hours indication of faults.**

The existing critical callout alarms for the plant process operation are considered to be:

- Filtered water turbidity;
- Power outage;
- Clear water tank or elevated reservoir overflow.

Future critical alarms may include:

- Treated water chlorine residual;
- Treated water pH.

6.1.8 Power Failure Protection

It is noted that there is an onsite emergency diesel generator. The generator can be used to power the plant when there is a local power failure at the WTP. Power supply is still required to run the raw water pumps.

The generator is housed in a shed behind the plant building. Diesel fuel for the generator is obtained from the Council construction crew.

6.2 Safety and Environmental Issues

The following safety and environmental issues were noted during CWT's WTP inspection, however this is not intended to be a full and exhaustive OH&S audit.

6.2.1 Chemical Bunding

It is noted none of the chemical solution tanks in the chemical shed is separately bunded. Also, none of the chemical dosing pumps is within a bund. Chemical spills would tend to leak into the pipe trenches in the floor of the chemical shed.

Chemical spills on the shed floor would be a health hazard. And it is likely that large spills would find their way outside the shed and potentially enter the environment.

It was noted that a spill kit containing equipment for cleaning up and isolating chemical spills is provided at the plant.

Photo of Alum Tanks and Pump (both unbunded)

All chemical storage and batching/ dosing tanks and all chemical dosing pumps should be bunded to prevent the spillage of chemicals. Bunds should be built to conform with standards on design and materials.

6.2.2 Manual Handling

Manual handling issues identified on the plant include:

- Manual handling of all bagged chemicals on delivery;
- Manual handling of lime and alum bags for batching;
- Manual handling of PAC and dosing procedure requiring buckets to be carried up the stairs to the filters.

It is noted that an electric hoist is provided for lifting the pallets onto the unloading platform. This helps to lift the bags more quickly and easily onto the platform, but does not remove the requirement for the manual lifting of bags across the platform to the unloading areas.

Any upgrades of the chemical systems should consider ways to further minimise manual handling requirements for the operators.

6.2.3 Contact with Chemicals

Because chemicals are batched manually, there is some potential for the operators to come in contact with the chemicals such as lime and alum dust, PAC and polymer powders.

It is noted that a dust extractor is provided for the lime and alum unloading systems. Dust masks and other PPE should be worn when handling PAC and polymer powder.

Any upgrades of the chemical systems should consider ways to further minimise the risk of operator contact with chemicals.

6.2.4 Stairways and Unguarded Platforms

There a number of stairways and platforms which may not conform to modern safety standards. These include:

- The chemical unloading platform – permanent railing or chain arrangement required where chemicals are unloaded;
- Stair-ladder for chemical loading platform – may be too steep;
- Stair-ladder to filters/ clarifier - may be too steep;
- Lockable cages on stair-ladder to filters/ clarifier and on clear water tank – Design may allow cage door to fall on hand/ head.

These installations should be checked against relevant standards. Improvements to increase safety on the above issues of concern should be progressed as soon as possible.

Photo of Bag Unloading Platform for Alum and Lime

6.2.5 Pontoon for Accessing Raw Water Foot Valves

As noted in the section on Raw Water Pumps above, the foot valves for the non-return valves need to be worked on from time to time. It was noted that **the size and design of the pontoon used for this task could be improved to make it more stable and therefore safer**.

6.2.6 Laboratory and Office Facilities

The laboratory area provided at the WTP is small and rudimentary, but appears to serve the purpose as a place for daily water testing and jar testing. It is noted that the room is not airconditioned, which may be a concern for operator comfort and for the storage of reagents and instruments.

The office hut also contains a small kitchen area for lunch preparation. The level of security for computers and other equipment stored in the office may potentially be a concern because of the remoteness of the site and the louver windows on the hut.

It is noted that a security fence has been erected around the plant area. The plant gates should be locked when the site is unattended.

The office and lunch facilities could be improved to provide better operator comfort and security.

6.3 Maintenance Tasks

Day to day operation and maintenance duties are understood to be carried out by staff based in Theodore with support from Moura. Other activities are organised by Council management representatives as required.

7. WTP and System Upgrade Requirements

7.1 Identified Potentials for WTP Improvement

A number of other potential improvement works have been identified in earlier sections of this report. These issues are tabulated below, with time frame and priority level noted. Potential upgrades to increase the WTP capacity are addressed separately in sub-section 7.5 below.

7.1.1 Treatment Process Improvements

System	Issue/ Requirement	Refer Section No.	Time Frame	Priority
Treatment aims	Improve WTP process with the aim of effectively removing pesticides and herbicides from the water e.g. PAC dosing or ozone BAC	3.3.5	Medium	Medium

7.1.2 Water Quality Monitoring Issues

System	Issue/ Requirement	Refer Section No.	Time Frame	Priority
Raw water quality	Continue to regularly monitor pesticides and herbicides; Consider these contaminants in incident management procedures developed for raw water contamination events	3.3.5	Short-Medium	Medium
Microbio-logical	Analyse raw water periodically for *Cryptosporidium* and *Giardia*	3.3.9	Short-Medium	Medium
Microbio-logical	Follow up any further *E.Coli* detections urgently to identify and address any issues leading to inadequate disinfection and/or faecal contamination of the treated water	3.3.9	Ongoing	**High**

7.1.3 Online Instruments

System	Issue/ Requirement	Refer Section No.	Time Frame	Priority
Flow meters	Investigate and correct discrepancies between the raw and treated water flow meters	2.4.1	Medium	Medium
Chlorine monitoring	Install online chlorine residual meter as soon as possible and connect to the SCADA system, with associated dial out alarm.	5.1.6	Short	**High**
Online monitoring	Provide online turbidity meter to monitor the raw water turbidity level	6.1.6	Long	Low

7.1.4 Raw Water Pumping Issues

System	**Issue/ Requirement**	**Refer Section No.**	**Time Frame**	**Priority**
Raw Water Pumps	Address foot valve and draw off pipe corrosion problems by maintenance and/or replacement with corrosion-resistant materials	4.2	Medium	Medium
Raw Water Pumps	Improve size and design of the pontoon used for maintenance of the intake foot valves	4.2, 6.2.5	Medium	Medium

7.1.5 Chemical Dosing Issues

System	**Issue/ Requirement**	**Refer Section No.**	**Time Frame**	**Priority**
Chemical Dosing	Provide bunds for chemical storage and batching/ dosing tanks and dosing pumps to conform with relevant standards	6.2.1	Medium	Medium
Chemical dosing	Minimise manual handling and risk of operator contact with chemicals	6.2.2, 5.1.1, 5.1.7	Medium	Medium
Pre-lime dosing	If alum dosing was to continue to be used as the coagulant, components to allow pre-coagulation alkali dosing would be recommended	5.2.1	Long	Low
Nalco coagulant dosing	Install pump failure alarm and installed standby dosing pump to improve process reliability	5.1.1	Medium	Medium
Nalco coagulant dosing	Confirm dose rates and pump maximum capacity	5.1.1	Short	Medium
Chlorine	Provide installed standby chlorine booster pump	5.1.6	Medium	Low
Chlorine	Improve chlorine installation to meet Australian Standards	5.1.6	Medium	Medium
Chlorine	Confirm current basis of recording the chlorine dosing rate and amend operational records sheet to calculate the dose in mg/L correctly	5.2.6	Short	Medium
Post-lime dosing	Provide automatic lime dose adjustment for pH correction using on-line pH analyser	3.2.5, 4.7.3	Medium	Low

7.1.6 Clarifier and Filters

System	**Issue/ Requirement**	**Refer Section No.**	**Time Frame**	**Priority**
Clarifier	Check best flocculation mixing conditions by conducting plant trials with central well flocculation mixer off and on at various speeds	4.5	Medium	Medium

System	Issue/ Requirement	Refer Section No.	Time Frame	Priority
Filters	Top up sand media level to the original design depth	4.6.1	Medium	Medium
Filters	Correct slope of the filter backwash trough to slope towards outlet.	4.6.1	Long	Low
Filters	Replace or repair failed inlet valve as soon as practical	4.6.1	Short	Medium
Filter backwash	Install timer linked to the clear water pump controls at the filter control panel to return pumps to automatic control after backwash	4.6.3	Short-Medium	Medium
Filter backwash	Upgrade control of filter valves to provide for automated backwash sequence	6.1.5	Long	Medium
Filter backwash	Further investigate backwash water flow capacity and optimum rates to check they are appropriate for effective backwashing	4.6.3	Medium	Medium

7.1.7 Clear Water Tank and Sludge Lagoons

System	Issue/ Requirement	Refer Section No.	Time Frame	Priority
Clear Water Tank	Install a baffle arrangement to ensure that the water does not short circuit through the clear water tank	4.8	Long	Medium
Sludge lagoons	The disposal of subnatant into the neighbouring paddock may become an environmental issue in the future, in which case an alternative system may need to be implemented	4.9	Long	Low

7.1.8 General

System	Issue/ Requirement	Refer Section No.	Time Frame	Priority
Nalco coagulant	Refer to Nalco coagulant product using the first part of the number, DVS C001	4.3.4	Short	Low
SCADA operation	Ongoing training of the operators and other staff on the various SCADA capabilities	6.1.2	Medium	Medium
Plant control	Separate pre- and post- chemical dosing start-up controls to make the plant easier to operate with varying flash mixer/ clarifier levels	6.1.3	Medium	Medium
Plant control	Reduce the number of plant start-ups per day by altering the start and stop levels in the clear water tank and elevated reservoir; and/ or fitting VSDs to the raw water pumps and making chemicals flow paced.	6.1.4	Medium	Low

System	Issue/ Requirement	Refer Section No.	Time Frame	Priority
SCADA alarms	Critical callout alarms should be re-enabled as soon as possible to provide out-of-hours indication of faults.	6.1.7	Short	**Very High**
General safety	Check stair-ladders and railings against relevant standards. Improve safety on issues of concern	6.2.4	Medium	Medium
General	The office and lunch facilities could be improved to provide better operator comfort and security	6.2.6	Medium	Low

7.2 High Priority Upgrade Requirements

The following improvement works are high priority and should be carried out as soon as possible:

- Re-enable critical callout alarms as soon as possible to provide out-of-hours indication of faults – Alarms should include high filtered water turbidity, power outage, clear water tank or reservoir overflow and, when online meters installed, high/ low chlorine and pH. Some of these alarms may also be configured to shut the WTP process down until an operator can attend site to rectify the problem;
- Install online chlorine residual meter as soon as possible and connect to the SCADA system, with associated dial out alarm;
- Follow up any further *E.Coli* detections urgently to identify and address any issues leading to inadequate disinfection and/or faecal contamination of the treated water.

7.3 Medium Priority Upgrade Requirements

7.3.1 Medium Priority, Short Timeframe Actions

The following improvement works are medium priority and should be carried out as soon as possible:

- Continue to regularly monitor pesticides and herbicides; Consider these contaminants in incident management procedures developed for raw water contamination events;
- Analyse raw water periodically for *Cryptosporidium* and *Giardia;*
- Investigate and correct discrepancies between the raw and treated water flow meters;
- Confirm coagulant dose rates and pump maximum capacity;
- Confirm current basis of recording the chlorine dosing rate and amend operational records sheet to calculate the dose in mg/L correctly;
- Install timer linked to the clear water pump controls at the filter control panel to return pumps to automatic control after backwash;
- Replace or repair failed filter inlet valve.

7.3.2 Medium Priority, Medium to Long Timeframe Actions

The following improvement works are medium to long priority and should be carried out in the medium to long term:

- Install coagulant dosing pump failure alarm and provide installed standby dosing pump to improve process reliability;
- Install a baffle arrangement to ensure that the water does not short circuit through the clear water tank;
- Improve WTP process with the aim of effectively removing pesticides and herbicides from the water e.g. PAC dosing or ozone BAC;
- Address foot valve and draw off pipe corrosion problems by maintenance and/or replacement with corrosion-resistant materials;
- Improve size and design of the pontoon used for maintenance of the intake foot valves;
- Provide bunds for chemical storage and batching/ dosing tanks and dosing pumps to conform with relevant standards;
- Minimise manual handling and risk of operator contact with chemicals;
- Install a standby chlorine booster pump to lessen the potential down time of the critical post-chlorine dosing system;
- Improve chlorine installation to meet Australian Standards;
- Check best flocculation mixing conditions by conducting plant trials with central well flocculation mixer off and on at various speeds;
- Top up sand media level to the original design depth by adding more 0.5 – 0.6 mm effective size sand of an appropriate uniformity coefficient (U.C.);
- Further investigate backwash water flow capacity and optimum rates to check they are appropriate for effective backwashing;
- Upgrade control of filter valves to provide for automated backwash sequence;
- Ongoing training of the operators and other staff on the various SCADA capabilities;
- Separate pre- and post- chemical dosing start-up controls to make the plant easier to operate with varying flash mixer/ clarifier levels;
- Check stair-ladders and railings against relevant standards. Improve safety on issues of concern.

7.4 Low Priority Upgrade Requirements

The following actions are considered lower priority than those actions listed above but nevertheless expected to bring benefits in terms of performance or operability of the WTP. Although listed as low priority under the current climate, some of these issues may become higher priority if conditions or concerns change in future:

- Refer to the Nalco coagulant product using the first part of the number, DVS C001, rather than D245;
- Provide automatic lime dose adjustment for pH correction using on-line pH analyser;
- Reduce the number of plant start-ups per day by altering the start and stop levels in the clear water tank and elevated reservoir; and/ or fitting VSDs to the raw water pumps and making chemicals flow paced;
- Improve office and lunch facilities to provide better operator comfort and security;

- Provide online turbidimeter to monitor the raw water turbidity level to give advance warning of poor incoming raw water quality;
- The slope of the trough should be corrected if possible to slope towards the outlet;
- The disposal of subnatant into the neighbouring paddock may become an environmental issue in the future, in which case a method of collection and recycling or disposal will need to be implemented;
- If alum dosing was to be used again as the coagulant, components to allow pre-coagulation alkali dosing would be recommended.

7.5 Upgrades to Achieve Higher Capacity

It is understood that Council expects marginal growth in Theodore in the near to medium future. The design flow rate of Theodore WTP at 27 L/s is expected to be adequate to meet a moderate increase in demand, however there are some limitations in achieving this flow rate, especially under conditions with a low river water level.

In order to achieve the design flow rate under all conditions, if required to meet potential future increases in demand, the following works would need to be undertaken:

- Upgrade the raw water pumps to deliver the full design flow rate of 27 L/s under all likely river water levels;
- Upgrade the pre- and post-chlorine and lime dosing systems to ensure they can achieve the expected highest chemical dose demands at a plant flow rate of 27 L/s.

The WTP was run at 27 L/s for several days in early 2010 and performance of the clarifier and filters were understood to be adequate, thus no significant upgrades of these system are expected to be required to achieve this output. However further extended trials at 27 L/s could be undertaken, when raw water pumping conditions and demand allow, to confirm adequate process performance under various conditions.

7.6 Budget Costs for Critical Upgrade Requirements

7.6.1 High Priority Actions

Indicative budget cost costs for the recommended high priority works are given in the following table.

Estimated Budget Costs

Action	Budget Cost	Notes
Re-enable critical callout alarms to provide out-of-hours indication of faults	Council to carry out internally, with assistance if required	-
Follow up any further *E.Coli* detections urgently to identify and address any issues leading to inadequate disinfection and/or faecal contamination of the treated water		
Online chlorine residual meter purchase, installation, connection to SCADA system, commissioning and set up of alarms	$10,000	Estimate

For medium and low priority upgrade requirements, upgrade requirements have not been costed. Many of these actions are tasks which the Council may undertake internally, with assistance if required.

The medium priority action with the most significant cost implications would be the addition of a system such as PAC automatic dosing or a full ozone BAC process to improve the removal of herbicides from the water. If PAC is found to be effective for adsorbing the herbicides of concern, provision of an automatic PAC dosing system is likely to cost around $250-300,000. An ozone BAC system may achieve more robust removal of herbicides than PAC dosing, but would also have considerably higher costs.

7.6.2 WTP Capacity Upgrade Works

Indicative budget costs for the actions to achieve the WTP design flow of 27 L/s under all conditions, if required, are given in the following table.

Estimated Budget Costs

Action	Budget Cost	Notes
New raw water pumps to deliver 27 L/s under all likely river water levels – 2 new (duty/ standby pumps) plus control panel, linked to SCADA, supply, installation, commissioning	$50,000	Allowance
Upgraded chlorine system capacity – Larger rotameters and/ or modification of drawoff from cylinders and/ or room heating	$5,000	Allowance
Upgraded lime system capacity – Larger dosing pump, supply, installation, commissioning	$5,000	Allowance

8. Findings and Recommendations

8.1 Findings

8.1.1 WTP Flow Rate and Demand Issues

The design flow rate of Theodore WTP is 27 L/s. Because of raw water pump capacity limitations the WTP normally operates at 18 – 24 L/s, which is sufficient to meet current maximum daily water demands.

Very high river levels in early 2010 allowed the WTP to run at 27 L/s for several days. Adequate process performance was reported at 27 L/s, although further extended trials could be undertaken to confirm performance under various conditions.

Council expects some future development in Theodore, which may result in moderate increases in water demand. The full WTP design flow rate of 27 L/s is expected to be well able to meet likely future demands.

8.1.2 Water Quality Issues

A review of the raw water and WTP treated water quality found that:

- Raw water issues include very high turbidity and colour from river flow events, periodic high manganese levels and taste and odours. Herbicides are known to be present. Algal toxins are a potential risk;
- WTP treated water typically meets target values, with periodic excursions on treated water turbidity and true colour. The chlorine residual measured after the clear water tanks is highly variable and low residuals may sometimes compromise disinfection. Manganese targets are occasionally exceeded;
- *E.Coli* has been detected in several samples from the reticulation system, which indicates disinfection failure and/ or faecal contamination and the potential for consumers to be exposed pathogens;
- Herbicides have been present in treated water, sometimes at levels exceeding the ADWG recommended level;
- From modelling of corrosivity potentials, the typical treated water is likely to be only mildly corrosive except under worst case conditions.

8.1.3 WTP Process, Chemical Systems and Operational Issues

A review of the WTP treatment processes and chemical dosing systems found that:

- Most of the plant components are sized to achieve the design flow of 27 L/s. The raw water pumps limit the achievable flow rate, particularly at low river levels.
- Of the chemical dosing systems, the capacity of the pre- and post-chlorine dosing systems and the lime system would need to be upgraded to allow the expected range of doses at WTP design flow rates of 27 L/s.
- Plant control and automation, safety and maintenance issues were also reviewed, with various recommendations identified in section 7 of this report.

8.2 Recommendations

It is recommended that all upgrade requirements identified in this report be addressed as practical, with the priority and timeframe assigned in Section 7 to be used as guidance for programming works.

In particular, the following improvement works are considered high priority and should be carried out as soon as possible:

- Re-enable critical callout alarms to provide out-of-hours indication of faults;
- Install online chlorine residual meter and connect to the SCADA system, with associated dial out alarm;
- Follow up any further *E.Coli* detections urgently to identify and address any issues leading to inadequate disinfection and/or faecal contamination of the treated water.

The following improvement works will be required if it is necessary to achieve the WTP design flow rate of 27 L/s in future to meet increased demands:

- Upgrade raw water pumps to deliver 27 L/s under all likely river water levels;
- Upgrade capacity of chlorine and lime dosing systems.

Budget costs for the high priority and WTP capacity upgrades are covered in Section 7 to assist Council in budgeting for the upgrades.

9. Appendices

APPENDIX A –WATER QUALITY - EXTERNAL LABORATORY ANALYSIS RESULTS

General Analysis Results for WTP Raw Water

Parameter	**Units**	**Raw Water 10/1/06**	**WTP Raw Water 28/11/06**	**WTP Raw Water 19/2/07**	**WTP Raw Water 16/5/07**	**WTP Raw Water 21/8/07**	**WTP Raw Water 17/9/07**	**WTP Raw Water 12/11/07**
Turbidity	NTU	353	129	75	35	16	166	157
True Colour	HU	44	28	14	25	23	37	28
Conductivity	μs/cm	216	351	221	271	259	209	244
pH @ 21^{o}C	-	7.38	7.64	7.47	7.27	7.84	7.49	7.82
Total Dissolved Solids (TDS)	mg/L	127	192	126	155	149	119	142
Total Dissolved Ions	mg/L	156	237	158	201	198	157	182
Total Hardness	mg/L $CaCO_3$	50	77	50	61	61	47	55
Temp Hardness	mg/L $CaCO_3$	50	77	50	61	61	47	55
Alkalinity	mg/L $CaCO_3$	72	94	70	96	97	78	84
Silica	mg/L	16	13	11	13	10	11	12
Sodium	mg/L	20	34	21	28	27	20	24
Potassium	mg/L	6.2	7.4	6.9	8.5	8.5	7.5	7.9
Calcium	mg/L	13	20	13	16	16	13	15
Magnesium	mg/L	4.1	6.5	4.4	5	4.9	3.6	4.5
Hydrogen	mg/L	0	0	0	0	0	0	0
Bicarbonate	mg/L	87	115	85	116	117	95	101
Carbonate	mg/L	0.1	0.3	0.1	0.1	0.5	0.2	0.4
Hydroxide	mg/L	0	0	0	0	0	0	0
Chloride	mg/L	18	46	24	23	20	13	22

Parameter	Units	Raw Water 10/1/06	WTP Raw Water 28/11/06	WTP Raw Water 19/2/07	WTP Raw Water 16/5/07	WTP Raw Water 21/8/07	WTP Raw Water 17/9/07	WTP Raw Water 12/11/07
Fluoride	mg/L	0.1	0.17	0.17	0.19	0.18	0.18	0.15
Nitrate	mg/L	1.7	0.8	<0.5	<0.5	<0.5	1.5	2.1
Sulphate	mg/L	4.8	6.5	3	3	3.9	3.4	4.6
Iron	mg/L	0.08	0.01	0.03	0.05	0.02	0.05	0.04
Manganese	mg/L	<0.03	<0.03	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	mg/L	0.19	<0.01	0.02	0.01	<0.01	<0.01	0.02
Aluminium	mg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Boron	mg/L	0.05	0.05	0.05	0.05	0.06	0.04	0.05
Copper	mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03

General Analysis Results for Treated Water

Parameter	Units	2002	2005		2006		2007					2008			2009
		19/8	27/9	1/11	10/1	28/11	19/2	16/5	21/8	17/9	12/11	18/2	26/5	18/8	29/1
Turbidity	NTU	3	<1	1	4	2	8	2	<1	1	1	3	2	3	<1
True Colour	HU	<1	<1	2	3	8	1	2	2	7	1	7	1	<1	1
pH @ 21°C	-	7.25	7.56	7.23	8.77	7.66	7.62	7.74	7.8	8.14	7.79	7.92	7.82	7.76	7.35
Conductivity	µs/cm	320	289	373	291	297	210	304	278	238	259	200	280	303	294
Total Dissolved Solids	mg/L	190	164	219	173	162	118	167	157	132	147	110	151	160	154
Total Dissolved Ions	mg/L	220	199	237	185	203	146	215	204	170	185	133	184	195	199
Total Hardness	mg/L $CaCO_3$	96	75	103	78	68	54	73	67	59	63	52	73	73	57

Parameter	**Units**	**2002**	**2005**		**2006**		**2007**					**2008**			**2009**
		19/8	**27/9**	**1/11**	**10/1**	**28/11**	**19/2**	**16/5**	**21/8**	**17/9**	**12/11**	**18/2**	**26/5**	**18/8**	**29/1**
Temp Hardness	mg/L $CaCO_3$	55	72	53	44	68	54	73	67	59	63	52	73	73	57
Alkalinity	mg/L $CaCO_3$	55	72	53	44	85	62	99	93	80	81	59	78	80	87
Silica	mg/L	12	9	15	14	12	10	12	11	11	11	13	15	14	9
Sodium	mg/L	21.5	24	29	20	26	16	28	27	20	23	12	22	24	32
Potassium	mg/L	6.5	6.2	5.2	6.1	7	6.3	8.3	8.4	7.5	7.6	6.9	7.1	6.9	6.9
Calcium	mg/L	31.5	22	30	25	19	16	21	19	18	18	16	21	21	15
Magnesium	mg/L	4.2	4.7	6.5	3.9	4.8	3.5	5.1	4.9	3.7	4.4	3.0	4.9	5.1	4.8
Hydrogen	mg/L	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bicarbonate	mg/L	67	88	65	50	103	75	119	113	96	98	72	95	97	106
Carbonate	mg/L	0.1	0.2	0.1	1.6	0.3	0.2	0.4	0.4	0.8	0.3	0.3	0.3	0.3	0.1
Hydroxide	mg/L	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0
Chloride	mg/L	28	27	39	21	36	25	30	26	20	28	21	30	36	32
Fluoride	mg/L	<0.1	0.1	<0.1	<0.1	0.16	0.16	0.16	0.17	0.17	0.15	0.08	0.1	0.1	0.14
Nitrate	mg/L	0.8	0.9	2.1	1.6	1.1	0.5	<0.5	<0.5	1.3	2.4	0.8	0.6	0.9	<0.5
Sulphate	mg/L	57	26	60	56	5	2.9	3	4	3.5	4.3	<1	3.0	3.5	2.0
Iron	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese	mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	mg/L	0.03	0.03	0.01	<0.01	<0.01	0.02	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Aluminium	mg/L	<0.05	<0.05	<0.05	0.07	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Boron	mg/L	0.06	0.04	0.05	0.08	0.05	0.04	0.05	0.07	0.04	0.04	0.02	0.04	0.04	0.05
Copper	mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03