Banana Shire Council
Baralaba WTP
Treatment Options Report

December 2011

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1. INTRODUCTION

1.1 Background

City Water Technology (CWT) was requested by Banana Shire Council ('Council') to prepare preliminary capital cost estimates for a possible new Baralaba Water Treatment Plant (WTP) and provide capital cost estimates for the refurbishment of the existing Baralaba WTP.

The proposed new Baralaba WTP would be based on conventional treatment which consists of coagulation/flocculation followed by clarification, granular media filtration, disinfection and fluoridation. The new Baralaba WTP will be based on 1.1 ML/d (15L/s with 20 hrs operation/day) or 2.2 ML/d capacity (30L/s with 20 hrs operation/day) which will meet future water demand. It may be possible to build a new WTP adjacent to the existing WTP and then once the new plant is operational the old plant would be refurbished for the extra capacity required in the future.

The existing Baralaba WTP has been found to have limitations in treating the potential contaminants that may be present in the raw water from Dawson River to the level required by the Australian Drinking Water Guidelines (ADWG). The existing WTP has a production capacity of 1.1 ML/d (15L/s operating at 20hrs/d) although it can be run at up to 17 L/s.

Any new Baralaba WTP would be on the same site and would continue to draw raw water from Dawson River. It was assumed that the proposed Baralaba WTP would adopt the treated water quality targets of the proposed new Moura WTP.

1.2 Project Development

An earlier Issues Paper (Baralaba WTP Performance Review, CWT March 2010) highlighted process and water quality issues from the existing WTP although these issues are expected to be minimized through improved instrumentation and automation currently being implemented. The quality of the treated water currently exiting the WTP has been improved by recent process optimization but there are issues around filtered water turbidity, tastes and odours, disinfection and manganese concentrations.

The WTP itself is of a simple design that does not fully deal with all process issues; it has failing components and it is not readily maintainable in all areas. It is also operations intensive despite its remote location.

Council is considering two possible scenarios. The two scenarios are as follows:

1. Construct a new WTP for Baralaba. The new WTP would be either a 1.1 ML/d (based on 15 L/s operating 20 h/d) or a 2.2 ML/d WTP (based on 30 L/s operating at 20 h/d), and/or
2. Refurbish the existing Baralaba WTP which will address all the process issues and produce treated water such that water quality targets are met.

A multi-barrier approach to treating potential contaminants is preferred.

2. WATER QUALITY

2.1 Raw Water Quality

The existing Baralaba WTP draws water from the Dawson River; this river also feeds the Theodore and Moura WTPs.

The raw water to the Baralaba WTP and Moura WTP are expected to be quite similar. The typical water contaminants from Dawson River are:

1. Turbidity (typically around 100 NTU and may exceed 2,000 NTU during the wet season)
2. Colour (typically around 50 HU and may greater than 800 HU during the wet season)
3. Iron (Fe) and manganese (Mn)
4. Pathogens
5. E.Coli and Total coliforms
6. Taste and odour issues
7. Potentially corrosive raw water
8. Trihalomethanes (THMs) after chlorination.

2.2 Treated Water Quality Targets

The Australian Drinking Water Guidelines (ADWG) provides a framework for good management practice. The ADWG defines what is considered as safe, good quality and aesthetically acceptable drinking water and provides some guidance as to how these standards can be achieved. The ADWG has been developed and updated over a number of years. The most recent ADWG was released in 2011.

The treated water quality targets shown in the following table had been determined in the Moura WTP: Scoping Assessment for Proposed New WTP (CWT, May 2011) and are assumed to be adopted by the Baralaba WTP

Table 1: Treated Water Quality Targets for New Baralaba WTP

Parameter	Units	ADWG (2004)		2011 ADWG		Common Industry Targets	Moura WTP Target
		Health	Aesthetic	Health	Aesthetic		
Turbidity	NTU	≤ 1	≤ 5	0.2 to 0.5 ex filters but <1 for disinfection	≤ 5	< 0.3	<0.5
True Colour	HU		≤ 15		≤ 15	≤ 5	≤ 10
pH	-		6.5 – 8.5		6.5 – 8.5	7.5 – 8.3	7.6
Chlorine	mg/L	≤ 5		≤ 5	≤ 0.6	Depends on system	0.6 – 0.8
Acid-soluble Aluminum	mg/L	≤ 0.2		≤ 0.2		≤ 0.1	-
Total Manganese	mg/L	≤ 0.5	≤ 0.1	≤ 0.5	≤ 0.1	≤ 0.03	-
Total Iron	mg/L		≤ 0.3		≤ 0.3	≤ 0.3	-
Total Alkalinity	mg/L as $CaCO_3$					≥ 40	-
Total Dissolved Solids (TDS)	mg/L		≤ 500		≤ 600	≤ 500	-
CCPP	mg/L as $CaCO_3$					-6 to 0	-
Total Trihalomethanes (THMs)	mg/L	≤ 0.25		≤ 0.25		≤ 0.15	-

3. WATER TREATMENT ISSUES

3.1 Process Requirements

The following process issues will need to be addressed in the design of the plant:

- Removal of *Giardia* and *Cryptosporidium* (and other protozoan parasites);
- The WTP will need to be able to treat high turbidity raw water (possibly greater than 2000 NTU occasional short periods) and 200-1000 NTU consistently throughout the summer months;
- The WTP will need to be able to treat high coloured raw water (~ 50 HU and may be as high as 800 HU) which generally correlates to turbidity
- Iron and manganese treatment;
- Taste and odour treatment;
- Algal toxin treatment;
- Fluoridation;
- Disinfection;
- THMs might be an issue with chlorination of raw water that contains high concentration of organics
- pH/ corrosion control is required. Relevant index set points (Langlier, CCPP or other relevant indices) are to be determined;
- Wastewater management (recycling and disposal streams) is to be addressed.
- Jar and pilot testing may be required to confirm/refine process design assumptions.

3.2 Multi-Barrier Approach

The multi-barrier approach is a risk minimisation strategy that provides multiple levels of protection against significant contaminants.

Table 2 Barriers to Contaminants

Potential Contaminant	Possible Barriers to be Provided
Manganese and Iron	• Pre- oxidation (pre-chlorination or potassium permanganate options) • Coagulation of oxidised metals and removal via filtration
Colour and dissolved organics	• Pre- oxidation (pre-chlorination or potassium permanganate options) • Coagulation/flocculation, clarification and filtration • Adsorption on PAC and removal via filtration
Turbidity and particulates	• Coagulation/flocculation, clarification and filtration
Pathogens e.g. *Giardia*, *Cryptosporidium and viruses*	• Catchment management (if possible) • Coagulation, flocculation and filtration • UV disinfection

	• Chlorination disinfection
Taste and odour compounds, Algal toxins and organic contaminants	• Adsorption on PAC • Coagulation and removal of whole algal cells via filtration • Ozone/BAC • Chlorination for algal toxins
Chemicals	• Catchment management • Adsorption on PAC

3.3 Issues Summary

In considering a new WTP at Baralaba, the key raw water quality issues to be addressed include:

- The seasonal nature of the Dawson River flow as a water source introduces large fluctuations in raw water quality entering the WTP, especially high levels of turbidity and colour
- Manganese removal
- Potential risk of high THMs in treated water from pre-treatment chlorination of raw water source with high DOC.
- Organic contaminant treatment is required for herbicides and algal and microbiological blooms;
- Mitigation of the factors leading to potential for corrosion;
- Risk of pathogen contamination in the treated water

Other important issues to be considered include:

- Incorporation of online monitoring and automation of plant processes where possible to improve safety and maintenance.
- Pre-oxidation options
- Coagulant options
- Disinfection options
- Waste water management
- Capital cost estimates of proposed new Baralaba WTP versus refurbishment of existing WTP

4. SCENARIO 1: NEW BARALABA WTP

The new Baralaba WTP would be based on conventional treatment. The process would ideally consist of pre-oxidation, powder activated carbon (PAC) dosing, coagulation/flocculation, clarification, granular media filtration, UV disinfection followed by chlorine and fluoride dosing. The process is based on a multi-barrier approach to treat all the contaminants that are present in the raw water from Dawson River that will bring the treated water quality in-line with water quality targets.

A summary of the process is shown in the following figure.

Dawson River	**Water Quality** High colour and turbidity, iron and manganese, algal toxins, chemicals, pathogens
Pre-Oxidation	**Pre-Oxidation** Potassium permanganate ($KMnO_4$) dosing or pre-chlorination options to treat iron, manganese and DOC. Note that pre-chlorination risk formation of THMs in high DOC raw water for this reason, $KMnO_4$ dosing is recommended for Baralaba WTP.
PAC Dosing	**PAC Dosing** Treat DOC, chemicals (pesticides), algal toxins and taste and odours
Coagulation/ Flocculation **Clarification** **Granular Media Filtration**	**Conventional Treatment** Option of primary coagulants and secondary coagulants. Jar testing is recommended to determine optimum dose rate and best coagulant. Removes particulates including oxidised manganese, iron and organics. An optimised WTP should be effective in reducing the turbidity to ~ 0.2 NTU and colour to < 5 HU. Up to 4 log removal credits for inactivation of *Cryptosporidium* oocysts. Up to 3 log removal credits possible for Giardia cyst. Up to 2 log removal credits possible for viruses
UV Disinfection	**UV Disinfection** Effective disinfectant of bacteria and viruses. Effective in the inactivation of *Cryptosporidium oo*cysts in filtered water (2 to 4 log inactivation). No significant production of disinfection byproducts. Treated water with >95% Transmittance typically required
Post-Chlorination	**Post Chlorination** < 1 NTU is recommended at the point of disinfection so as not to compromise the disinfection process. Generally < pH 7.6 recommended for effective disinfection.
Fluoride dosing and Clear Water Tank	

Pre-chlorination is the preferred pre-oxidation option. However, provision for potassium permanganate dosing will be considered if pre-chlorination is not sufficiently effective or if excessive THM formation. Jar testing is required to determine dose rates and effectiveness of manganese oxidation.

pH adjustment may be required if potassium permanganate ($KMnO_4$) is selected as the pre-oxidation treatment option. $KMnO_4$ is dosed at the head of the works prior to coagulation. The effectiveness of $KMnO_4$ oxidation is most noticeable over pH 8.5 but is also somewhat effective at pH values lower than this. It is also dependent on the contaminants present in the raw water.

Coagulation is also a pH dependent process and different coagulants are effective at different range of pHs. Depending on the choice of coagulant, pH adjustment to achieve optimum coagulation pH after $KMnO_4$ oxidation may be required. The optimum coagulation pH for Alum is from pH 6.5 to pH 7. Ferric coagulants have a wider optimum pH range of between pH 5 to pH 8

Lime dosing is typically used to raise the raw water pH prior to $KMnO_4$ dosing to ensure effective manganese oxidation and carbon dioxide is typically used to lower the pH to achieve optimum coagulation pH. Other aluminium based coagulants such as aluminium chlorohydrate (ACH) and poly aluminium chloride (PACl) are effective at higher pHs of between pH 7 to pH 8 and pH adjustment may not be required. The coagulant choice will also impact the dose rate and hence the sludge production.

Jar testing should be undertaken to determine the optimum $KMnO_4$ dose rate, oxidation pH coagulation dose rate and coagulation pH.

4.1 New Baralaba WTP: Conventional Treatment with PAC and Potassium Permanganate Dosing

4.1.1 Option Description

Conventional treatment consists of coagulation/flocculation, pre-treatment clarification followed by granular media filtration.

Pre-treatment clarification is typically used as a pre-filtration stage, which reduces the solids loading on the granular media filters. The raw water is dosed with coagulant that causes the particles and organic contaminants to form dense flocs that settle out during the clarification process. Polymer can be used to strengthen the floc and improve settlability which will enhance the clarification process. Conventional WTPs alone are able to achieve the following log credits against pathogens (US Environmental Protection Agency's (USEPA) Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR)):

i. Maximum of 4 log credits for inactivation of *Cryptosporidium* oocyst

ii. Maximum of 3 log credits for the inactivation of *Giardia* cyst with adequate disinfection

iii. Maximum of 6 log credits for the inactivation of viruses with adequate disinfection

This process addresses all of the contaminants of concern to a significant level and comprises:

- Pre-chlorination oxidation with option for potassium permanganate oxidation if required. Optional lime/ carbon dioxide dosing up front. Initial lime dosing to raise the alkalinity of the raw water will also raise the pH to assist in manganese oxidation if $KMnO_4$ dosing is the preferred pre-oxidation step. Subsequent carbon dioxide dosing to reduce the pH for coagulation. Option for enhanced coagulation at reduced pH (approximately 5.8 to 6) with primary coagulant.

- Pre-oxidation with 30 minute effective contact time for oxidation.
- PAC dosing will remove algal toxins, taste and odour compounds, pesticides, herbicides, THMs and organics. Contact tank of approximately 30 minutes and mixer is required.
- Primary coagulation with polyacrylamide dosing just prior to flocculation to improve floc formation
- Flocculation and sedimentation would be carried out. There are several clarification options which may be considered but they are of similar cost.
- Conventional granular media filters would be employed for filtration with air scour and backwashing.
- UV disinfection to remove pathogens. It is effective for *Giardia* cyst and *Cryptosporidium* oocyst (2 to 4 log inactivation).
- Post-treatment alkali to enable pH adjustment and corrosion control. Final alkali dosing will allow for accurate pH control for pipeline water quality management. Post dosing would include chlorination (chlorine gas or sodium hypochlorite) for final disinfection and residual protection and fluoridation.

4.1.2 Multi-barrier Protection

For optimised operation and WTP performance this option has the following capabilities with regard to the water treatment contaminants/ issues identified:

- *Pathogens* – At least 5 log removal credits for *Cryptosporidium* and *Giardia* and at least 7 log removal for viruses.
- *Turbidity* – Full turbidity protection against very high levels of turbidity through coagulation/flocculation, clarification and filtration.
- *Colour and organics* – High level colour and organics removal through pre-chlorination, PAC, coagulation, sedimentation and filtration
- *Iron and manganese* – High level protection through pre-chlorination with adequate contact time followed by particulate removal through coagulation/flocculation, clarification and filtration. PAC will also improve Fe and Mn removal.
- *Tastes and odours and algal toxins and organic contaminants* – Taste and odour compounds, algal toxins and organics treated by adsorption onto PAC, followed by coagulation/flocculation, clarification and filtration.
- *Corrosion and pH control* – Alkali at the back of the plant to reduce corrosivity of treated water through the reticulation system. Optional lime/ CO_2 up front to reduce corrosivity of raw water through the WTP.
- *Disinfection by-products* –PAC, followed by coagulation/flocculation, clarification and filtration is capable in removing THM.

4.1.3 Risks

Risks associated with this option include:

- Pre-oxidation release released toxin from algal cells, pre-chlorination forms THMs and other disinfectant by-products
- Corrosion issues in WTP if lime/CO_2 dosing is not used

- Potassium permanganate pre-oxidation may be more effective in manganese oxidation. Jar testing is recommended to determine suitability of pre-chlorination
- DOC and colour removal will be less effective without enhanced coagulation. Jar testing is recommended to determine optimum dose rates and coagulation pH
- Supernatant recycling will need to be carefully managed to minimise turbidity, pathogen and manganese spikes being returned to the raw water

4.1.4 Exclusions

The capital cost estimate assumes that the new Baralaba WTP will be built on the existing site. The existing assets such as buildings, concrete slab, WTP lighting raw water tank and inlet pipe works, clear water tank, raw water and clear water pumps and sludge disposal was assumed to be re-used.

The capital cost estimate excludes the following costs:

i. GST;

ii. Raw water pumps (in river) and delivery pipework;

iii. Clear water tanks and pumps;

iv. Lab and equipment;

v. Waste water management

vi. Power Supply to site;

vii. Telemetry off site;

viii. Any land purchase;

ix. Decommissioning of existing WTP;

x. Civil works (storm water drains, inlet pipe works, building and slab);

xi. Excavation and earth moving (i.e. significant site preparation).

4.1.5 Capital Cost Estimate for New Baralaba WTP

The following table shows the preliminary capital cost estimates for a 1.1ML/d and 2.2 ML/d conventional WTP at Baralaba.

Table 3: Capital Cost Estimate for Conventional Treatment with PAC and Pre-Chlorination

Item	Cost ($) 1.1 ML/d	Cost ($) 2.2 ML/d	Description
Preliminaries	30,000	30,000	Insurance, approvals and permits, inductions, meetings, contracts
Design and Documentation (by contractor)	120,000	120,000	Preparation and maintenance of contract program, QA system, OH&S, EMP, public safety development plan, process design and drawings, HAZOP
Raw Water Tank	60,000	75,000	Including pipework modifications and pump station
PAC Dosing System	40,000	45,000	
Oxidation System	30,000	35,000	

Item	Cost ($) 1.1 ML/d	Cost ($) 2.2 ML/d	Description
Chemical Dosing Systems	250,000	300,000	Coagulant, Polymer, Post Chlorine disinfection, Fluoride, pH adjustment
SCADA,.HMI	50,000	50,000	Modification of current (upgraded) system for full automation, online analysers
Clarifier and Filter	600,000	720,000	Rapid mixer Flocculation Granular media filtration and associated equipment
UV Disinfection	75,000	100,000	UV disinfection module, UV intensity sensor, UV lamps
Electrical	200,000	250,000	Site electrical, switchboard and lighting,
Commissioning, WasEx Drawings, O&M manuals	30,000	30,000	
Sub Total	**1,485,000**	**1,755,000**	
External Engineering (20%)	297,000	351,000	Survey, Investigation, Design, Specification and Commissioning Supervision, Project management, Consultants
Contingency (20%)	297,000	351,000	
Total (ex GST)	**2,079,000**	**2,457,000**	

There may be some additional cost for a 2.2 ML/d WTP not included in the above capital cost estimate. Some of the existing infrastructure such as waste water management, raw water and clear water tanks and raw water pump capacity which would be fine for a 1.1 ML/d WTP may be inadequate for a 2.2 ML/d WTP. Additional civil works may also be required due to a larger WTP footprint. Further investigation would be required to determine if any additional modification to site is required.

5. Scenario 2: Refurbishment of Existing Baralaba WTP

The refurbishment and addition of process equipment will upgrade the existing Baralaba WTP to produce treated water that is in-line with current water quality targets. The water treatment issues were discussed in Section 2 of this report. The general upgrades to the existing WTP are shown below as items 1 to 7.

1. PAC dosing system for chemicals and taste and odour
2. Pre-oxidation tank for treating manganese with pump station
3. Chlorine residual analyser after raw water tank
4. UV disinfection
5. General modifications to existing plant (media replacement, additional valving and monitoring

5.1.1 Multi-barrier Protection

These options provide similar levels of protection to Scenario 1.

5.1.2 Risks

- The existing WTP is generally old and there may be some older process equipment that need replacement soon and is not included in the preliminary capital cost estimates.
- There may some OH&S issues on the WTP that no longer meet newer Australian Standards. Further investigation is required to determine these if any.
- Pre-chlorination may risk formation of THMs due to high concentration of organics that are likely to be present in Dawson River.

5.1.3 Exclusions

The capital cost estimate excludes the following costs:

i. GST;

ii. Any additional land purchase;

iii. Excavation and earth moving (i.e. significant site preparation).

iv. Any civil works

5.1.4 Capital Cost Estimates of Refurbishment

The following table shows the preliminary capital cost estimate.

Table 4 Refurbishment of Existing Baralaba with Pre-chlorination and PAC Dosing

Item	Cost ($) 1.1 ML/d	Description
Preliminaries	5,000	Insurance, approvals and permits, inductions, meetings, contracts
Design and Documentation	10,000	Preparation and maintenance of contract program, QA system, OH&S, EMP, public safety development plan, process design and drawings, HAZOP
Raw Water Tank	60,000	Including pipework and pump station
PAC Dosing System	40,000	
Oxidation System	30,000	
Chlorine Analyser	10,000	Online analyser, quote from manufacturer
SCADA modifications	20,000	Further to that currently underway
UV Disinfection	100,000	UV disinfection module, UV intensity sensor, UV lamps - retrofit
Various improvements	70,000	New media, valving, vacuum system etc
Electrical modifications	40,000	
Commissioning and O&M manuals update	15,000	
Sub Total	**400,000**	
External Engineering (20%)	80,000	Survey, Concept Design and Specification, Commissioning, Project management, Consultants
Contingency (20%)	80,000	
Total (ex GST)	**560,000**	

6. Summary

The options for the various scenarios are summarised in the following table. The first scenario is for a new WTP at Baralaba. There are two production capacities considered for Scenario 1, which are for either a 1.1 ML/d or a larger 2.2 ML/d WTP which will cater to future water demand. Scenario 2 is to refurbish the existing Baralaba WTP.

The proposed new Baralaba WTP would be based on conventional treatment and would consist of the following treatment processes:

1. Pre-oxidation
2. PAC
3. Raw water storage for oxidation and PAC adsorption
4. Coagulation/flocculation
5. Clarification
6. Granular media filtration
7. UV Disinfection
8. Post-chlorination pH adjustment and fluoride dosing

The refurbishment of the existing WTP will address the water treatment issues which include:

1. PAC dosing for treating organics, taste and odour, chemicals
2. Pre-oxidation to treat iron, manganese and organics
3. UV disinfection to treat pathogens
4. General modifications for improved WTP

Table 5 Summary of Preliminary Capital Cost Estimate for Baralaba WTP Options

		Project Cost Estimate ($)	Advantages	Disadvantages
Scenario 1	**1.1 ML/d Conventional Treatment, PAC, Pre-Chlorination**	2,079,000	Treated water quality will meet all ADWG limits, New automatic WTP	Minimal
	2.2 ML/d Conventional Treatment, PAC, Pre-Chlorination	2,457,000	Treated water quality will meet all ADWG limits New automatic WTP Provides for future water demand	
Scenario 2	**Refurbishment of Existing WTP**	560,000	Cheaper option than new WTP Treated water quality will meet all ADWG limits	There may be some older process equipment still currently operational but may require replacement in the near future.

Other Issues to consider include the following:

1. Waste water management options
2. Jar testing to determine pre-oxidation and coagulant options
3. Age of process equipment on existing WTP
4. Modifications to raw water and treated water systems