# APPENDIX 12

# OPTIONS REVIEW AND RISK ASSESSMENT

Coffs Harbour City Council

# Coffs Harbour WTP Options Review

Report

April 2005

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GHD

# Executive Summary

It is concluded that water treatment is required for the Coffs Harbour water supply to:

- Meet its commitment to meet the ADWG requirements
- Ensure effective disinfection of water supplied to customers
- Control the risk posed by *Cryptosporidium* contamination
- Provide security and quality of supply in the event of an algal bloom in a water source or storage
- Reduce dirty water episodes
- Reduce the reliance on intensive management which on its own cannot control the water quality risks
- Meet current industry standards in Australia
- Reduce Council's potential legal liability.

**Table E1 Summary of Treatment Option Performance and Costs**

| | Options | | | | |
|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4a** | **4b** |
| | **PAC / DAFF** | **PAC/ MF** | **PAC/DAFF / UV** | **DAFF / $O_3$ / GAC** | **MF / $O_3$ / GAC** |
| **Capital ($m for 45 ML/d)** | 16 | 25 | 17 | 24 | 33 |
| **O&M ($m pa for 7 GL)** | 0.9 | 1.5 | 1.0 | 1.8 | 2.4 |
| **Capital ($m for 90 ML/d)** | 26 | 40 | 28 | 39 | 53 |
| **O&M ($m pa for 14 GL)** | 1.6 | 2.2 | 1.7 | 3.3 | 3.9 |
| Risk 1.1: Diatoms, algae | ✓ | De-rate | ✓ | ✓ | De-rate |
| Risk 1.2: BGA toxins | ✓? | ✓? | ✓? | ✓ | ✓ |
| Risk 1.3: Taste and Odour | ✓ | ✓ | ✓ | ✓✓ | ✓✓ |
| Risk 2.1: Dirty water (Colour/Iron/Manganese) | ✓ | ✓ | ✓ | ✓ | ✓ |
| Risk 2.2: Turbidity > 1NTU | ✓ | ✓ | ✓ | ✓ | ✓ |
| Risk 3: Crypto/Giardia | ✓ | ✓✓ | ✓✓ | ✓✓ | ✓✓ |

Table Notes:

| | |
|---|---|
| ✓ | Will achieve risk removal to an acceptable level. |
| ✓✓ | Additional risk removal above an acceptable level, or additional benefit. |
| ✓? | Uncertain outcome. |
| × | Will not achieve acceptable level of risk reduction OR may not function at all under this type of loading. |
| De-rate | Will achieve acceptable risk reduction if run at lower rate (typically 25 to 50% lower). |

The final decision on treatment plant selection will depend on CHCC's customers view as well as those of other key stakeholders.

# 1. Introduction

## 1.1 Scope

Coffs Harbour City Council (CHCC) engaged GHD to undertake a desktop review of the need for water treatment for the Coffs Harbour water supply, to assess the most likely treatment options and develop a cost estimate for the treatment options.

## 1.2 Previous Reports

The main previous reports which we have relied on are:

- Water Quality Management Strategy Discussion Paper, Part B, Coffs Harbour, DPWS, May 2001.

  This will be referred to as WQMSDP throughout this report.

  This report was prepared as a discussion paper for the purposes of community consultation. As a result, it rightly does not make any recommendations on whether to provide water treatment or not.

- Shannon Creek Raw Water Conceptual HACCP Plan, MEU, August 2003.

  This will be referred to as SCRWCHP throughout this report.

  This report was focussed on risk identification in the proposed Nymboida/Shannon Creek scheme and specifically did not consider the catchment of the Orara River or Karangi Dam.

## 1.3 Coffs Harbour Water Supply

The following description of the Coffs Harbour water supply system is sourced and adopted from the two previous reports listed above and discussions with CHCC staff.

Coffs Harbour has traditionally drawn its raw water from the Orara River at Cochrans Pool. Under the Regional Water Supply Agreement with North Coast Water (NCW), CHCC is currently expanding the supply to source raw water from the Nymboida River and Shannon Creek Dam in addition to the Orara River supply.

A pipeline connecting the Nymboida River supply to the Coffs Harbour supply has recently been completed and Coffs Harbour currently sources water from both the Orara and Nymboida Rivers. The existing supply will be expanded further with the construction of a new dam and connecting infrastructure on Shannon Creek. This will allow CHCC to draw from the Orara and Nymboida Rivers or Shannon Creek Dam to maintain supply to Coffs Harbour. The three sources of supply are discussed further in the following sections. A schematic of the system is provided in Figure 1.

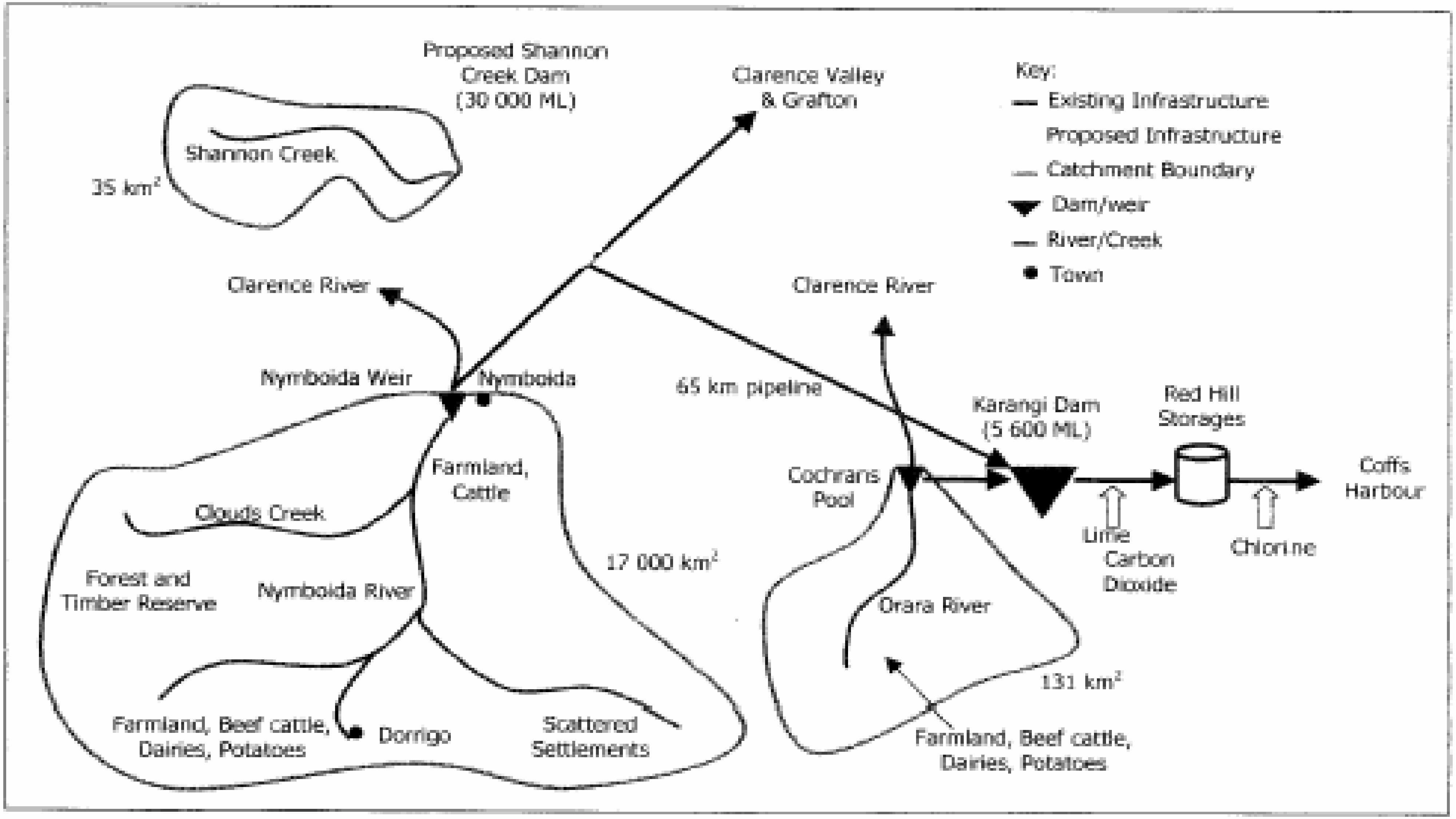


**Figure 1 Coffs Harbour Water Supply Schematic**

### 1.3.1 Orara River Supply

The Orara River at Cochrans Pool has a catchment 135 $km^2$ made up predominantly of forest and cleared agricultural land including market gardens, turf farms, cattle grazing and dairies. Water is harvested from the river at Cochrans Pool and pumped to Karangi Dam. Generally water is only pumped from Cochrans Pool when the turbidity is less than 2 NTU. However, during high demand or drought conditions, poorer quality water is harvested to maintain supply.

Karangi Dam is a 5 600 ML storage with a minimal local catchment of 134 Ha. The dam is aerated throughout the year to oxidise iron and manganese from the source water and to prevent stratification. Water drawn from Karangi Dam is dosed with lime and carbon dioxide to reduce the corrosiveness of the water. It is then pumped to the Red Hill balance tanks where it is chlorinated prior to supply to Coffs Harbour.

CHCC currently undertakes quarterly flushing of the reticulation system to remove residual iron and manganese and minimise dirty water issues.

### 1.3.2 Nymboida River Supply

The Nymboida River has traditionally provided water for the Clarence Valley and Grafton and has only recently supplied water to Coffs Harbour. Water is harvested from the Nymboida Weir located near the town of Nymboida. The catchment of the Nymboida River at the weir is around 1 700 $km^2$.

The catchment is split between forest and cleared agricultural land. The primary agricultural activities within the catchment are potato cropping, horticulture, beef cattle grazing and dairies. In addition to the agricultural activity, the town of Dorrigo is located in the catchment. Dorrigo is sewered with treated sewage entering the Bielsdown tributary of the Nymboida River within the catchment.

Rural settlements with onsite septic systems are scattered throughout the cleared agricultural portion of the catchment and septage from the unsewered town of Nymboida may also enter the water supply at the weir.

Water gravitates from Nymboida Weir along a duplicate pipeline northeast to the Clarence Valley and Grafton. Generally water is only harvested from the weir by CHCC when the turbidity is less than 2 NTU. However, during drought or high demand periods, poorer quality water is harvested from the weir.

Clarence Valley Council (CVC) has recently constructed a 62 km underground pipeline which taps into the Nymboida – Grafton pipeline to draw water from the Nymboida supply system to Coffs Harbour. Under the current arrangement, water gravitates from the Nymboida weir, along the existing Nymboida-Grafton pipeline and new underground pipeline to Karangi Dam at a rate of approximately 16 ML/d and can be increased to 25 ML/d using booster pumping. This supply now supplements water sourced from the Orara River.

### 1.3.3 Proposed Shannon Creek Supply

To augment the security of supply to Coffs Harbour, the Clarence Valley and Grafton, NCW and CHCC propose to construct a 30 000 ML storage on Shannon Creek.

The proposed dam will source water from a relatively small local catchment of around 35 $km^2$ with additional water supplied from the Nymboida Weir. The dam is to be "transparent" in that an equivalent volume of water caught in the catchment is to be released to the downstream Shannon Creek. The Shannon Creek catchment is predominantly vegetated with about a quarter cleared for agricultural activity. A significant proportion of the forested section of the catchment is privately owned and may be logged in the future.

The proposed Shannon Creek Dam would be connected to the Nymboida – Grafton pipeline and could supply water to both Coffs Harbour via Karangi Dam, and the Clarence Valley and Grafton. Once the dam is completed, NCW and CHCC would be able to source water stored in the Shannon Creek Dam to preserve environmental flows in the Nymboida and Orara Rivers during low flow periods.

# 2. The Need for Water Treatment

## 2.1 Australian Drinking Water Guidelines (ADWG)

CHCC formally adopted the ADWG in February 2001 (WQMSDP, p19).

The ADWG are risk based. Current risks to water quality which have been identified for Coffs Harbour are:

- Potentially ineffective disinfection due to turbidities above 1 NTU
- *Cryptosporidium* contamination from the catchment particularly due to the presence of septics, sewage and dairy farming given that chlorine is ineffective for *Cryptosporidium* disinfection
- Potential for algal blooms given nutrient runoff from agricultural catchment
- Aesthetic hazards such as iron and manganese

These are discussed further in the following sections.

## 2.2 Disinfection Effectiveness

Based on the data available, turbidities leaving Karangi Dam can exceed 1 NTU. The ADWG limit to ensure effective disinfection is 1 NTU. Turbidities above 1 NTU bring into question the effectiveness of chlorine disinfection and therefore the safety of the Coffs Harbour supply given the importance of disinfection as a water quality barrier.

## 2.3 *Cryptosporidium* Control and Standards

*ADWG*

The ADWG do not provide detailed guidance on how to determine a suitable level of *Cryptosporidium* control but instead recommend that there are multiple barriers, typically including filtration. The Coffs Harbour supply would not appear to meet this criteria.

*Multiple Barriers*

The catchments supplying Coffs Harbour are compromised by human and agricultural activities. In other words, none are protected catchments. The activities in the catchment increase the risk of protozoan contamination of the water supply.

Currently there are two active barriers to protozoan risks in the Coffs Harbour water supply. They are selective diversion (not diverting when source water turbidity exceeds 2 NTU) and reservoir storage in Karangi Dam.

During drought conditions, it has been known for diversions to be necessary above 2 NTU due to water shortages thus weakening the effectiveness of the selective diversion barrier, leaving a single barrier under these conditions.

When the new abstraction licence conditions (linked to the Shannon Creek Dam completion) to provide environmental flows in the Orara and Nymboida become effective, the selective diversion barrier could be further weakened and the protozoa barrier would be solely reliant on storage.

Note that storage volumes are variable meaning that in times of water shortage, storage levels could be low reducing the detention time and the effectiveness of water storage as a barrier. In other words, water storage is a water quality barrier that is not totally controllable by CHCC.

The Shannon Creek Dam and Nymboyda River could also suffer algal blooms at the same time resulting in a significant risk to supply in critical low supply conditions.

*International Guidelines*

International guidelines can also be used to assist in determining the appropriate level of *Cryptosporidium* removal for a given supply. The USEPA has developed the *Long Term 2 Enhanced Surface Water Treatment Rule (*LT2ESWTR*)*. The LT2ESWTR assigns 'bins' to water supply catchments based on the raw water quality and then a range of technologies and approaches that would provide sufficient *Cryptosporidium* removal based on the assigned "bin". At best, the Coffs Harbour supply would fall into "Bin 1" and would typically require filtration.

## 2.4 Algal Blooms

Under the current arrangement, a significant algal bloom in Karangi Dam would require isolation of the dam and direct supply from either the Orara or Nymboida Rivers. This would remove two key existing water quality barriers in the supply, namely the capability for selective diversion and storage in Karangi Dam. It would also likely reduce the effectiveness of disinfection given the potential for elevated turbidity from the raw river sources. Therefore the existing supply is very vulnerable in the event of a significant algae bloom in Karangi Dam.

Given the level of agricultural activity in the Nymboida River catchment and frequency of algal blooms in similar water storages in nearby catchments, the possibility of a significant algal bloom in Karangi Dam increases if nutrient levels rise due to inputs from the Nymboida River.

## 2.5 Aesthetic Hazards

Continuous aeration of Karangi Dam is required to partly manage iron and manganese concentrations in the water supplies to customers. Despite this barrier, elevated levels are recorded in the reticulation, potentially leading to dirty water complaints, staining of laundry and discolouration of the supply.

## 2.6 Optimising Water Quality Management

CHCC is doing an impressive job of optimising the performance of the existing system from a water quality perspective e.g. selective diversion based on on-line turbidity measurement, destratification of Karangi Dam and quarterly mains flushing. There appear to be limited opportunities for further improvements to the existing system other than significant initiatives in the catchment, such as completely restricting cattle access to watercourses, providing buffer strips and removal of the potential for human faecal contamination to enter the supply.

Tightening environmental constraints on extraction from the Orara and Nymboida Rivers and the proposed Shannon Creek Dam will pose increased complexity for management of the system for water quality and quantity. Therefore reliance on management practices to maintain or improve quality in the system will become increasing difficult and unreliable.

## 2.7 Risk Assessment

*WQMSDP*

A preliminary risk assessment of the historic (Karangi) CHCC water supply (WQMSDP Table 9.6 last column) was carried out as part of the WQMSDP. The major risks identified in approximate rank order were:

- Turbidity > 1 NTU
- Dirty Water
- Algae, Taste & Odour
- Algal toxins
- Elevated *Cryptosporidium/Giardia*

The probability of elevated *Cryptosporidium* in the water supply was assessed as occurring every 2$^{nd}$ year with a potential consequence of significant illness throughout the community.

The WQMSDP concluded that overall water quality risks for CHCC would increase from the historic situation once the Nymboida/Shannon scheme was implemented. This was due to increased algae risks. Note from Section 2.4 the implications on *Cryptosporidium* control of an algal event.

*SCRWCHP*

The SCRWCHP identified as the highest water quality risks for the proposed Nymboida/Shannon scheme a range of possible events which would make Shannon Creek Reservoir water poor in quality and possibly unusable due to dirty water/algae in the Reservoir.

Therefore the CHCC could need to operate for an extended period using Nymboida and Orara River water with higher environmental constraints leading to possible compromise of its selective diversion approach.

## 2.8 Australian Benchmarks

A survey was conducted of the larger water supplies in Australia that do not provide filtration of their surface water supply. The outcome is shown in Table 2.1.

**Table 2.1 Australian Unfiltered Surface Water Supplies – Ranked by Size**

| Supply | Approx. Population | Source Type | Major Barriers |
|---|---|---|---|
| Melbourne | 3.3 Million | Dams | Protected catchments<br>Very long detention times<br>Dams in series<br>Melbourne Filter Study provides scientific backing |
| Perth | 1.3 Million | Rivers | Treatment Plants being constructed |
| | | Dams | (Note: Unprotected catchments)<br>Very long detention times<br>Multiple sources (10 dams)<br>Surface sources are less than 50% of Perth's water supply (majority is ground water) |
| Hobart | 190 000 | Dams | Protected catchments<br>Multiple sources |
| Townsville | 147 000 | Dam/Creek | Water Treatment is to be implemented (other source is already treated) |
| Cairns | 120 000 | Creek | Small rainforest catchment. Other source is treated. |
| Darwin | 100 000 | Dam | Protected catchment<br>Very long detention time |
| Coffs Harbour | 60 000 | Dam | (Note: Unprotected catchment)<br>Detention time (nom 1 year in Karangi) |

Table 2.1 shows that Coffs Harbour will potentially be the largest unfiltered water supply in Australia which draws solely from unprotected catchments (Orara, Nymboida) without very long detention time storages (many years).

## 2.9 Legal Liability

The WQMSDP obtained legal advice on the civil liability for CHCC should it happen to supply contaminated water to consumers. The text in italics is directly quoted from the WQMSDP.

In considering the tort of negligence *it would need to be proven in a negligence action against CHCC.... that it breached its duty of care to the plaintiff* (the consumers). *The Court approaches the question of whether the duty of care has been breached by inquiring whether the conduct in question falls below the standard of care expected of a "reasonable person" based on the circumstances of the defendant at the time of the alleged negligent act.*

*... in assessing the standard of care which could be exercised by the hypothetical reasonable person a court would pose questions* of the kind shown in Column 1 of the following table.

Column 2 provides possible answers to these questions.

| Posed Question | Possible Answer |
|---|---|
| *Was the likelihood of the contamination foreseeable? Even if the expert advice to CHCC was that the risk of occurrence is unlikely, a court may nonetheless conclude that the risk was foreseeable if its likelihood of occurrence was not far-fetched.* | Yes, the likelihood of contamination is foreseeable as shown by the risk assessment provided in the WQMSDP as an example |
| *What precautions could have been taken to minimise or eliminate the risk of harm?* | Water Treatment |
| *Would Water Treatment decrease or eliminate the risk of contamination occurring?* | Yes |
| *Are there monitoring programs, incident plans and response protocols that could minimise or eliminate the risk of harm?* | Possible, but reliability is not certain. However stringent protocols would be required like frequent boil water notices, restricted use etc. |
| *Can the existing supply together with an appropriate monitoring program, incident plan and response protocol minimise or eliminate the risk of harm to a level commensurate with water treatment?* | No, as shown by Figure 9.1, WQMSDP as an example |
| *Does CHCC have properly trained staff and management to implement the above types of management procedures?* | We are unable to assess this. |
| *Does CHCC have the financial resources to bear the cost of Water Treatment?* | We are unable to assess this. |

*As a general proposition, where a defendant is dealing with substances which potentially can involve a high risk of injury to others, experience has shown that the courts take the view that a very high standard of care should be imposed. If a defendant falls below that standard, it will be said to have breached its duty of care owed and will be prima facie liable to any person suffering damage as a result of that breach.*

The fact that CHCC would be relatively unique in Australia for its size in its water quality management arrangements (i.e. without filtration), as shown in Section 2.8, would further weaken CHCC's defence.

## 2.10 Conclusion

It is concluded that water treatment is required for the Coffs Harbour water supply to:

- Meet its commitment to meet the ADWG requirements
- Ensure effective disinfection of water supplied to customers
- Control the risk posed by *Cryptosporidium* contamination
- Provide security and quality of supply in the event of an algal bloom in a water source or storage
- Reduce dirty water episodes
- Reduce the reliance on intensive management which on its own cannot control the water quality risks
- Meet current industry standards in Australia
- Reduce Council's potential legal liability.

# 3. Options for Water Treatment

Options for water treatment need to be considered in the context of the water quality risks that have been identified for the supply.

Based on the risk assessment in the WQMSDP, the major risks to water quality in the CHCC supply are set out below together with commentary on treatment implications.

| Risk | Treatment Implications |
|---|---|
| • Turbidity > 1 NTU<br>• Dirty Water | Both of these risks can be dealt with using a standard coagulation/filtration system. |
| • Algae, Taste & Odour | The most cost-effective system in Australia to treat stored water subject to algal activity is Dissolved Air Flotation/Filtration (DAFF).<br><br>Although a DAFF system will effectively remove algal cells present in the raw water it will not be able to deal with dissolved taste & odour compounds.<br><br>The least capital cost approach to dealing with low level sporadic algal tastes & odours in the use of powdered activated carbon (PAC). |
| • Algal Toxins | Reliable treatment for algal toxins is expensive. It is usually provided when significant algal blooms are a chronic problem. In these cases ozone/granular activated carbon (GAC) has been used to provide certainty of outcome against toxins.<br><br>Ozone/GAC is also very effective in removing algal taste and odours |
| • *Cryptosporidium* | Filtration is the preferred primary barrier against *Cryptosporidium.*<br><br>A DAFF plant will provide good removal of *Cryptosporidium* usually 3-log (99.9%). For high risk sources or where more positive removal is required microfiltration (MI) can be used.<br><br>Ultraviolet (UV) disinfection is effective in inactivating *Cryptosporidium.* It can be used in conjunction with a conventional plant e.g. DAFF to provide improved performance.<br><br>Ozone is also an effective disinfectant against *Cryptosporidium.* |

Based on the above assessment, a range of treatment process "trains" have been identified which could be considered for Coffs Harbour.

1. PAC/DAFF: This deals with the basic risks except toxin removal may not be certain.

2. PAC/MF: This deals with the basic risks except toxin removal may not be certain. MF provides more certainty in *Cryptosporidium* removal than DAFF.

3. PAC/DAFF/UV: As for 1. but has *Cryptosporidium* performance similar to 2

4a. DAFF/Ozone/GAC:
4b. MF/Ozone/GAC:
} Both of these provide a higher level of certainty for removal of algal toxins and tastes & odours.

These treatment processes are described in more detail in the following sections.

## 3.1 Chlorination/Final Disinfection

All options considered include final chlorination or equivalent disinfection. Chlorination provides:

- An additional (and critical) barrier against bacteria and virus as part of the multi-barrier approach to drinking water quality.
- A chlorine residual within the distribution system which:
  - Provides some residual disinfection in the event of recontamination
  - Restricts regrowth of micro-organisms which can cause water quality issues such as taste and odour.

An existing chlorination facility is located at the Red Hill tanks. Part of the design of the upgrade to water treatment would involve:

- Review of the existing chlorination facility to determine the extent to which it can be incorporated into the new treatment plant; and
- Review of alternative disinfection options such as chloramination to determine the optimum disinfectant for Coffs Harbour.

## 3.2 Option 1: PAC / DAFF

Dissolved Air Flotation / Filtration (DAFF) removes particles through flotation as fine bubbles of air pass upwards through the unit carrying solids to the surface. The water then passes through multimedia filters located in the same tank. This is conventional technology for algal cell removal and has proved reliable during periods of severe algal blooms. DAFF also reduces turbidity and colour, and the process will successfully remove organics, oxidised manganese and iron during treatment. The process backwash water requires treatment and sludge disposal and /or drying.

DAFF alone does not remove algal toxins or tastes and odours. Dosing powdered activated carbon (PAC) prior to the DAFF process will allow removal of algal tastes and odours, along with some THM precursors. A minimum of 30 minutes of contact time is required which means a tank prior to the system. Increased loads will mean additional float/backwashing of the DAFF system. Organic molecules are attracted and held to the surface of the (PAC), a process known as adsorption. When the available adsorption sites have been filled, the carbon can no longer remove any further organic molecules from the water and the carbon has reached exhaustion. The carbon then needs to be removed/replaced or regenerated. In practice PAC is simply disposed of in the sludge. PAC is not considered a reliable and consistent treatment for removing all algal toxins.

PAC is expensive to operate and therefore the system is typically only turned on when required.

### 3.3 Option 2: PAC / Microfiltration

This option involves the use of PAC prior to microfiltration (MF). The PAC system will be similar to that for the DAFF system as commented on above. An additional concern is the possible impact of the PAC on the membranes as this combination is not very common in practice.

Microfiltration is a membrane process that removes particles of greater size than the pore size, typically around 0.2 μm. Microfiltration will remove algae, reduce turbidity and colour and remove *Giardia* and *Cryptosporidium.* Whilst the process alone does not remove algal toxins, tastes and odours, PAC will remove the tastes and odours as mentioned previously. Ultra filtration is a variant with a smaller pore size. Microfiltration is in use in a number of plants of this size worldwide.

The MF option assumes coagulation can be used with MF to deal with colour, and oxidised iron and manganese.

MF is an automated process that is easy to operate when raw water quality is variable as the filtrate turbidity is always low. Backwash water generated contains chemicals that require treatment and sludge that must be disposed of as well as chemical cleaning wastes.

### 3.4 Option 3: PAC / DAFF / UV

UV offers protection against cysts that may pass through previous treatment and has been used for disinfection of drinking water for some time, particularly for supplies where the use of chlorine has been opposed in the community. However chlorine will still be required to deal with recontamination, biofilms, etc. Recent work in the USA has demonstrated that UV can be effective against *Cryptosporidium.* Option 3 adds the cyst inactivation capability (*Giardia/Cryptosporidium*) of UV to the PAC/DAFF combination mentioned above (algae, algal tastes and odours, turbidity, colour, manganese and iron).

Key issues under consideration in the design development of larger UV systems include provision of duty standby, online irradiance measurement, lamp cleaning and replacement, and appropriate pre-treatment.

## 3.5 Option 4A: DAFF / Ozone / GAC

This combination involves dosing ozone to the filtrate post DAFF and then filtering the resultant stream into Granular Activated Carbon (GAC) filter beds.

Ozonation is a powerful oxidant and disinfectant that breaks down algal toxins and natural organics into more biodegradable forms. Some form of filtration such as GAC must follow the ozonation step. Post-ozonation filtration provides a medium for biological activity to reduce the biodegradable fraction before it is delivered into the distribution system.

GAC is used in beds like conventional filters. Water passes slowly through the bed and molecules are adsorbed onto the GAC particles. Biological growth develops on the bed leading to the removal of most organic molecules.

Ozone / GAC is an effective treatment for taste and odour, algal toxins and cysts and is commonly used in combination with primary treatment such as DAFF or MF to provide comprehensive water treatment.

Examples of ozone/GAC plants in Australia generally correspond to supplies with chronic algal problems e.g. Trentham, Orange, Noosa, Maroochy, Hamilton Island.

## 3.6 Option 4B: MF / Ozone / GAC

This combination adds the capabilities of ozone GAC, as set out above, to microfiltration. It offers very reliable risk reduction, but is a complex and expensive plant. It is a technology combination which has been selected by BOOT contractors when they face risks in the source water (e.g. Bendigo).

# 5. Treatment Plant Process Selection

From a technical point of view it is considered that as a minimum, the PAC/DAFF option in conjunction with existing and new water quality management practices should be adequate to satisfactorily control the risks that have been identified to date. Should the *Cryptosporidium* risks be later identified as higher than anticipated in the WQMSDP and SCRWCHP, then UV could be added to the PAC/DAFF train or PAC/MF adopted. Should it be found that algae is a chronic problem with real toxin risks then ozone/GAC can be added to either train as a later stage.

The final decision on treatment plant selection will depend on CHCC's customers view as well as those of other key stakeholders.

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Coffs Harbour City Council

# Water Quality Risk Assessment

## Risk Assessment Guide & Summary of Risk Workshop Outcomes

**March 2007**

INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

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# 1. Hazard Identification and Risk Assessment Overview

A water quality risk assessment requires an understanding of several things:

1. Where are the sources of hazard? Sources of hazard in this context include things like cattle faecal matter, spills of pesticides/fuels and discharge of treated sewage into the water supply.
2. What are the hazards? In this context hazards are the chemicals and microbes in the water e.g. *Cryptosporidium*, virus, pesticide, taste and odour.
3. What natural or manmade controls reduce the risk? Controls may include offstream watering and fencing to prevent cattle getting near water courses.
4. What is a risk and how is it ranked? For each hazard from each source, a likelihood of its occurrence and a view on the consequence or impact on people drinking the water can be assessed. A high likelihood and high consequences means a very high risk. In defining these factors controls need to be considered as they can reduce likelihood or consequence.

The process for identifying sources and hazards, and assessing the risk to drinking water supply requires the following components to be completed.

- Review of existing water quality data.
- Inspection of the water supply system from catchment to tap.
- Discussions with Coffs Harbour City Council (CHCC) key staff involved with management and operation of the water supply system.
- Discussions with external stakeholders (e.g. Catchment Management Authority, other Water Quality Officers using this water).
- Water quality risk assessment workshop with key staff and external stakeholders.

The risk assessment process involves separate consideration of each element of the water supply system, from the catchment through to tap. The workshop methodology includes a process where the risks of High and Very High significance from one element are 'rolled through' various 'barriers' that generally reduce the likelihood or consequences (e.g. reservoirs, water treatment plants (WTP's)).

The main intent of this approach to risk assessments is to determine firstly, whether the management of water quality is sufficient to provide adequate control of hazards (e.g. micro organisms) in the drinking water prior to customer taps and secondly which controls are Critical activities (Critical Control Points). Where control is considered inadequate it means that improvements are necessary, such as additional water treatment to allow adequate control of risks.

The above approach is consistent with the Australian Drinking Water Guidelines and CRC's 'A Guide to Hazard Identification and Risk Assessment for Drinking Water Supplies'. These references provide more detailed explanations of the above processes.

# 2. Water Quality Hazards Identification

The following explanations provide an overview of the technical background to risk assessments with respect to analysis of water quality hazards within drinking water supply systems.

## 2.1 Pathogens

The most common and widespread health risk associated with drinking water is microbiological contamination, either directly or indirectly, by human or animal excreta and the microorganisms contained in faeces.

Harmful bacteria, virus, giardia and cryptosporidium are found in human faecal matter. Most warm blooded animals excrete harmful bacteria and giardia but not viruses that are harmful to human health. Sources of human faecal contamination are overflows from septic tanks and treated sewage discharges. Cattle faecal matter is a major source of *Cryptosporidium* and *Giardia*.

Bird droppings contain bacteria such as salmonella and campylobacter.

There are septic tanks and cartage of septic tank waste within catchments leading to the risk of release of septage from blocked septic tanks and also risk of septage dumping into watercourses. Septage contains bacteria, virus and *Cryptosporidium.*

Pathogenic (disease-causing) organisms of concern include bacteria, viruses and protozoa; the diseases they cause vary in severity from mild gastroenteritis to severe and sometimes fatal diarrhea, dysentery, hepatitis, cholera or typhoid fever.

*E.coli* is commonly used as an indicator of faecal contamination and therefore if present, there is a pathogen risk in water supplies.

Pathogen reduction through treatment processes is critical to ensure safe drinking water. Chlorination of filtered water is effective against bacteria and viruses, however it is not as effective against protozoa and is ineffective against *Cryptosporidium*. *Cryptosporidium* is discussed separately below.

The usual way monitoring for potential pathogenic organisms in drinking water, is regular monitoring of the microbial indicator organism, *E.coli*, and coliforms at customer taps.

Other microorganisms that can help indicate microbiological risk are Total Plate Counts (37C).

## 2.2 *Cryptosporidium*

*Cryptosporidium spp.* is a parasite that occupies the gut wall of humans and many animals. Cattle, sheep (especially young animals) and humans are major sources of *Cryptosporidium*, which is released from the gut during defecation. There are septic tanks and cartage of septic tank waste within catchments leading to the risk of release of septage from blocked septic tanks and also the risk of septage dumping into watercourses. Septage contains bacteria, virus and *Cryptosporidium.*

Consumption of drinking water contaminated with low levels of *Cryptosporidium* oocysts can result in illness. *Cryptosporidium* oocysts are robust and can survive for months in fresh water.

*Cryptosporidium* is not inactivated by chlorine disinfection. This finding combined with the observation that ingestion of one *Cryptosporidium* oocyst can cause severe gastrointestinal illness means this microorganism is of significant concern to water authorities. Stringent criteria are beginning to emerge. For example, the UK Water Supply (water quality) Regulations, 2000 regard detection of an average of > 0.01 oocysts/L in treated drinking water on any day as a criminal offence.

*Cryptosporidium* is typically removed by filtration or alternative disinfectants, including ozone and UV (where iron levels and turbidity are low).  These processes require significant energy and are expensive to build.

Research work on this organism is ongoing, and information is limited on some aspects. The Australian Drinking Water Guidelines (ADWG) fact sheet, and the Water Services Association of Australia (WSAA) fact sheet for *Cryptosporidium* are useful resources for a summary of current understanding.

The following points are useful in understanding *Cryptosporidium* risk.

- All catchments, even those that are protected, typically show some level of *Cryptosporidium.* The peak levels quoted in the literature for typical protected catchments are above typical targets for drinking water therefore some removal is always required. The USEPA and the NZ MOH have adopted an approach where even protected catchments must demonstrate 2 log (99%) or more of removal post catchment and before consumption. The ADWG are less prescriptive.
- It is not clear in typical tests whether all of the *Cryptosporidium* that are counted are actually alive and/or will infect humans. However, it is also noted that typically only about 10 to 30% of *Cryptosporidium* oocysts present in the water are detected by the analytical test method. Australian native animals do carry *Cryptosporidium*, but it is not yet clear whether these are infective to humans, and there is no simple test to determine whether a particular *Cryptosporidium* oocyst is infectious to humans. Complex DNA typing is required and is rarely done.
- Cattle are known to be a very significant source of high numbers of potentially human infective *Cryptosporidium* especially calves with diahhorea.
- Septics, sewage plants, swimmers and any other opportunity for human faecal contact are key sources of risk of *Cryptosporidium,* which is infectious to humans.
- Storage times of minimum 3 to 6 months or more offer some reduction of *Cryptosporidium.* The literature and various international guidelines are not consistent on how much reduction. The ADWG draft suggests 1 to 2 log removal for 1 to 6 months detention.

- Storages can readily short-circuit due to stratification or storm events. Such events can have a detention time of only days in storage when the average detention time, based on total storage volume and inflow rate, is several hundred days. Therefore, storages only receive risk reduction credit based on the reduced detention during a storm or stratification event especially as this is typically the high risk time for *Cryptosporidium* contamination. Aeration systems in dams can create enough mixing to prevent shortcircuiting but must be in use to do it.
- Filtration offers around 2 to 3 log removal depending on configuration and plant performance. At typical doses, chlorine dioxide offers around 1 log removal.
- UV has just recently been recognised as an effective disinfectant against *Cryptosporidium*, and workable doses can give up to 3 log removal.

## 2.3 Algae Toxins, Taste and Odour

Blue green algae can lead to taste and odour, and to algae toxins that are harmful to humans.

Various green and blue green algae can impact significantly on taste and odour. Certain blue algal species can also produce potentially harmful toxins.

Processes such as powdered activated carbon dosing (PAC), alkaline chlorination and ozone-GAC may be required to control these risks.

Nutrients, particularly nitrogen and phosphorus, can be indicators of conditions potentially conducive for algae growth. Generally the higher the phosphorus level the higher the algae concentration that can occur.

## 2.4 Disinfection By-products (e.g. THMs)

The byproducts of disinfection are the products of reactions between disinfectants, particularly chlorine, and naturally occurring organic material. Most disinfectants used to render drinking water safe from pathogenic microorganisms will produce byproducts in the disinfection process.

Chlorine is the most common disinfectant in the chlorination process as it reacts with naturally occurring organic matter to produce a complex mixture of byproducts. Other disinfectants can produce different types of byproducts. The presence of organics in chlorinated water leads to the formation of disinfection by-products such as Triahalomethanes (THMs), Haloacetic Acids (HAAs) and chloral hydrate.

One main control for disinfection by-products is the removal of organics from the water through effective coagulation, sedimentation and filtration and/or PAC or Ozone/GAC.

The Victorian Safe Drinking Water Act (SDWA) regulations require monitoring of THM's and HAA's if chlorine based chemicals are dosed. If ozone is dosed then monitoring of bromate is required. In New Zealand chloral hydrate also needs to be monitored if chlorine based disinfectants are dosed.

## 2.5 Physical Parameters

The appearance, taste, odour, and ‘feel’ of water determine what people ‘experience’ when they drink or use water and how they ‘rate its quality’. Other physical characteristics can suggest whether corrosion or encrustation are likely to be significant problems in pipes or fittings. The measurable physical characteristics that determine these largely subjective qualities are:

- Colour (i.e. the colour that remains after any suspended particles have been removed);
- Turbidity (the cloudiness caused by fine suspended matter in the water);
- Hardness (the reduced ability to get a lather using soap and cause of white ‘scales’ in pipes and white deposits glassware and sinks);
- Total dissolved solids (TDS) – salt; and
- pH/alkalinity/calcium (measure of water corrosiveness).

Colour and turbidity influence the appearance of water. Taste can be influenced by TDS, and pH. The feel of water can be affected by pH and hardness. Rates of corrosion and encrustation (scale build-up) of pipes and fittings are affected by pH, alkalinity, hardness, TDS and dissolved oxygen.

There are a range of sources of raw water **turbidity** including storms, floods, erosion and bushfires leading to fine sediments entering the waterways. High levels of turbidity can make raw water difficult to treat and affect the aesthetic quality of the water. Turbidity, post filtration, is often used as an indicator for effective removal of pathogens.

**True Colour** indicates the presence of organics that, after chlorination result in the formation disinfection by-products. Colour is generated by vegetation, swamps and during events such as storms and bushfires (e.g. leaching of leaf litter washed into dams after fires). The main controls for colour are raw water source selection and coagulation plus sedimentation and filtration. Chlorine can also decolourise water.

The **pH** and **alkalinity** of the source water can significantly impact on water treatability and treatment plant performance. If too little alkalinity is present compared to the alum dose, then the pH can drop too low for effective coagulation resulting in filtration failures and thus lead to ineffective control of risks such as *Cryptosporidium*. It can also lead to elevated aluminium levels in the treated water. Alkalinity levels often drop during storm events, as rainwater has no alkalinity. Levels less than 20 mg/L are often problematic. After filtration, adjustment of pH, calcium and alkalinity is usually needed to prevent corrosion of pipes.

**TDS** leads to salty tastes (particularly chlorides) in drinking water. TDS is not removed be typical water treatment processes.

## 2.6 Iron and Manganese

High levels of iron and manganese in treated water can lead to customer complaints due to staining of white porcelain surfaces as well as poor laundry results. Biofilms or chemical slimes commonly detected in water supplies arise from entry of soluble iron or manganese into reticulation pipework. These slimes/Biofilms can detach causing stains in laundry, unpleasant taste or discolouration and problems for industrial processes (e.g. soft drinks and chicken processing).

Iron and manganese occur naturally in soils, and can be released into water as a byproduct of biological process in the sediments at the base of dams and storages during stratification periods in summer when dissolved oxygen levels fall below about 5-6 mg/L just above the floor of a storage.

Iron is readily removed through filtration. Manganese is less readily removed through filtration without pre-oxidation (e.g. potassium permanganate/high pH or green sand filters)

## 2.7 Industrial Chemicals (e.g. Pesticides/Fuel Residues)

There are a wide variety of chemicals, particularly pesticides, that have varying levels of toxicity to humans. There is also an 'outrage' phenomenon that can occur if pesticides or industrial chemicals are detected in drinking water.

There are risks related to the use of, or spills, of agricultural and industrial chemicals in the catchment. The herbicide Atrazine (water soluble) is sometimes important, particularly where new pine plantations are being established.

The key controls for these risks are the procedures that are followed by the chemical users or transport companies and the likelihood that a spill would be reported by the relevant organisation or authority in time to take some action, such as temporary bunding of a spilled liquid or onsite treatment. The other control—depending on where the spill is—is dilution in the water course and absorption by soils.

Some treatment processes such as PAC dosing or Ozone-GAC are effective barriers to passage of these contaminants into the treated water reaching customer taps.

## 2.8 Treatment Chemicals (Chlorine/Lime/Alum)

The risk assessment identifies water quality risks associated with overdosing of treatment chemicals or the use of contaminated treatment chemicals. The ADWG health limit for chlorine residual is 5 mg/L and for aluminium (from alum) the aesthetic limit is 0.2 mg/L. Lime dosing increases pH and adds hardness and turbidity but rarely causes water quality problems provided doses are low. High pH inhibits effective chlorination. Online analysers provide a basis for controlling the risk of overdosing of such treatment chemicals.

Good QA processes on delivery of chemicals minimizes the risk of introducing contaminants into the water supply when these chemicals are added.

## 2.9 Inorganic Chemicals

Inorganic chemicals in drinking water usually occur as dissolved salts such as free carbonates and chlorides in solution, as part of the composition of suspended material in the water, or as soluble complexes with naturally occurring organic compounds. Their presence may result from the following sources:

- Natural leaching from mineral deposits into source waters

- Land-use activities in catchments leading to exacerbation of natural leaching processes such as mobilisation of salts
- Carryover of treatment chemicals, e.g. iron from ferric chloride coagulant
- Addition of chemicals such as chlorine and fluoride
- Corrosion and leaching of pipes and fittings
- Discharges from industry (e.g. electroplating).

Specific parameters are arsenic, cadmium, chromium, cyanide, fluoride, mercury, selenium, sodium, chloride and sulphate. Typically these are detected by monitoring and not removed by typical treatment processes. An important one present sometimes present in springs or bores is arsenic and a low level is required (< 0.007 mg/L in ADWG).

## 2.10 Organic Compounds

Naturally occurring organic compounds in water are not generally a concern to human health, except for specific toxins (such as blue green algae toxins) and some organic compounds resulting from human activity (e.g. endocrine disruptors) and disinfection byproducts (e.g. THM, HAA's).

## 2.11 Radiological Parameters

Radioactive materials occur naturally in the environment (e.g. uranium, thorium and potassium). Some radioactive compounds arise from human activities (e.g. from medical or industrial uses of radioactivity) and some natural sources of radiation are concentrated by mining and other industrial activities. A very low proportion of the total human radiological exposure comes from drinking water.

Exposure at low to moderate doses may increase the long-term incidence of cancer and the rate of genetic disorders.

Acute health effects of radiation, ranging from skin burns to nausea, vomiting, diarrhea, reduced blood cell counts and death, occur at much higher doses that are well beyond what can naturally occur in water and therefore are not a concern for water supplies except in extreme accident situations.

Radiological parameters, including gross alpha and gross beta, are rarely monitored in water supplies (usually only on an annual basis) and a very rarely an issue.

# 3. Risk Assessment Methodology

The risk assessment process uses the approach outlined in AS 4360 'Risk Management' and involves separate consideration of each major segment or 'barrier' of the water supply system, from the catchment segment through raw water storages and then treatment/reticulation system.

The risk assessment contained several key elements:

- Identification of the potential water quality hazards through review of the water quality data, inspecting and understanding the water supply systems, and discussions with CHCC staff.
- Identification of potential sources and causes of these hazards associated with each segment of the water supply system.
- Determination of the preventative measures or controls (if any) for each hazard.
- Assessment of the likelihood, consequences and then risk rating associated with each hazard for each source of hazard.

The likelihood, consequence and risk rating for each source of hazard are assessed based on the general criteria and risk matrix contained in Table 1, 2 and 3. These criteria etc. are found in AS 4360 and ADWG's.

**Table 1 Likelihood Scale**

| Likelihood Ranking | Probability/Frequency |
|---|---|
| 1 | **Rare**<br>The event may occur only in exceptional circumstances; once in 100 years |
| 2 | **Unlikely**<br>The event could occur at some time; once in 50 years |
| 3 | **Possible**<br>The event should occur at some time; once in 5 to 10 years |
| 4 | **Likely**<br>The event will probably occur in most circumstances; annually |
| 5 | **Almost Certain**<br>The event is expected to occur in most circumstances; several times a year to monthly |

### Table 2 Consequence Scale

| Consequence Ranking | Description |
|---|---|
| 1 | **Insignificant - Insignificant impact**<br>*No media interest, stakeholder indifference, negligible impact on service delivery* |
| 2 | **Minor - Minor impact for a small (1) population**<br>*Local press coverage, stakeholder aware of issue, corrective action required to restore service delivery* |
| 3 | **Moderate - Minor impact for a large (2) population**<br>*State or multiple local press coverage, stakeholder actively expressing dissatisfaction, service restored after major intervention but within performable indicator levels* |
| 4 | **Major - Major impact for a small (1) population**<br>*National or repeated state press interest, stakeholder alarm or grave concern, service delivery interrupted failing performance indicators* |
| 5 | **Catastrophic - Major impact for a large (2) population**<br>*Repeated adverse state or national press coverage, enraged stakeholder or external intervention ordered by government, major failure to service delivery and considerable time to restore* |

Notes:

1. A small population is considered as a small proportion of people within the town under assessment, not a town with a small population in total.
2. A large population is considered as a large proportion of the population within the specific town undergoing the assessment, not a town with a large population

### Table 3 Risk Matrix Significance Scale

| **Significance** | | **Consequence** | | | | |
|---|---|---|---|---|---|---|
| **Likelihood** | | 1 | 2 | 3 | 4 | 5) |
| | 1 | Low | Low | Medium | High | High |
| | 2 | Low | Low | Medium | High | Very High |
| | 3 | Low | Medium | High | Very High | Very High |
| | 4 | Medium | High | High | Very High | Very High |
| | 5 | Medium | High | Very High | Very High | Very High |

The workshop methodology included a process where the risks of High and Very High significance from one segment ('Barrier') are 'rolled through' downstream 'Barriers'.

For example, High and Very High water quality risks in raw water from the catchments are 'rolled through' to the raw water storage, then to the treatment facilities and then on to customer taps. The significance of the risk for most sources of hazards from the catchments and storage are reduced to an insignificant risk when 'rolled through' the raw water reservoir and water treatment plant (WTP). This approach is consistent with the ADWG and the CRC 'A Guide to Hazard Identification and Risk Assessment for Drinking Water Supplies' and highlights the important controls for risks and their location in the catchment to tap water supply system.

Rarely does any risk reduction occur in the reticulation pipes so this segment is often not considered as an additional 'control' for hazards still present after any WTP 'barrier'.

For example, septic tanks in the catchment are a source of the hazard virus. A very high risk occurs at the entry point to the untreated water storage. After dilution/decay in this storage a high risk could still be present. A water treatment plant usually has a chlorination step, but may allow this pathogen to get through because it could fail relatively often and no significant risk reduction subsequently occurs for this hazard. Hence, a high risk could still be present at customer taps. The Critical Control Point (CCP) is chlorination, but improvements to the chlorination system are required in this example. This and other examples of the 'rolling through' process are illustrated in Figure 1 below.

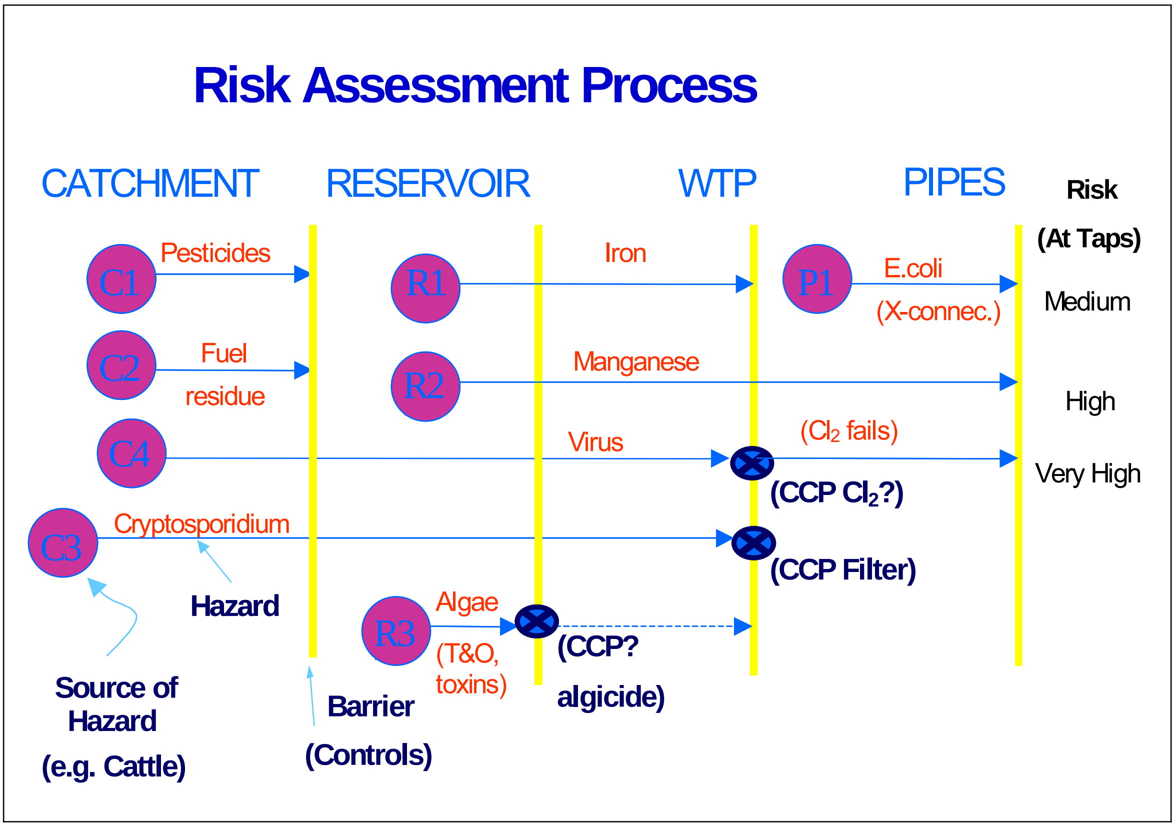



**Figure 1 Examples of Risks in Supplies & Movement Through Barriers**

# 4. Summary of Risk Workshop Outcomes

The risk assessment process involved separate consideration of risks to water quality arising in the catchments, reservoir, existing water treatment (i.e. chlorination) and distribution system 'elements' of the Coffs Harbour water supply system from current supplies (Nymboida and Orara River) and future additional supply (Shannon Creek Dam).

The water supply catchment and system were inspected on 30 and 31 May 2006 and a risk assessment workshop was held on 19 and 20 June 2006. The main intent of this approach was to identify the key water quality risks present at customer taps that should be addressed in the design of the new water treatment plant for Coffs Harbour. The key risks identified are summarised in the following section.

The risk assessment workshop was attended by relevant CHCC personnel responsible for water supply and quality, and stakeholders from North Coast Water, River Care, Catchment Management Authority, NSW Department of Primary Industries (Agriculture).

## 4.1 Key Water Quality Risks Identified

An outline of the Coffs Harbour water supply system and the important water quality characteristics is shown in Figure 2 on the following page. The water quality risk assessment identified a number of key high risks to the water quality. These are described in Table 4 following Figure 2.

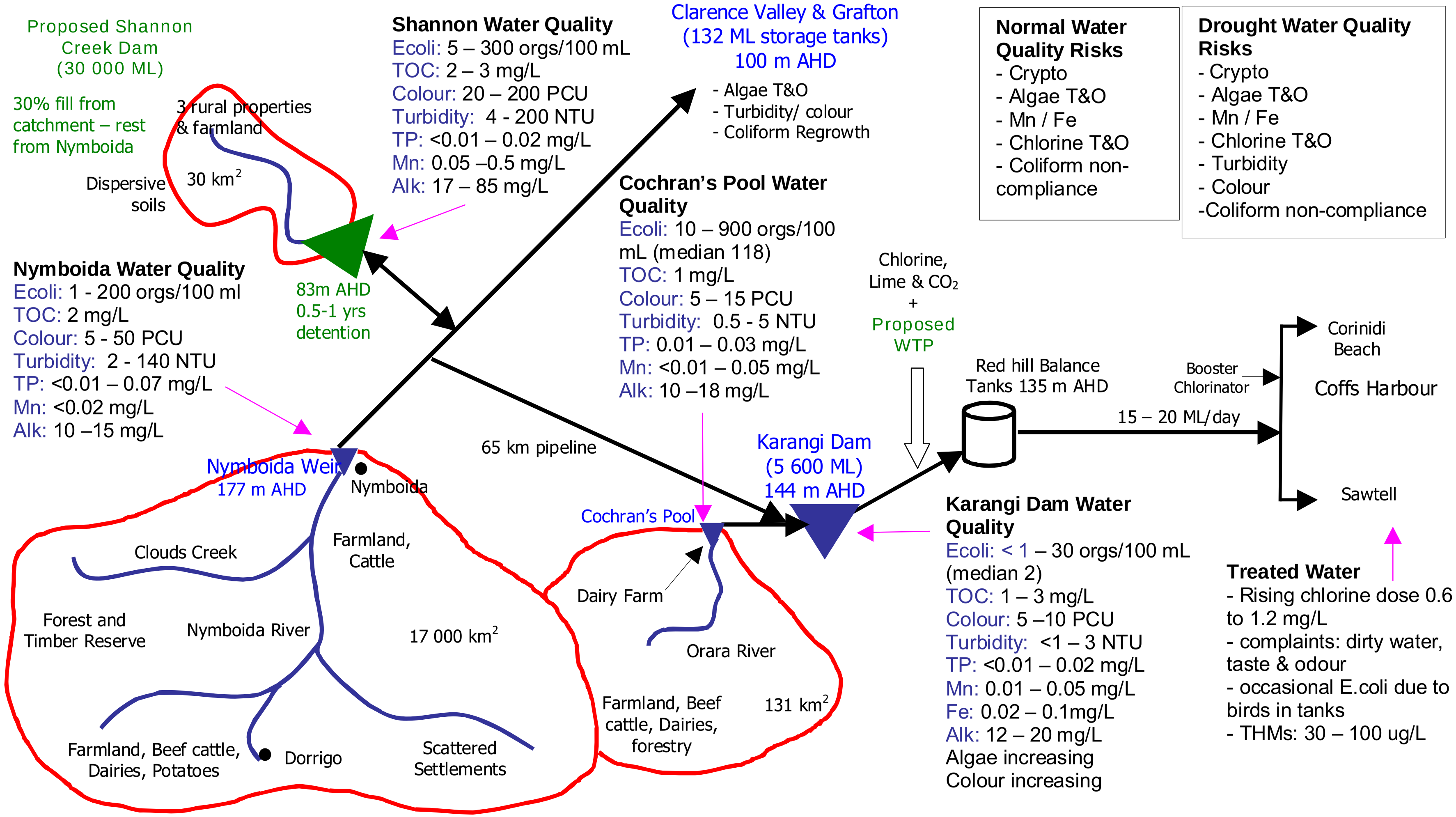



**Figure 2 System Schematic, Typical Water Quality and Risks**

**Table 4 High Risk Water Quality Hazards and Sources of Hazard**

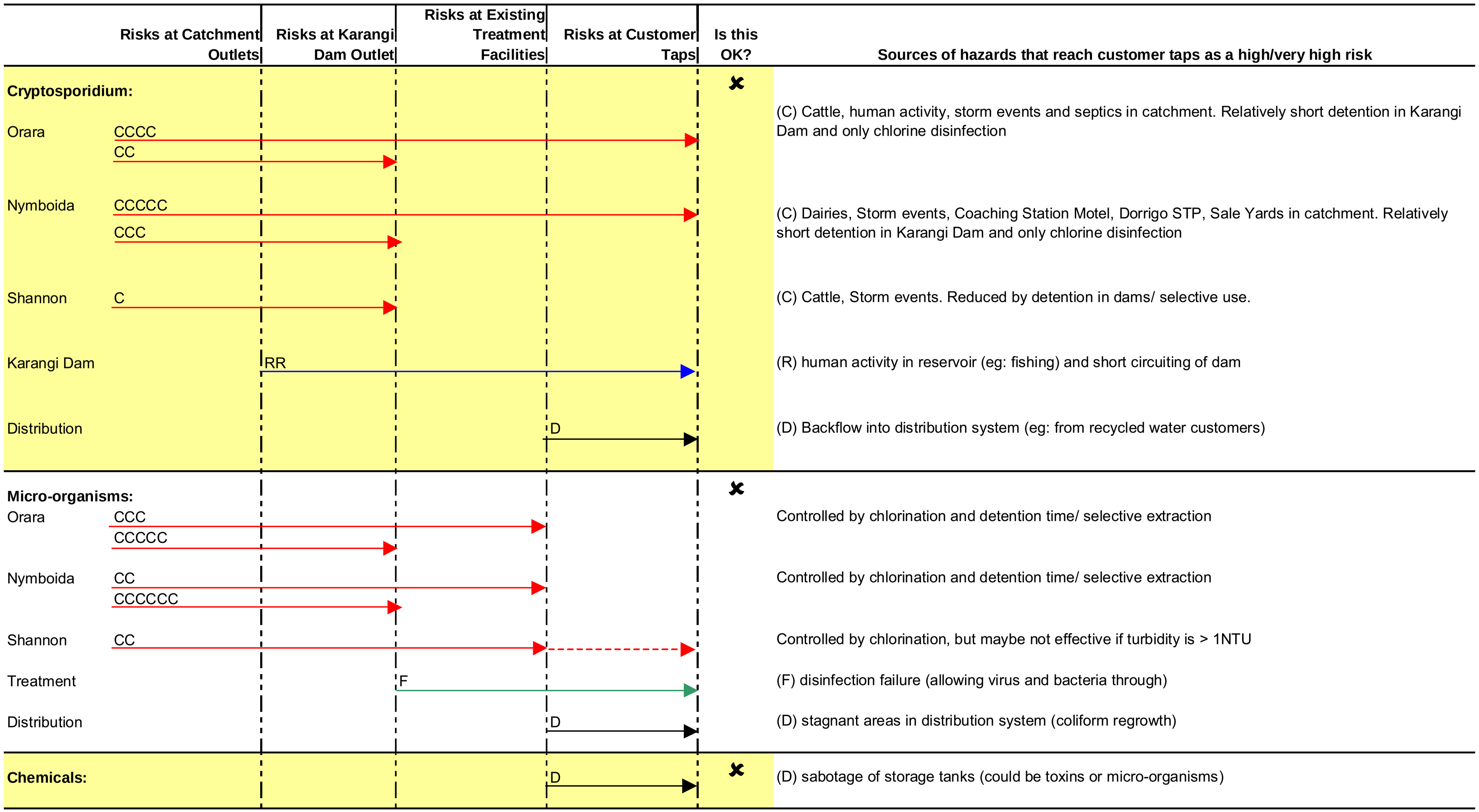
| Stage of supply | Water Quality Hazard | Description | Source of Hazard | Adopted Treatment Methods for Control of Hazard |
|---|---|---|---|---|
| Catchment and reservoir (recreation activities) | Cryptosporidium | Parasite from the gut of water blooded animals – humans, cattle and sheep.<br>Can cause severe gastrointestinal illness.<br>Not destroyed by chlorine. | ◗ Cows – dairies and stockyards. Particularly calves.<br>◗ Septic tanks – effluent disposal, overflow, pumping out<br>◗ Sewage treatment plant<br>◗ Bad toilet practices of people using waterways (e.g. fishermen and swimmers) | Coagulation<br>Flotation<br>Filtration<br>UV disinfection |
| Catchment | Turbidity and Colour (variable water quality) | Colour and turbidity influence the appearance of water.<br>Colour indicates the presence of organics that, after chlorination result in the formation disinfection by products | ◗ Storms, floods, erosion and bushfires leading to fine sediments entering the waterways.<br>◗ Dispersive soils<br>◗ Rotting vegetation | Coagulation<br>Flotation<br>Filtration |
| Catchment and Reservoir (recreation activities) | Virus | Micro-organisms in septic waste and sewage can cause severe gastrointestinal illness<br>Chlorine destroys them if turbidity is low (< 1 NTU) and contact time is sufficient | ◗ Ineffective chlorination when Shannon turbidity is high and in use<br>◗ Chlorination failure | Chlorination |
| Catchment and reservoir | Manganese and Iron | Biofilms or chemical slimes commonly detected in water supplies arise from entry of soluble iron or manganese into reticulation pipe work.<br>These slimes/Biofilms can detach causing stains in laundry, sinks and appliances as well as an unpleasant taste. | ◗ Occur naturally in soils washed into waterways<br>◗ Released from reservoir sediment under low oxygen conditions (e.g. after bushfire event flushing in of leaf litter) | Reservoir aeration (existing)<br>Pre-oxidation (with $KMnO_4$)<br>Pre-pH correction (with lime & $CO_2$)<br>Filtration |

| Stage of supply | Water Quality Hazard | Description | Source of Hazard | Adopted Treatment Methods for Control of Hazard |
|---|---|---|---|---|
| Reservoirs and Nymboida Weir | Algae - Taste and Odour and possible future toxins | Algae blooms can be caused by excess nutrients in water.<br>Certain blue algal species can also produce potentially harmful toxins.<br>Various green and blue green algae can impact significantly on taste and odour. | ◗ Animal and human activity in the catchment providing a source of algae growth nutrients<br>◗ Agriculture – fertiliser wash off<br>◗ Leaching from rotting vegetation and sediments in low oxygen conditions in reservoirs | PAC (powdered activated carbon) dosing |
| Distribution system | Mains recontamination | Contamination enters the water mains during repairs and is not completely flushed out | ◗ Contaminated groundwater<br>◗ Seepage from leaking sewers<br>◗ Backflow from recycled water systems | Residual chlorination |
| Distribution system | Coliform non-compliance | Regrowth of coliforms in the distribution system | ◗ Organics in the water providing food source for micro-organisms<br>◗ Low chlorine residual due to long detention time | Improved chlorination control |
| Distribution system | Chlorine T&O | High chlorine residual | ◗ Variable organics in water and unreliable chlorination | Improved chlorination control |
| Distribution system | Sabotage | Faecal matter, pesticides or rat poisons | ◗ Recontamination at tanks | Asset security |

The above risks are presented schematically in Figure 3 and Figure 4 on the following pages. The figures show where the sources of risk begin and how they move through the water supply system.

Figure 3 shows the high health related risks (i.e. Cryptosporidium, Micro-organisms, Chemicals).

Figure 4 shows the high aesthetic risks (i.e. Turbidity, Iron / Manganese, Taste & Odour, Colour, THM's)




C - Source is catchment element R - Source is reservoir element F - Failure in the treatment element T - Source is treatment element D - source is within the water distribution system element

Number of letters (i.e. C, R, etc) indicates number of sources of risks.

## Figure 3 Summary of Health Related Risks – Very High and High

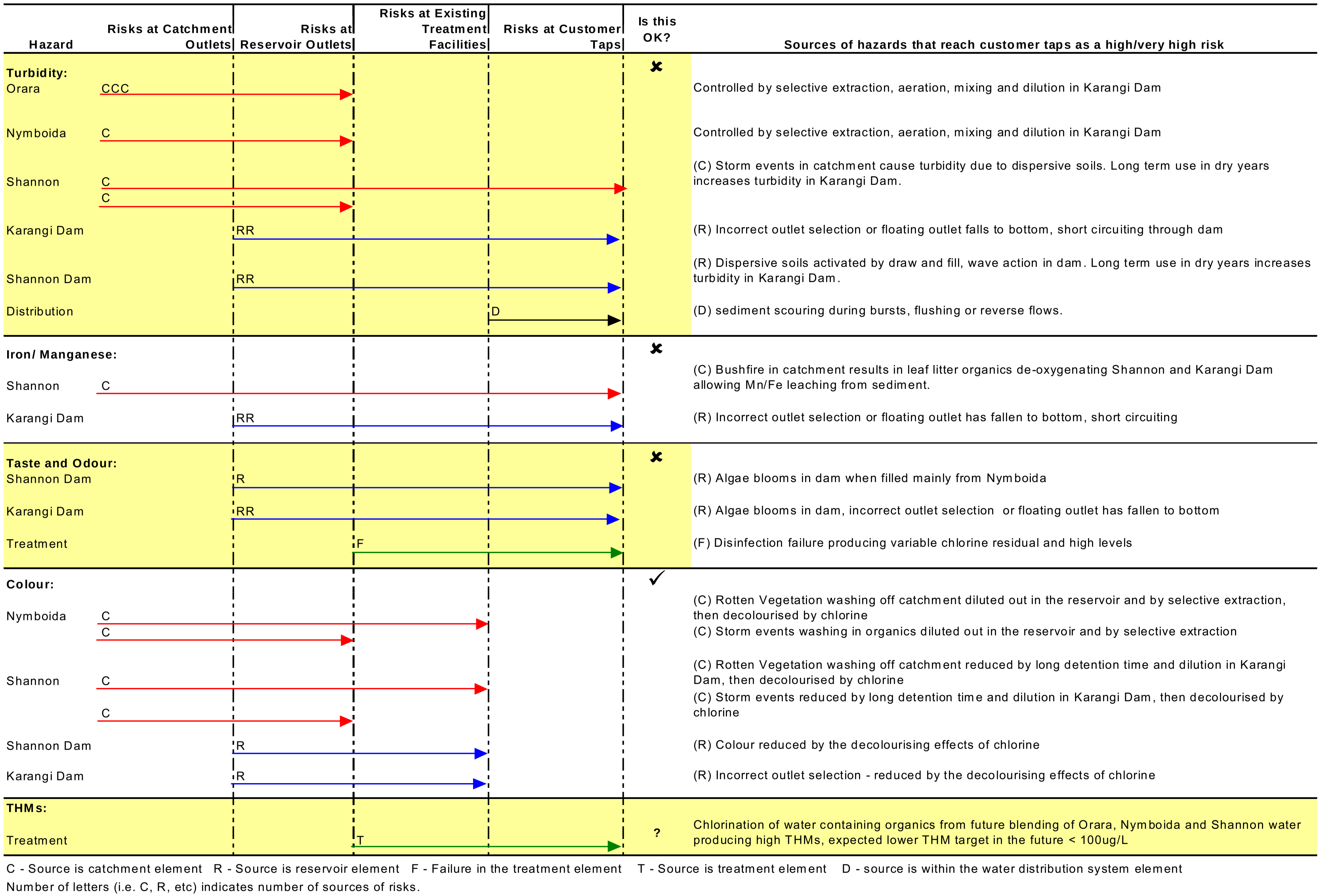



**Figure 4 Summary of Aesthetic Risks – Very High and High**

The water quality risks that have been identified will be managed through actions which will be outlined in a (yet to be prepared) plan referred to as a Hazard Analysis and Critical Control Point (HACCP) Plan. This will be developed and implemented during and after the construction phase of the proposed WTP.

## 4.2 Summary of Treatment Process Selection

The preceding Table 4 nominated the following treatment processes to adequately control the identified high water quality risks:

- PAC (powdered activated carbon) dosing
- Pre-pH correction (with lime & $CO_2$ – carbon dioxide)
- Pre-oxidation (with $KMnO_4$ – potassium permanganate)
- Coagulation
- Flotation (i.e. dissolved air flotation)
- Filtration
- UV (ultra violet) disinfection
- Chlorination

The combined flotation and filtration steps are commonly referred to as 'DAFF' – Dissolved Air Flotation and Filtration. This process, together with the other processes listed above, form the basis of the proposed water treatment plant.

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* Denotes signature on original.