Water Quality Monitoring in the Western Corridor Recycled Water Scheme

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The Urban Water Security Research Alliance (UWSRA) is a $50 million partnership over five years between the Queensland Government, CSIRO's Water for a Healthy Country Flagship, Griffith University and The University of Queensland. The Alliance has been formed to address South-East Queensland's emerging urban water issues with a focus on water security and recycling. The program will bring new research capacity to South-East Queensland tailored to tackling existing and anticipated future issues to inform the implementation of the Water Strategy.

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FOREWORD

Water is fundamental to our quality of life, to economic growth and to the environment. With its booming economy and growing population, Australia's South-East Queensland (SEQ) region faces increasing pressure on its water resources. These pressures are compounded by the impact of climate variability and accelerating climate change.

The Urban Water Security Research Alliance, through targeted, multidisciplinary research initiatives, has been formed to address the region's emerging urban water issues.

As the largest regionally focused urban water research program in Australia, the Alliance is focused on water security and recycling, but will align research where appropriate with other water research programs such as those of other SEQ water agencies, CSIRO's Water for a Healthy Country National Research Flagship, Water Quality Research Australia, eWater CRC and the Water Services Association of Australia (WSAA).

The Alliance is a partnership between the Queensland Government, CSIRO's Water for a Healthy Country National Research Flagship, The University of Queensland and Griffith University. It brings new research capacity to SEQ, tailored to tackling existing and anticipated future risks, assumptions and uncertainties facing water supply strategy. It is a $50 million partnership over five years.

Alliance research is examining fundamental issues necessary to deliver the region's water needs, including:

- ensuring the reliability and safety of recycled water systems.
- advising on infrastructure and technology for the recycling of wastewater and stormwater.
- building scientific knowledge into the management of health and safety risks in the water supply system.
- increasing community confidence in the future of water supply.

This report is part of a series summarising the output from the Urban Water Security Research Alliance. All reports and additional information about the Alliance can be found at http://www.urbanwateralliance.org.au/about.html.

C. Davis

Chris Davis
Chair, Urban Water Security Research Alliance

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Water Supply (Safety and Reliability) Act 2008
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List of Abbreviations

ADWG	Australian Drinking Water Guidelines
ANZECC	Australian and New Zealand Environment Conservation Council
AO	Advanced Oxidation
ARWG	Australian Recycled Water Guidelines
AWTP	Advanced Water Treatment Plant
BOD	Biochemical Oxygen Demand
BOD_5	5-day Biochemical Oxygen Demand
CCP	Critical Control Points
CI	Confidence Interval
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
HACCP	Hazard Analysis Critical Control Point
IPR	Identified Prohibited Substances
MF	Microfiltration
NDMA	*N*-Nitrosodimethylamine
NRWG	National Recycled Water Guidelines
NTU	Nephelometric Turbidity Unit
OC	Organic Carbon
PCB	Polychlorinated Biphenyls
PRW	Purified Recycled Water
QACFW	Quality Assurance and Control Frame Work
QLD-RWG	Queensland Recycled Water Guidelines
QRWG	Queensland Recycled Water Guidelines
RO	Reverse Osmosis
RWMP	Recycled Water Management Plan
SCADA	Supervisory Control and Data Acquisition
SEQ	South East Queensland
SS	Suspended Solids
STP	Sewage Treatment Plant
UF	Ultrafiltration
WCPRWS	Western Corridor Purified Recycled Water Scheme
WCRWMP	Western Corridor Recycled Water Management Plan
WQICS	Water Quality Information Collection System
WQMS	Water Quality Monitoring Schedule
WS	Water Supply (Safety and Reliability) Act 2008
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

With the introduction of the purified recycled water system, a potential closed water loop has been established in which purified recycled water would be fed into the water supply system. This gives rise to potential water quality risks from possible contaminants in the treated wastewaters. Consequently, new legislation governing the PRW operation has been framed to minimise the human health impact, which means that a tougher water monitoring regime is required. It is therefore essential that the water quality monitoring practices employed can service these requirements before PRW is introduced.

In Stage 1 of the Water Quality Information Collection System Project, the available water quality data collected from the seven barriers of the PRW system during 2003-2007 was analysed. As the existing sewer catchments and wastewater treatment plants were not originally designed for the PRW system, an assessment was conducted to identify if the current water quality monitoring practices employed at each of the seven barriers were adequate. The major objective was to identify if any sensing technology developments were required to better safeguard the PRW system operation. Particular emphasis was placed on Barriers 1 (Source Control) and 2 (Wastewater Treatment Plant), as they are critical to the delivery of wastewater of sufficient quality so that the subsequent purification steps can operate satisfactorily.

The water quality monitoring regimes currently employed at Barriers 1 and 2 are mainly based on traditional laboratory-based analytical methods using weekly or fortnightly grab or composite samples. This is appropriate for environmental discharge monitoring and long-term system performance evaluation. However, it is not suited for providing real-time water quality information for source control purposes.

To achieve effective source control and treatment plant performance, a cost effective option would be to implement a real-time event detection system to identify any significant water quality upsets. This would form the basis of an early warning system employing event detection systems strategically located at key points in the sewer network. This would enable any questionable water to be contained before it could potentially breach subsequent barriers. However, to the best of our knowledge, there is no such commercial system currently available which can operate reliably long-term in sewage effluent. Therefore, it is recommended that a real-time event detection system should be developed for Barriers 1 and 2.

It is also recommended that development should commence of suitable on-line sensing systems capable of real-time analysis of targeted water quality parameters (e.g. chemical oxygen demand, nutrients and free chlorine). Such systems provide additional information that can help to characterise and identify a detected event.

For the remaining barriers, there was insufficient compliance monitoring data available for any meaningful assessment, so we have simply reported current monitoring practice at the barriers. Some parameters were monitored on-line, but laboratory-based analyses of twice weekly, weekly or monthly grab or composite samples are employed to monitor the majority of water quality parameters for operational control and compliance purposes. For certain heavy metals, the sensitivity of the current analytical method may need to be improved. The effectiveness of these proposed water quality monitoring practices cannot be investigated until after the PRW is in operation and sufficient water quality data become available.

1. BACKGROUND

The Western Corridor Purified Recycled Water Scheme (WCPRWS) is an important part of the emerging South East Queensland (SEQ) water grid that is designed to utilise purified recycled water (PRW) as an alternative water source to enhance the water supply capacity to SEQ. When fully operational, the scheme has the capacity to supply up to 232 ML/day of PRW. The WCPRWS consists of seven key barriers that are used to control the quality of sewage treatment, advanced water treatment, surface water return to storages, and potable water treatment and distribution (see Figure 1).

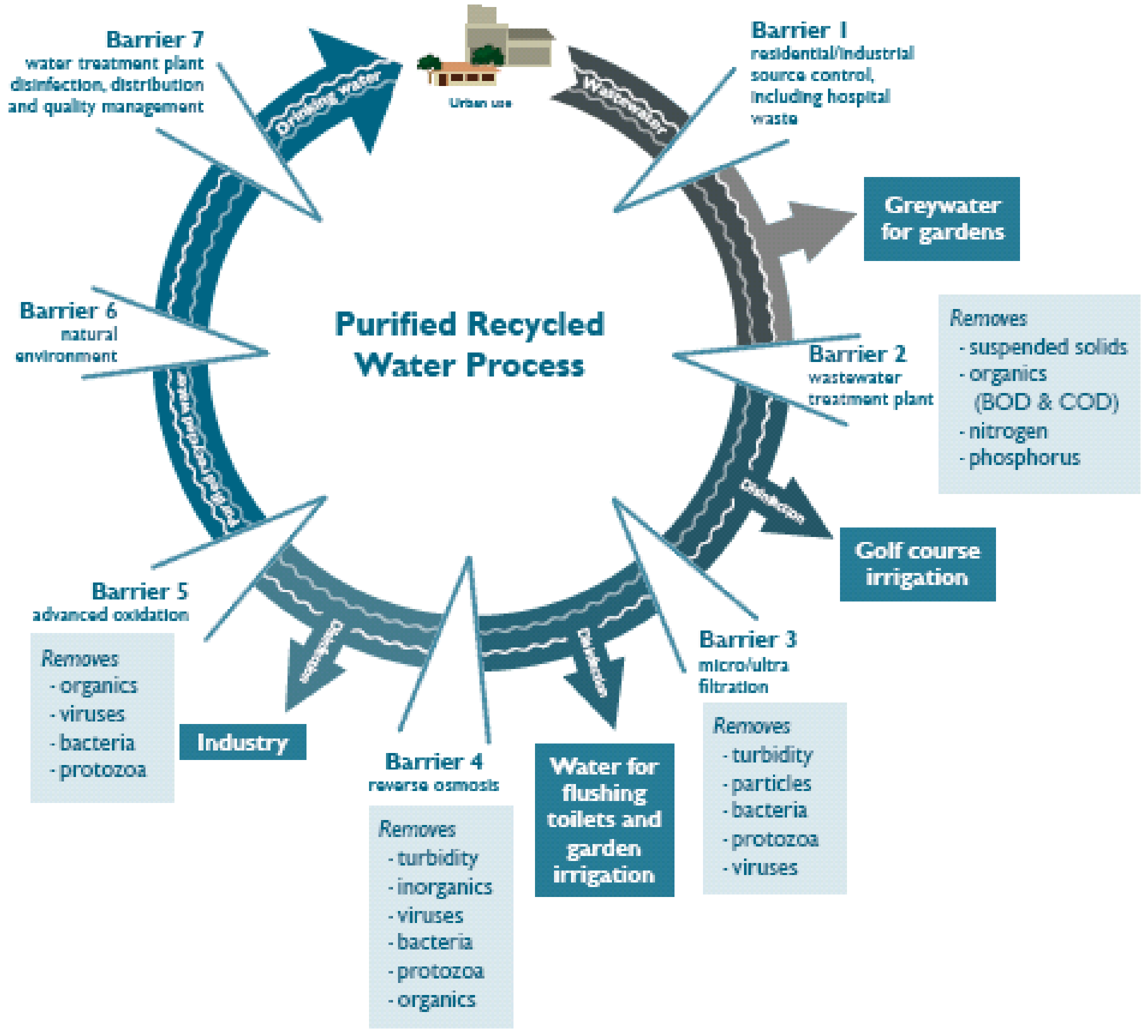

Figure 1 Schematic of a Closed Water Loop Operation via the Seven-Barrier Treatment Process Employed in the Western Corridor Purified Recycled Water Scheme. (source; Queensland Water Commission Fact Sheet 4)

Barrier 1 covers the sewer catchments of the WCPRWS and is set up to control the quality of raw wastewater sources entering the PRW system.

Barrier 2 involves the wastewater treatment plants (WWTP) of the WCPRWS. It is the first treatment barrier of the PRW system, and is designed to purify the raw wastewaters via biological means to produce high quality treated water that can be used as source water for the advanced water treatment plant (AWTP).

Barriers 3 to 5 cover the advanced water treatment plants of the WCPRWS. The primary treatment processes of Barrier 3 are microfiltration (MF)/ultrafiltration (UF), which are designed to transform the source water supplied from Barrier 2 into an appropriate feed water for Barrier 4. Barrier 4 utilises the reverse osmosis membrane process to further purify the water supplied from Barrier 3. Barrier 5 employs advanced oxidation (AO) treatment processes and is the final process of the AWTP. This barrier is designed to provide additional assurance by removing trace organics, pathogens, viruses and protozoa potentially remaining after the RO treatment process. The AWTP ensures the output water meets the water quality requirements for direct industrial use and for discharge into the natural environment/water catchment (Barrier 6).

Barrier 6 consists of the western corridor natural environment, water catchments and storages. This barrier provides a large buffering capacity to neutralise any potential effect of the PRW on the raw drinking water source. Barrier 6 is also used as a natural incubator to further purify the PRW via naturally occurring biological processes.

Barrier 7 comprises the western corridor drinking water treatment plants using source water supplied by Barrier 6. The treated water is supplied directly to the end-users for consumption. The wastewater generated by the end-users is discharged into Barrier 1 and, in so doing, completes the water cycle.

A closed water loop operation in which purified recycled water is introduced into the water supply system gives rise to potential water quality risks from possible contaminants in the treated wastewaters. The safety, reliability and efficiency of the WCPRWS are of prime importance for the success of such a large scale closed water loop operation system, and every effort should be made to ensure the integrity of all barriers is maintained so that contaminants from the wastewater stream cannot enter the clean water stream. In this regard, implementation of an advanced water quality information collection system could provide an effective tool for the operators to better safeguard operation of the PRW system. Consequently, the Water Quality Information Collection System (WQICS) project was established to develop an advanced system enabling real-time acquisition of critically important water quality parameters for event/incident detection.

The WQICS project involves two stages of development. Stage 1 of the project is focused on the evaluation of existing water quality information generated from the seven barriers of the PRW system, with particular emphasis on Barriers 1 (Source Control) and 2 (Wastewater Treatment Plant). The purpose of the evaluation is to identify the sensing technology development required to further improve the level of control hence better safeguarding the system operation. Stage 2 of the project will then be conducted to develop the sensing technologies identified by the investigations carried out in Stage 1.

This document reports the Stage 1 project findings. The report is formulated based on water quality information gathered from water policy/legislative documents, stakeholder survey and workshop feedback, and the stakeholders' water quality data. The required sensing developments are recommended for relevant barriers based on qualitative and quantitative analysis of available water quality information.

2. BARRIER 1: SOURCE CONTROL

2.1 Overview of Barrier 1

The Western Corridor Purified Recycled Water Scheme will deliver up to 232 ML/day of purified recycled water to power stations, industry, agriculture and the Wivenhoe Dam. The scheme will process wastewater from 6 sewer catchments within South East Queensland through a seven-stage (barrier) treatment process to produce high quality PRW.

Barrier 1 is the first and is set up to control the wastewater source. The primary function of this barrier is to ensure that the quality of industrial, commercial and residential wastewaters entering the sewers meet the input requirements of Barrier 2 (wastewater treatment plant) so that it can produce effluent of suitable quality to feed the next barrier in the PRW system.

The current sewer network involved in the WCPRW scheme comprises 7623 kilometres of sewer mains and approximately 305 pumping stations. The raw wastewaters come from three major sources - namely, residential, commercial and industrial wastes. The wastewaters are discharged into the sewer catchments via a series of entry points from residential, commercial and industrial establishments located throughout the catchments, and are then distributed through a series of major and minor sewer pump stations to six wastewater treatment facilities (Barrier 2) of SEQ. Table 1 provides an overview of wastewater sources and compositions for each of the sewer catchments in the WCPRW scheme. The volume of wastewater received by the sewer catchments varies from 4 ML/day (Wacol) to 120 ML/day (Luggage Point). Residential wastewater comprises over 85% of the total volume and is the main source for all sewer catchments in the WCRW scheme, especially for Wacol where 97% of the total volume comes from residential wastewater. For all cases, the commercial and industrial wastewaters make up less than 15% of the total volume received.

Table 1 Wastewater Source and Composition for Sewer Catchments of SEQ PRW Scheme

Sewer Catchment	Source Water Volume (ML/day)	% Residential	% Commercial and Industrial
Bundamba	11.2	≈ 87%	≈ 13%
Goodna	6.4	≈ 90%	≈ 10%
Luggage Point	120	≈ 85-87%	≈ 10-15%
Wacol	4	≈ 97%	≈ 2-3%
Oxley	40	≈ 85-87%	≈ 10-15%
Gibson Island	40	≈ 85-87%	≈ 10-15%

2.2 Objectives

As the sewer catchments involved in the WCPRW scheme were not originally designed for the closed water loop PRW system, an assessment of Barrier 1 was therefore conducted to identify if the current water quality monitoring practice could be further improved to better safeguard the PRW system operation. The specific objectives were:

- To understand water quality requirements of the barrier;
- To investigate current water quality monitoring practice at the barrier;
- To identify any sensor developments required, especially the real-time water quality monitoring technology that could be used to further improve the water quality monitoring practice.

2.3 Methods of the Assessment

The assessment of whether the water quality information collected in Barrier 1 is suitable for reliably maintaining its integrity and performance was based on a qualitative and quantitative data assessment according to a Hazard Analysis Critical Control Point (HACCP) management approach.

It involved the following:

- Examining how data are collected at the barrier;
- Intended purpose of the data at time of the collection;
- Evaluating its format, quality, accuracy and reliability in achieving the required treatment specifications; and
- It's usability for assisting operators/grid managers in delivering water according to its treatment specifications.

The available data and metadata for Barrier 1 from 2003 to 2008 were analysed to characterise temporal and seasonal variations in the sewer catchment at the inlet to Barrier 2 prior to and during the introduction of 6 different levels of water restrictions. All available water quality data were assembled to allow the analysis of data within the specified time frame and scope of the project. The raw source water data collected at the boundary of the Barriers 1 and 2 was quantitatively analysed, but the data within Barrier 1 was not analysed because there were no specific critical control points/levels associated with the information collected. The biosolids data at the boundary of the Barriers 1 and 2 was also analysed.

2.4 Water Quality Requirements

The baseline water quality requirements for Barrier 1 are defined by the EPA Licence Agreements and Trade Waste Discharge Agreements. Table 2 shows the baseline water quality monitoring schedule used for assessing the integrity of the barrier. However, with the introduction of PRW, the water quality requirements for Barrier 1 must now include a human health aspect as defined by the Water Supply Safety and Reliability Act 2008.

Table 2 Baseline Water Quality Monitoring Schedule for Barrier 1

Sewer Catchment	Measurement Methods	Measurement Frequency
pH	Laboratory-based analysis	Fortnightly
DO	Laboratory-based analysis	Fortnightly
Sulphide	Laboratory-based analysis	Fortnightly
Temperature	Laboratory-based analysis	Fortnightly
Flow	On-line	-
Influent		
Flow	On-line	Real-time
Suspended Solids	Laboratory-based analysis	Weekly/Fortnightly
pH	Laboratory-based analysis	Weekly/Fortnightly
Conductivity	Laboratory-based analysis	Weekly/Fortnightly
COD	Laboratory-based analysis	Weekly/Fortnightly
Nitrate	Laboratory-based analysis	Weekly/Fortnightly
Nitrite	Laboratory-based analysis	Weekly/Fortnightly
Organic Nitrogen	Laboratory-based analysis	Weekly/Fortnightly
Total Nitrogen	Laboratory-based analysis	Weekly/Fortnightly
Total Phosphorus	Laboratory-based analysis	Weekly/Fortnightly
Biosolids		
Total Solids	Laboratory-based analysis	Fortnightly/Monthly
Arsenic	Laboratory-based analysis	Fortnightly/Monthly
Cadmium	Laboratory-based analysis	Fortnightly/Monthly
Chromium	Laboratory-based analysis	Fortnightly/Monthly
Copper	Laboratory-based analysis	Fortnightly/Monthly
Lead	Laboratory-based analysis	Fortnightly/Monthly
Mercury	Laboratory-based analysis	Fortnightly/Monthly
Molybdenum	Laboratory-based analysis	Fortnightly/Monthly
Nickel	Laboratory-based analysis	Fortnightly/Monthly
Selenium	Laboratory-based analysis	Fortnightly/Monthly
Zinc	Laboratory-based analysis	Fortnightly/Monthly
DDT	Laboratory-based analysis	Fortnightly/Monthly
DDD	Laboratory-based analysis	Fortnightly/Monthly
DDE	Laboratory-based analysis	Fortnightly/Monthly
Aldrin	Laboratory-based analysis	Fortnightly/Monthly
Dieldrin	Laboratory-based analysis	Fortnightly/Monthly
Chlordane	Laboratory-based analysis	Fortnightly/Monthly
Heptachlor	Laboratory-based analysis	Fortnightly/Monthly
HCB	Laboratory-based analysis	Fortnightly/Monthly
Lindane	Laboratory-based analysis	Fortnightly/Monthly
PCBs	Laboratory-based analysis	Fortnightly/Monthly

The water quality monitoring requirements of the barrier must take into account any potential risks associated with identified prohibited substances (IPR). A list of the categories of IPR contaminants is given in Table 3. The assessment of IPR has been based on the legislative and guideline documents as shown in Table 4.

Although the monitoring schedule has not been finalised for Barrier 1, it must mitigate the hazard and IPR contaminants that have been identified in sewer catchment characterisation programs and the literature.

Table 3 Hazards in Sewer Catchment

Hazardous Substances	Examples
Physical	Solids and sanitary products
Microbiological	E.Coli and other bacteria
Heavy Metals	Copper, Magnesium
Radiological	Alpha and Beta radiation
Gross Organics	TOC and suspended solids
Volatile Organic Carbon	Benzene
Haloacetic Acids	Dichloroacetic Acid
Nitrosamines	NDMA
Nutrients	Total Nitrogen and Total Phosphorus
Endocrine Disrupting Compounds	Bisphenol A and Nonylphenol
Pharmaceuticals	Caffeine and Diazepam
PCBs	PCB 77
Polycyclic Aromatic Hydrocarbons	Pyrene
Carbamates	Aldicarb
Synthetic Pyrethroids	Fenvalerate
Organophosphorus Pesticides	Aldrin, Total DDT
Pesticides	Glyphosate
Phenols	Phenol

Table 4 Legislative and Operational Documents Reviewed for Assessment of Barrier 1

Legislative Documents
National Recycled Water Guidelines (NRWG), Phase II
AS/NZS 4360:2400 – Risk Management
Australian Drinking Water Guidelines (ADWG)
QLD Recycled Water Guidelines (QLD-RWG)
Substances as Defined in Schedule 1 of the Water Act 2000 (Ipswich)
Radioactive Substances Act 1958 (QLD)
Guidelines for Waste Management in Health Industry, National Health and Medical Research Council
Risk Analysis based on Total System Recycled Water Management Plan
Recycled Water Management Plan (RWMP, Ipswich)
Risk and ANZIC Code (double check with AS/NZS 4360:2400)

2.4.1 Water quality monitoring schedule

Every wastewater treatment plant (WWTP) is required to develop a specific Water Quality Monitoring Schedule (WQMS) to guide the source water quality monitoring within its sewer catchment and assess potential upstream impacts. The WQMS requires routine monitoring of flow, pH, conductivity, COD, SS, BOD_5, nitrate, nitrite, organic nitrogen and total phosphorus at the inlet to the WWTP (normally at the cusp of Barriers 1 and 2). The raw water influent, which is measured at the boundary of the Barriers 1 and 2, is analysed using grab or composite samples collected on a weekly or fortnightly basis, depending on the EPA licence agreement. In addition pH, DO, hydrogen sulphide, temperature and flow are also measured at certain locations of the sewer catchment on a fortnightly basis.

The WQMS also includes acquisition of biosolids information that is obtained from Barrier 2 on a fortnightly or a monthly basis. Biosolids are important for assessing the level of the accumulated heavy metals, OC, pesticides and PCBs entering the WWTP from the sewer catchment. This information is used by trade waste regulators to ascertain the bioaccumulation levels of key contaminants over time and to assist with identifying if non-compliant trade waste breaches or illegal discharges may have occurred.

The assessment has revealed that the information provided by the WQMS is predominantly obtained from grab or composite samples using laboratory-based measurement techniques, except for flow data which is measured continuously at the WWTP inlet via a centralised SCADA or a localised system.

The assessment has also revealed that the current WQMS does not require a WWTP to have on-line water quality monitoring for real-time acquisition of critical water quality information.

2.4.2 Use of the water quality data collected

The information currently collected in Barrier 1 is used for operational and compliance monitoring purposes, with respect to adhering to EPA licences and Trade Waste Agreements based on an environmental health perspective. However, with the introduction of the Water Supply (Safety and Reliability) Act 2008, the data collected in Barrier 1 must also now ensure that the sewer catchment source water meets the human health requirements in accordance with an approved Recycled Water Management Plan (RWMP).

With the shift from an environmental health based risk of the traditional water supply to a human health based approach for the PRW system, the water quality information collected within Barrier 1 must be sufficient to allow an adequate assessment of potential hazards and implementation of effective critical control processes in accordance with a HACCP based management plan. This is in addition to its prior requirement for operational and compliance monitoring in a traditional water supply system.

Table 5 summarises the required hazards monitoring at the CCPs in Barrier 1. In a sewer catchment, the CCPs are designed to gather information related to hydraulic flow, contamination from hazards and water quality parameters that potentially affect the performance of the WWTP in Barrier 2.

Table 5 Required Hazards Monitoring at the Control Points for Barrier 1

Barrier Monitoring	CCP	Hazard	Critical Limit
Sewer Catchment	Pump Station Flow	Health/Environmental - Overflow	High-High level alarm in pump well
Sewer Catchment	Pump Station	Operational –overflow	Loss of power twice per month
Sewer Catchment	Pump Station	Physical – pump failure	Two break-downs per week
Sewer Catchment	Pump Station	Physical – structural failure	Corrosion of walls
Sewer Catchment	Pump Station	Chemical – pump failure	70% of trade waste monitoring are non-compliant
Sewer Catchment	Pump Station	Control/Instrument Telemetry Failure	Two defects/faults recorded in inspection report
Sewer Catchment	Trade Waste Discharge	Operational – discharge of non-compliant waste into sewer	Site specific (for non-compliance limits
Transitions Barrier 1 and 2	Influent WWTP	Flow	3 x ADWF
Transitions Barrier 1 and 2	Influent WWTP	COD	As per design specification of WWTP
Transitions Barrier 1 and 2	Influent WWTP	Suspended Solids	As per design specification of WWTP
Transitions Barrier 1 and 2	Influent WWTP	BOD_5	As per design specification of WWTP
Transitions Barrier 1 and 2	Influent WWTP	Organic Nitrogen	As per design specification of WWTP
Transitions Barrier 1 and 2	Influent WWTP	Total Phosphorus	As per design specification of WWTP

2.5 Critical Control Point Monitoring in WWTP

The available historical data collected by the WWTP were quantitatively analysed and reported in this section. All data used for this section were provided by Ipswich Water, unless otherwise stated.

It should be noted that some of the compliance and operating limits used here are only in draft form, and come from Ipswich Water's Treated Wastewater Management Plan, Treated Wastewater Management Plan (Bundamba), Bundamba Catchment and HACCP Plan (September 2007), and Water Quality Management and HACCP Plan (February 2007). For each variable up to three plots are presented. The first plot is a time series plot which presents: the observations; identifies any left or right censored observations (i.e. out of range); compares the observations against any given compliance or operating limits; identifies when the various water restriction levels came into effect; fits an estimated trend with approximate 95% confidence interval (CI); and for some variables the rainfall data is also plotted. Note the estimated trend is only given as an exploratory tool. No attempt has been made to optimise the trend fit. For all variables the trend fit assumes the data are normally distributed, and does not account for any censored observations. Not properly accounting for censored observations means that the trend may not be as pronounced as it should, and the 95% CI may be too narrow. The violation of the normality assumption would also make any inference questionable. However, we will only present the time series plot data in this report.

2.5.1 Sewer Infiltration and Overflow

As indicated by the RWMP and risk analyses for Barrier 1, several critical control points within the sewer catchment have been set up to mitigate the risks associated with hydrodynamic flow/over-flow. Figure 2 shows the raw influent flow data collected from the sewer catchment between 2003 and 2008.

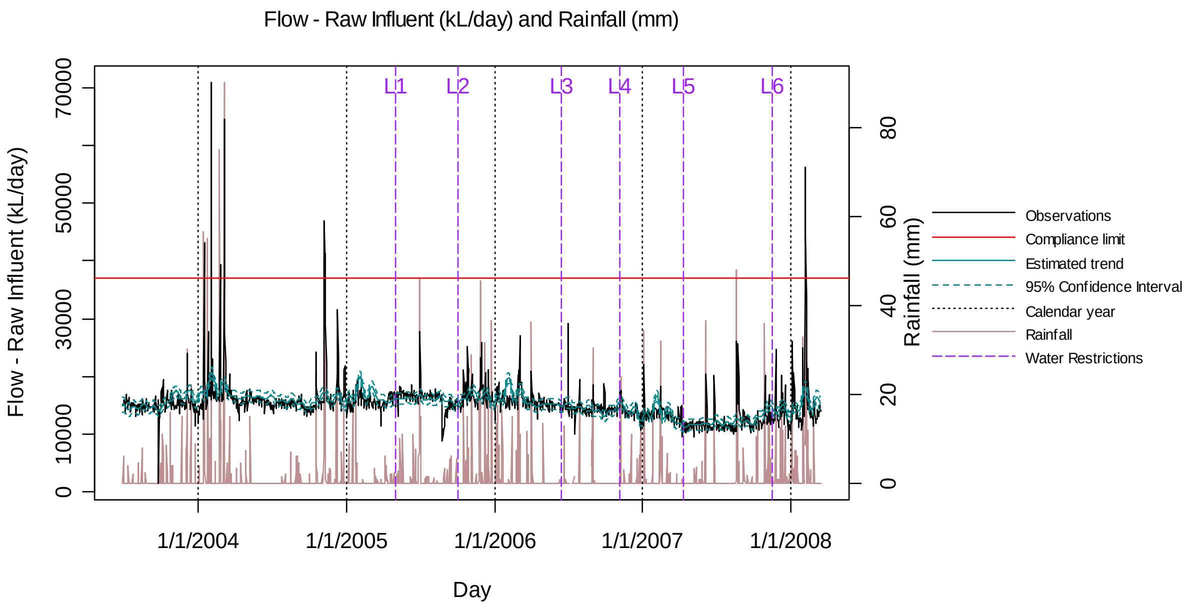

Figure 2 Effect of Rainfall on Raw Influent in the Sewer Catchment

The data analysis indicates that sewage infiltration can occur during the wet season and the overflow events were found to be generally associated with heavy rainfall events. The consequences of overflow entering Barrier 2 beyond compliance limits (which are 3 times of the Average Dry Weather Flow) could be to dramatically reduce the quality of the treated effluent produced. Catchment overflow can also create additional entry points, which makes it more difficult to control the sewer catchment. It should be noted that an overflow event could also lead to the loss of mixed liquor solids or biosolids in Barrier 2, incidentally releasing certain IPR contaminants to the downstream barriers, which could be of concern for human health and the environment.

The investigation revealed that such potential risks could be mitigated by implementing a more comprehensive real-time on-line flow monitoring regime. A centralised SCADA system based on a monitoring network that incorporates real-time flow data gathered from all major sewer pump stations can provide valuable information to allow the operator to rapidly respond to an overflow event, better maintaining the barrier's integrity. In addition, the availability of real-time information to treatment plant operators would enable a more preventative management approach. Such an approach could further strengthen the level of control to ensure the WWTPs can still produce high quality treated wastewater suitable for the AWTP irrespective of weather conditions (e.g. high rainfall events).

2.5.2 Non-compliant waste discharges

The available data were analysed to characterise diurnal, seasonal and temporal variations. The measured data for each parameter were compared to the operational and compliance limits. These results should assist trade waste regulators and operators to understand the barrier's performance and to determine if the level of hazardous substances has exceeded the capacity of the subsequent treatment processes.

Figure 3 shows the influent BOD_5 data over a 5-year period. It can be seen that over 65% of the measured BOD_5 exceeded the compliance limit during the period. The increasing trend in BOD_5 observed was found to be associated with the increasing severity of water restrictions. Three major non-compliance events were observed during 2006 and 2007; each lasted for more than a month.

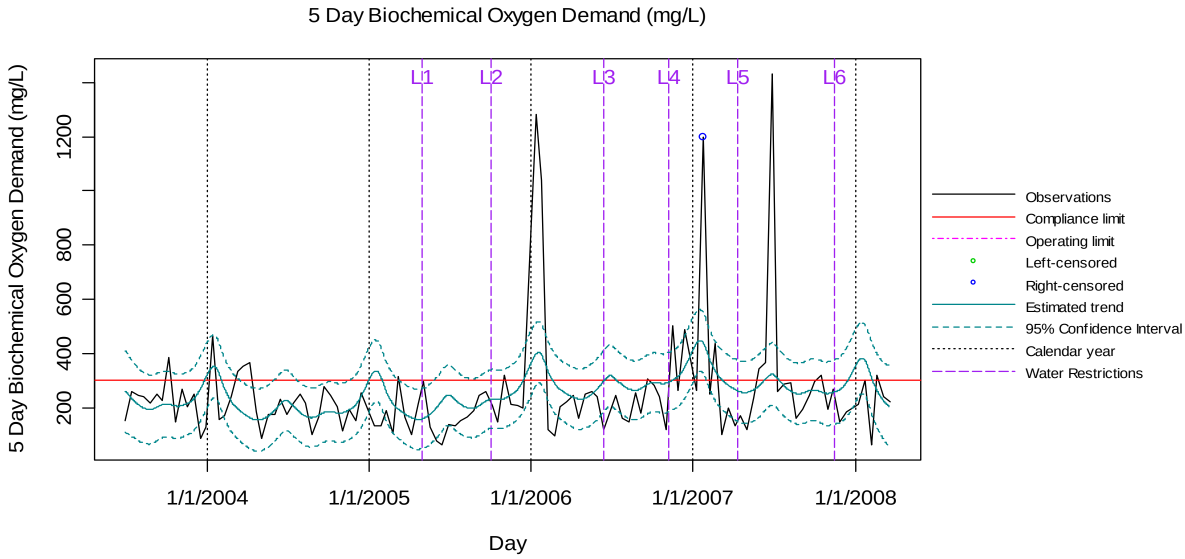

Figure 3 Observed Raw Influent BOD_5 Levels Over Time

Nearly 35% of Total Kjeldahl Nitrogen levels over the same 5-year period were also found to be over the compliance limits (see Figure 4); as were 32% of the total phosphorus measurements (Figure 5). In addition, a number of noticeable increases in the chromium accumulated in the biosolids were observed, with a particularly dramatic increase being observed during late 2007 (Figure 6).

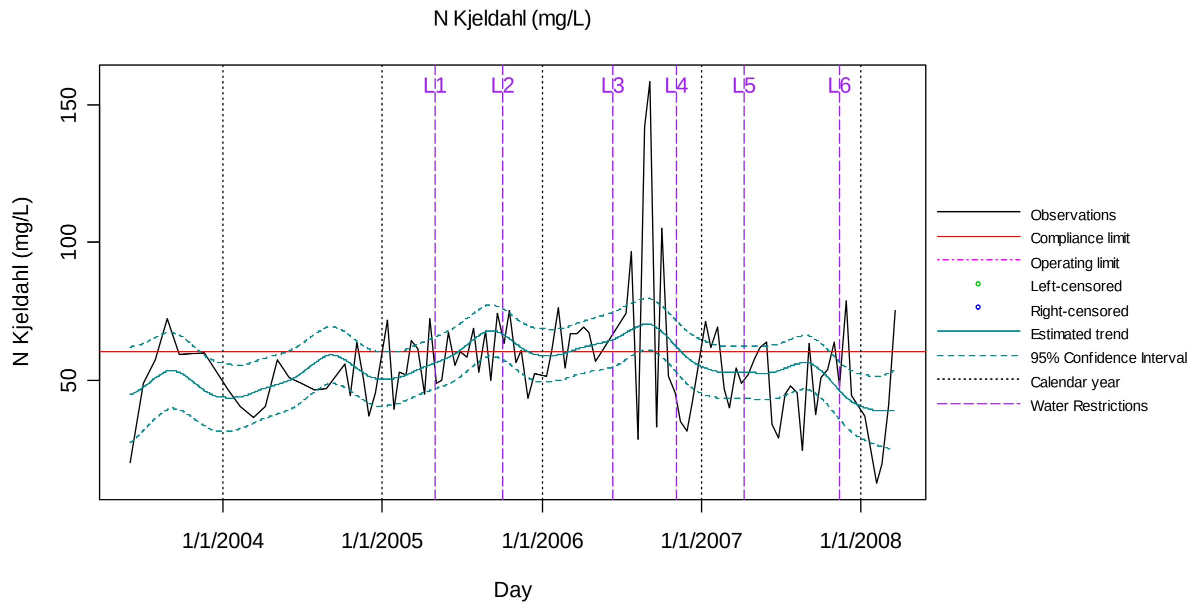

Figure 4 **Observed Influent Total Kjeldahl Nitrogen Levels**

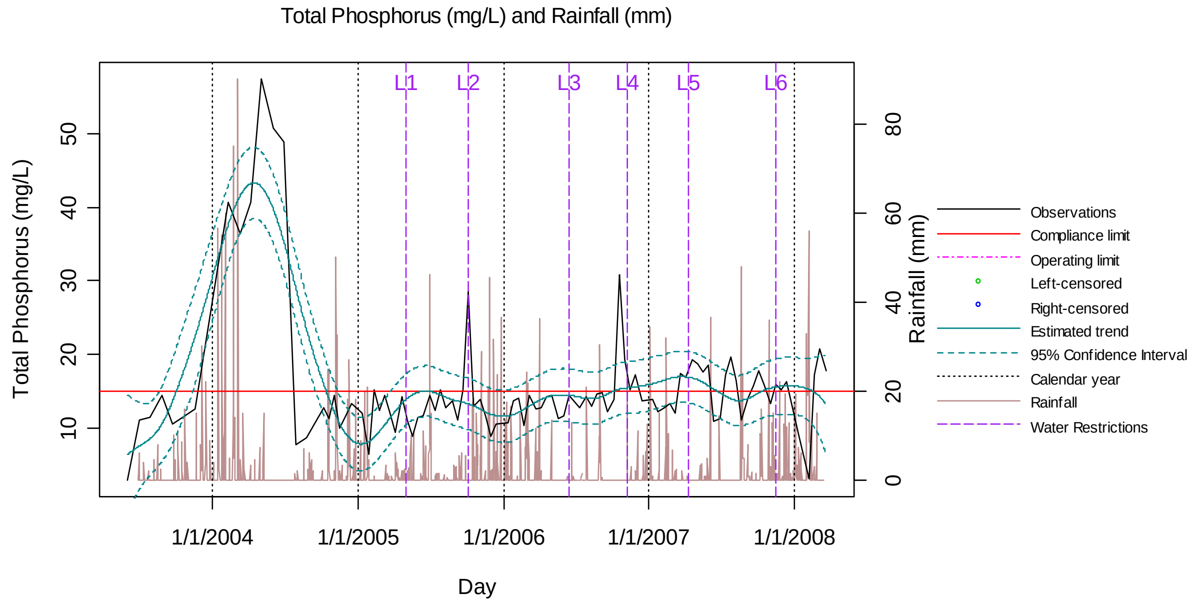

Figure 5 **Observed total phosphorus and rainfall levels**

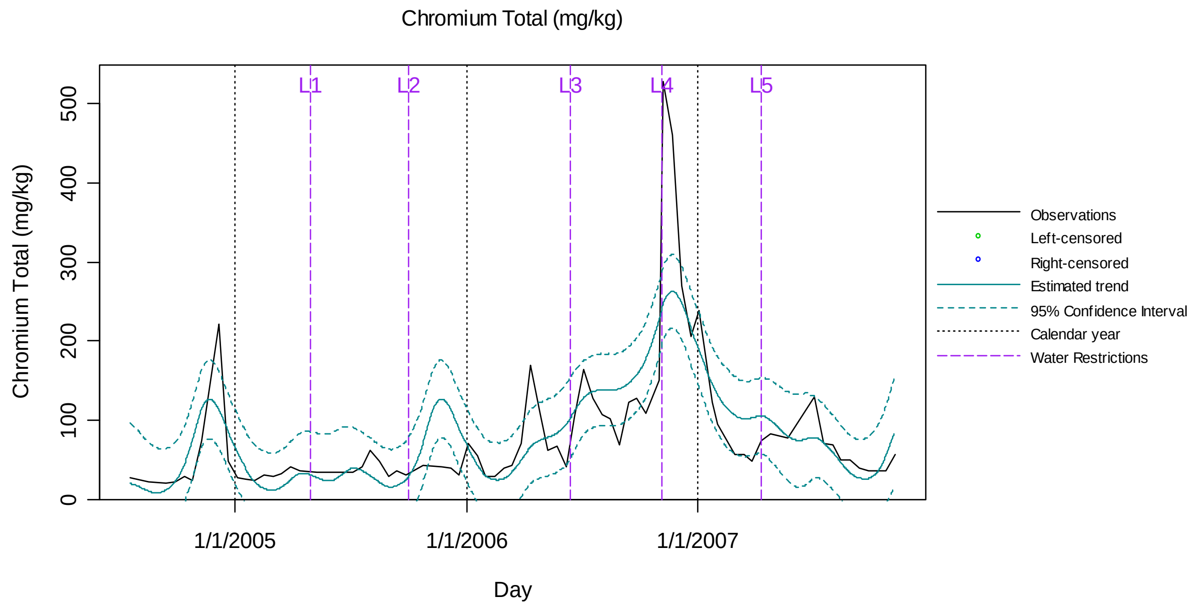

Figure 6 Observed Chromium Accumulation in the Biosolids

2.5.3 Other water quality parameters at the inlet of the WWTP

The other water quality parameters such as pH, conductivity, suspended solids and chemical oxygen demand were also collected and analysed for diurnal, seasonal and temporal variations and compared against rainfall and water restriction levels.

Figure 7 shows the plot of pH values against time over a 5-year period. The observed pH varied between 6.5 and 7.3, and was found to be within the operational limits over the whole period investigated. It was found that the observed pH tends to be lower during a dry period, and that a rainfall event normally increased pH values to above 7. No noticeable change in the pH values was observed when different water restriction levels were imposed. Data analysis revealed a clear seasonal/annual pH variation pattern in which the observed pH reached its maximum and minimum values during each year's summer and winter period, respectively. This closely follows the annual temperature pattern, suggesting the pH variation was dominated by dissolved CO_2. It is well known that the solubility of CO_2 in aqueous media is governed by Henry's law of gas solubility. Given the partial pressure of CO_2 in the atmosphere is relatively constant, an increase in temperature will lead to a decrease in solubility of CO_2 in aqueous media resulting in an increase in the pH. In other words, higher temperatures during the summer reduce the concentration of dissolved CO_2 in the influent, which results in higher pH; and lower temperatures during the winter increase the concentration of dissolved CO_2 in the influent that results in lower observed pH values.

Figure 8 shows a plot of measured conductivity values against time over a 5-year period. Analysis revealed a clear seasonal/annual conductivity variation pattern, in which the conductivity values observed during summer were higher than those observed during winter. The conductivity values tended to decrease during a rainfall event, suggesting the observed variation in conductivity is governed by the yearly rainfall pattern. A clear increasing trend in conductivity was observed as the water restriction levels were increased. The conductivity increased sharply after the introduction of level 3 water restrictions during the middle of 2006, and reached its maximum during the middle of 2007 after level 5 water restrictions were introduced. Following this, the conductivity decreased due to increased rainfall.

Figures 9 and 10 are time plots over a 5-year period of suspended solids and COD values, respectively. It was found that 27.8% of suspended solids and 73.91% of COD observations were outside the compliance limits. The annual variation pattern observed for both parameters was found to be similar to that observed for conductivity. In fact, rainfall and water restriction levels affected both parameters in the same manner as they affected the conductivity.

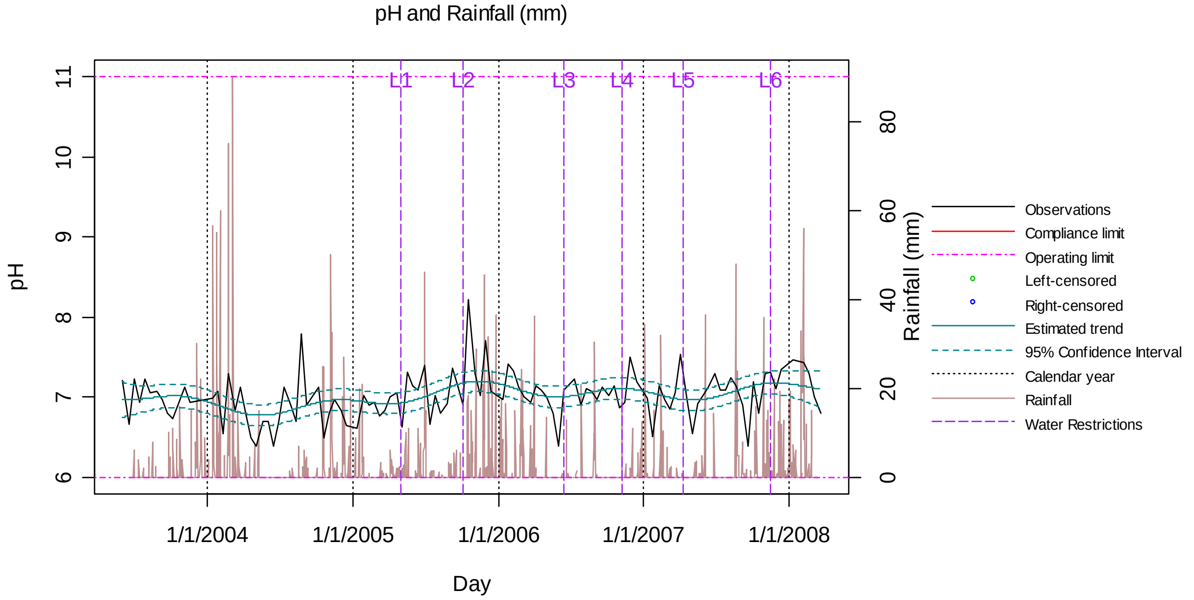

Figure 7 Observed pH Values at the Entrance of the WWTP

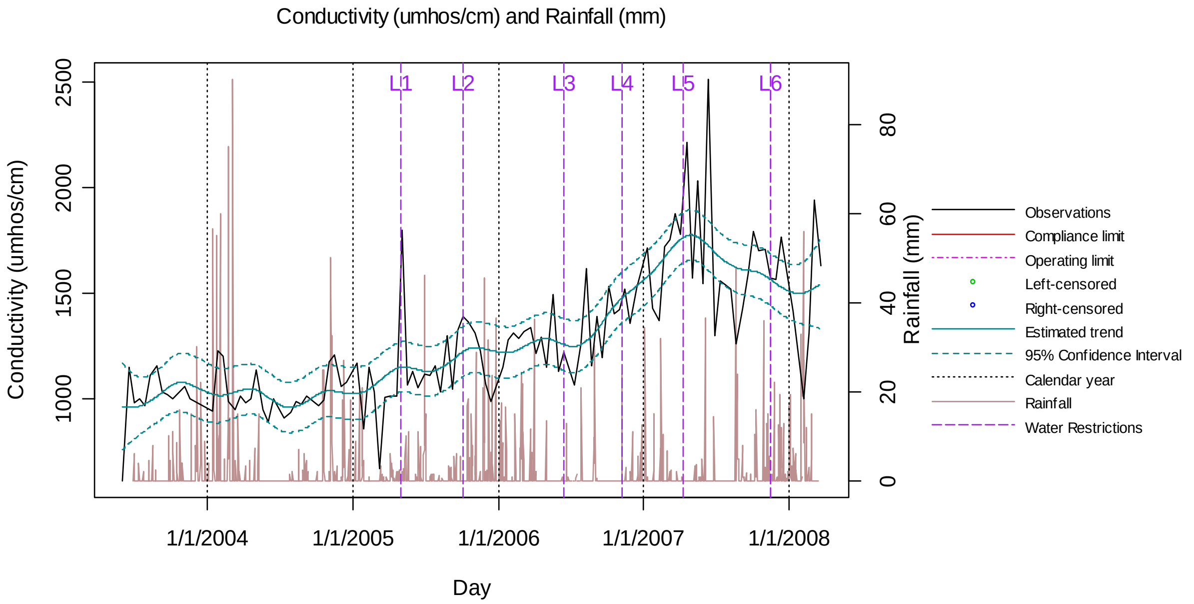

Figure 8 Observed Conductivity Values at the Inlet of the WWTP

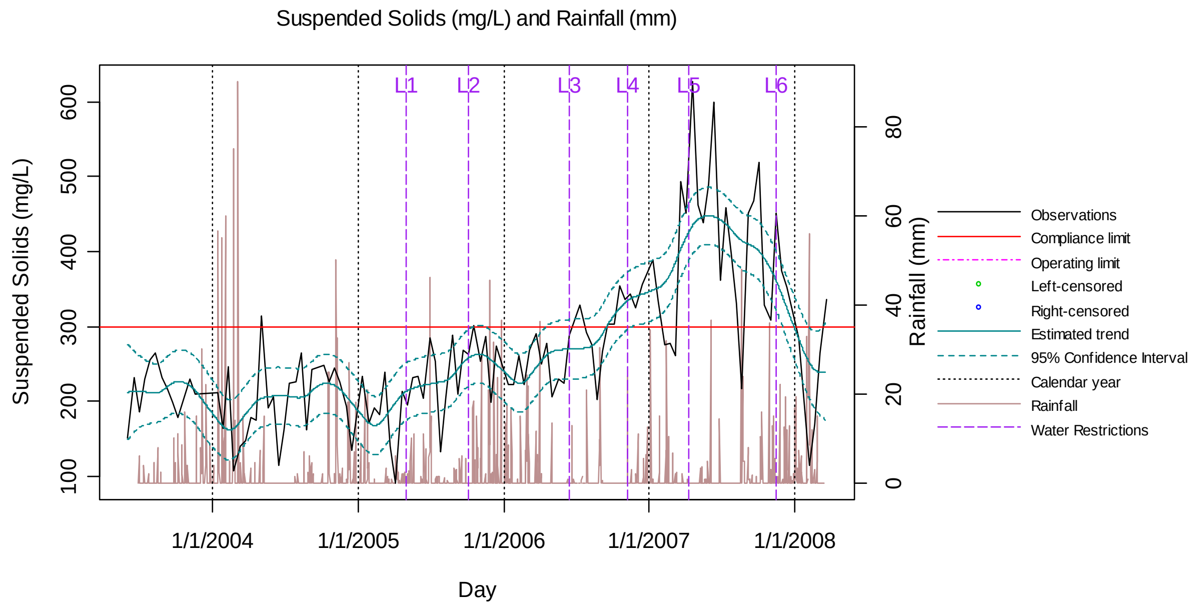

Figure 9 Observed Suspended Solids Values at the Inlet of the WWTP

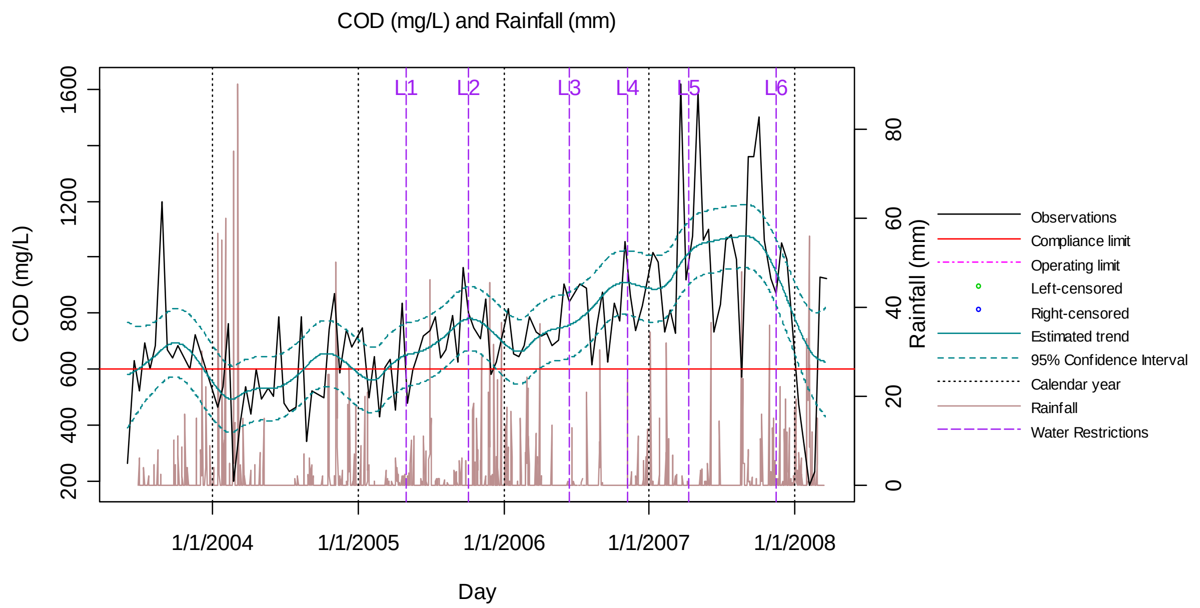

Figure 10 Observed COD Values at the Inlet of the WWTP

2.6 Summary of Findings and Recommended Sensor Developments for Barrier 1

This section summarises the findings revealed during Stage 1 investigations and makes recommendations relevant to the project.

Closed water loop operation in which purified recycled water is introduced into the water supply system gives rise to potential water quality risks from possible contaminants in the treated wastewaters. The emphasis on the human health impact reflected in the new legislation governing operation means a more restrictive water quality requirement; hence a tougher water monitoring regime is required. The investigation revealed:

- The new policy documents have outlined a range of new legislative measures to counter any potential risk that may be introduced by the closed water loop operation.
- The water quality monitoring practices employed must be able to service these requirements before PRW is introduced.
- The water quality monitoring regimes currently in place are mainly based on the traditional laboratory-based analytical methods to analyse grab or composite samples on a weekly or fortnightly basis.
- The water quality information currently collected is useful for long-term system performance evaluation and its effectiveness for closed water loop operation could only be validated after the PRW scheme is in operation.
- There is no evidence to suggest the water quality monitoring technologies in use are capable of providing real-time water quality information for source control purposes.

It is known that the WWTPs currently in operation were not originally designed to treat wastewater to a specified quality for the purpose of PRW. It is also known that the design of a WWTP can reliably produce quality effluent so long as the quality of the source water meets the design criteria. In the majority of cases, malfunction of a WWTP is caused by the source water quality being well outside the designed buffering capacity. This means that the associated risk can be greatly reduced if a source control regime is in place to ensure the quality of source water entering the WWTP. One way of achieving this is to modify or rebuild the current wastewater collection infrastructure/network to prevent illegal discharges and natural events such as overflow, and to allow certain non-complying streams of wastewaters to be collected and treated separately. This would clearly be a costly and time consuming option. Another option to achieve effective source control may be to implement a real-time event detection system to inform the operator of any significant source water quality changes, enabling the operator to contain the questionable source water before it enters the WWTP. We believe such an option is economically viable and technologically feasible. However, to the best of our knowledge, there is no commercial analytical system currently available for such tasks. The sensing technology development required to implement such a system is therefore recommended as below:

- Develop an event detection system capable of identifying any significant source water quality change at Barrier 1 in real-time.
    - To save time and reduce costs, existing sensors that are commercially available should be used for system development;
    - The system should be simple, robust, reliable, low-cost and easy to operate;
    - The system should consume no reagents, generate no waste materials and require no on-going calibration;
    - The system should also incur low operational cost and require little or no maintenance; and
    - The system should be designed with an auto-sampling device in which a detected event will automatically trigger sample collection for further investigations.

- Use of this event detection system as the basis of an early warning system that is capable of providing real-time alarms would enable an operator to protect the WWTP. The early warning system would comprise event detection systems (serving as the information collection units) strategically located at key points in the sewer network such as major pump stations. A fully developed early warning system should be able to provide:
    - Precise time, duration and location of an event;
    - Nature of the detected event (i.e. quality and quantity);
    - Time required for the questionable discharge to travel between monitoring points, and an estimate of the time it would arrive at the WWTP or at any purpose built effluent diversion facility; and
    - Real-time alarm function to inform the operators/grid manager with adequate information to facilitate decision making.
- Development of suitable on-line sensing systems capable of real-time analysis of targeted water quality parameters such as COD (organic pollutant level), nutrients (i.e. organic nitrogen/ammonia and phosphorus) and free chlorine. This on-line analysis system would provide additional information to help characterise any events detected by the early warning system.

We believe that implementation of this system will provide an essential management tool to allow the operators/grid managers to better safeguard the PRW operation.

3. BARRIER 2: WASTEWATER TREATMENT PLANT

3.1 Overview of Barrier 2

Barrier 2 of the Western Corridor Purified Recycled Water Scheme involves six wastewater treatment plants which convert raw sewer influent from the Barrier 1 into quality effluent suitable as the source water for the Barrier 3. The details of treatment capacities and compositions of raw sewage influents for the wastewater treatment plants are given in Table 1.

The treatment processes of a WWTP involve three consecutive treatment stages; namely preliminary, primary and secondary treatment. Preliminary treatment is required to physically remove large pieces of material and grit from the raw waste influent. The primary treatment process is designed to biologically remove carbon, nitrogen and in some cases phosphorus. Although some WWTPs within the scheme were not originally designed for phosphorus removal, there is incidental phosphorus removal as a result of the treatment processes. Secondary treatment clarifies treated wastewater via a sedimentation process to remove the suspended solids. The effluent produced by the WWTP must comply with the water quality requirements set by the EPA licences and the supply contract to the Western Corridor. With the shift towards closed water loop PRW operation, the effluent must also comply with EPA’s Environmental Health Licence Agreements and the Human Health Licence Agreements from the Department of Natural Resources and Water and Queensland Health. The effluent produced at Barrier 2 will only be supplied to Barrier 3 if it is deemed to be of the specified quality. If not, it will be disinfected to produce Class B Recycled Water that can be used by WWTP customers or released into the natural environment.

3.2 Objectives

The WWTP involved in the WCPRW scheme were not originally designed for the closed water loop PRW system. An assessment of this barrier has therefore been conducted to identify if the current water quality monitoring practice can be further improved in order to better safeguard the PRW system operation. The specific objectives are:

- To understand water quality requirements of Barrier 2;
- To understand current water quality monitoring practice at the barrier; and
- To identify the required sensor developments, especially real-time water quality monitoring technology that could be used to further improve water quality monitoring practice.

3.3 Methods of the Assessment

The assessment of available water quality information was carried out according to a Hazard Analysis Critical Control Point (HACCP) management approach.

It involved the following:

- Investigate data collection methods used at the barrier;
- Examine the intended purpose of the data at the time of collection;
- Evaluation of the data format, quality, accuracy and reliability in achieving the required treatment specifications; and
- It’s usability for assisting operators/grid managers in delivering water meeting its treatment specifications.

The available data and metadata for Barrier 2 from 2003 to 2008 were analysed statistically. All available water quality data was assembled to enable analysis to be completed within the specified time frame and scope of the project.

3.4 Water Quality Requirements

With the transition to a closed water loop PRW operation, the water quality requirements for Barrier 2 specified in the previous EPA environmental health requirement have been modified to incorporate human health risk management. The quality of the effluent produced at Barrier 2 must comply with the water quality requirements for closed water loop PRW operation as defined by the standards, guidelines and licence agreements summarised in Table 6.

Table 6 A List of Policy Documents Used for the Investigation

Standards, Guidelines and Agreements
Hazard Analysis and Critical Control Points AS/NZS Global : 2003
Occupational health and safety management systems AS/NZS 4801 : 2001
Quality management systems AS/NZS ISO 9001 : 2000
Risk management AS/NZS 4360 : 1999
Environmental management systems AS/NZS ISO 14001 : 1996
Queensland Water Recycling Guidelines (EPA, 2005),
Environmental Protection Act 1994
Agreements for Western Corridor Recycled Water Pty Ltd (part EPA)
Recycled Water Management Plan (part EPA)
Treated Wastewater Management Plan
Integrated Planning Act 1997
Water Act 2000
Queensland Plumbing and Wastewater Code
Environment Protection and Biodiversity Conservation Act 1999
Water Supply (Safety and Reliability) Act 2008
Australian Guidelines For Water Recycling

There have been a number of contaminants or water quality issues of concern identified that could affect the capabilities of treatment processes within the WWTP and AWTPs, in addition to impairing the quality of the purified water produced. The parameters of concern that have been identified thus far within Barrier 2 are as follows:

- Organic Loads (with emphasis on BOD_5 and COD)
- Suspended Solids
- Total Nitrogen
- Total Phosphorus
- Inorganics
- Heavy metals
- pH
- Microbiological indicators such as E.Coli
- Pesticides
- Endocrine Disrupting Compounds
- Radioactivity
- VOCs and THMs
- Haloacetic acids
- Nitrosamines
- Semi-volatile organics
- Pharmaceuticals
- Phenoxyacid herbicides
- Glyphosate and AMPA
- PAHs and Phenols
- EDTA

Though the WWTPs currently in operation were not originally designed for removal of all PRW contaminants of concern, the quality of the effluents produced suggested that the majority of the PRW contaminants listed above are removed. Under the agreement between each individual WWTP and the Western Corridor Pty Ltd, a WWTP must perform to the best of its ability to supply treated effluent to the AWTP with a specified quality, all year round, irrespective of diurnal, seasonal or climatic variations.

The general water quality specifications for treated effluent used as the source water to the AWTP are summarised in Table 7. It should be noted that these specifications may vary slightly depending on the treatment processes and membranes employed in Barriers 3 and 4 and the advanced oxidation technology employed at Barrier 5, in addition to source water characteristics, PRW contaminants of concern and the treatment performance capabilities of each individual WWTP.

It is important to note that according to the Western Corridor Agreement, the temperature and free chlorine levels must never exceed their maximum compliance limit. It is also important to note that the service standard for all other measurements should have no more than 1 non-complying result in 20 consecutive tests (i.e. a compliance level of 95% for most parameters, except ammonia which is 99.75% and chlorine and temperature which must be 100%).

Table 7 General Treated Water Quality Specifications for the WWTP

Parameter	Specification Requirements (mg/L unless other units listed)	Maximum Duration of Event	Measurement Method	EPA Licence Agreement
Temperature*	< 30 °C	Must never exceed	Portable Field	Weekly/Fortnightly
Free Chlorine*	< 0.05	Must never exceed	Laboratory	Weekly/Fortnightly
Biochemical Oxygen Demand	< 30	5 days	Laboratory	Weekly/Fortnightly
Suspended Solids	< 30	5 days	Laboratory	Weekly/Fortnightly
TOC*	< 40.0	2 days	Laboratory	Weekly/Fortnightly
Conductivity*	< 1600 µS/cm	24 hours	Laboratory	Weekly/Fortnightly
TDS	< 1000		Laboratory	Weekly/Fortnightly
Calcium	< 60	5 days	Laboratory	Weekly/Fortnightly
Sulphate	< 500	5 days	Laboratory	Weekly/Fortnightly
Aluminium	< 3	5 days	Laboratory	Weekly/Fortnightly
Ammonia (as N)*	< 7.5	24 hours	Laboratory	Weekly/Fortnightly
Total Nitrogen (as N)	< 15.0	24 hours	Laboratory/ Some On-line	Weekly/Fortnightly
Nitrate (as N)*	< 5.0	24 hours	Laboratory	Weekly/Fortnightly
Silica	< 16.0	5 days	Laboratory	Weekly/Fortnightly
Total Phosphorus (as P)	< 6.0	24 hours	Laboratory/ Some On-line	Weekly/Fortnightly
Chloride	< 250	24 hours	Laboratory	Weekly/Fortnightly
Nitrite (as N)	< 1.0	5 days	Laboratory	Weekly/Fortnightly
Magnesium	< 50		Laboratory	Weekly/Fortnightly
Sodium	< 250	5 days	Laboratory	Weekly/Fortnightly
Potassium	< 40	5 days	Laboratory	Weekly/Fortnightly
Strontium	< 0.25	5 days	Laboratory	Weekly/Fortnightly
Barium	< 0.05	5 days	Laboratory	Quarterly
Iron	< 2.0	48 hours	Laboratory	Quarterly
Manganese	< 0.5	5 days	Laboratory	Quarterly
Fluoride	< 2.0	5 days	Laboratory	Quarterly
Copper	< 0.1	5 days	Laboratory	Quarterly
Zinc	< 0.3	5 days	Laboratory	Quarterly
Organic N (as N)	< 5.0	3 days	Laboratory	Weekly/Fortnightly
pH*	6.5-8.5 pH units	24 hours	Laboratory	Weekly/Fortnightly
Turbidity*	<100 NTU	24 hours	Laboratory	Weekly/Fortnightly
Dissolved Oxygen*	> 2.00	N/A	Laboratory/ On-line	Weekly/Fortnightly

** Indicate test results are required within 24 hours of sample collection.*

3.5 Current Water Quality Monitoring Practices

The assessment of current water quality monitoring practices at Barrier 2 was based on the water quality parameters shown in Table 7. It was evident that the monitoring practices adopted are based on routine collection of grab or composite samples and analysis using conventional laboratory-based methods. This approach is adequate for measuring compliance with existing licence and service agreements. The samples are monitored weekly or fortnightly for raw and treated wastewater depending on licence agreements, whilst biosolids are measured on a fortnightly or monthly basis. The monitoring of organic loads (BOD5, COD and SS), nutrients (total nitrogen and total phosphorus), inorganic such as metals and pH usually occur on a weekly or fortnightly basis depending on the EPA licence agreement and the size of the WWTP.

This is often a labour intensive process that requires samples to be collected from the sampling location, preserved appropriately and transported back to the laboratory for the required analysis within a specified time frame. In addition, the analytical methods require calibration with standard reagents and sample pre-treatment. Using this traditional monitoring approach, the measurements are discrete and only representative of a single point in time. The cost associated with such forms of monitoring also limits the number of samples that can realistically be measured.

For operational monitoring, there have been a limited number of on-line analysers and sensors employed within Barrier 2, especially at CCPs to evaluate and monitor the effectiveness of treatment processes. All WWTPs within the Western Corridor PRW scheme can obtain on-line, real-time hydraulic flow information in addition to in situ DO information through a localised or centralised SCADA system. The DO sensors are usually installed in-situ in the biological reactors within the primary treatment process. Additionally on-line turbidity is used in those WWTPs that employ UV disinfection, whilst chlorine analysers have been installed in most WWTPs for disinfection control in case the water must be discharged to the environment or used as Class B recycled water. In some WWTPs, on-line analysers for pH, nitrogen and phosphorus have been installed, however, at the treatment plants we have inspected, these instruments are currently not in operation due to maintenance problems associated with poor reliability of the instrument and calibration issues.

Although ‘real-time’ measurements (less than 24 hours) of parameters such as temperature, free chlorine, conductivity, TOC, nitrate, ammonia, pH, turbidity and dissolved oxygen are required for CCPs monitoring at Barrier 2 to ensure the treated water quality meets requirements for the AWTP, it was evident that in most cases these ‘real-time’ measurements were obtained by laboratory analysis, apart from temperature and DO.

3.5.1 Use of collected water quality data

In addition to system validation and verification, the data collected is used by the operator to assess the system performance at the critical control points for operational control purposes. The operator uses the water quality data obtained from a CCP to assess whether critical operational limits are being approached at the preliminary, primary and secondary treatment processes, and it also allows the operator to evaluate if the treatment processes are working effectively. In addition, the water quality information collected may be used to implement remediation processes to ensure that the compliance limits and licence agreements are not breached.

With respect to system validation and verification, the data collected can be used to determine if the effluent produced is suitable for use by the AWTP, or if it must be diverted for release into the environment. For the PRW scheme, the treated water data will be used for adhering to the QRWG and the ADWG guidelines, as well as for internal and external reporting purposes.

3.5.2 Performance of current water quality monitoring practice

The preliminary treatment process begins at the boundary of Barriers 1 and 2. The inflow information is measured in real-time as previously shown in Figure 2. No other water quality information is collected for the preliminary treatment process.

Examination of the historical data from the primary treatment zone indicates that it is insufficient for any meaningful assessment. The performance assessment of the current water quality monitoring practice will therefore focus on the water quality data obtained from the secondary treatment zone.

The secondary treatment is the final treatment process at Barrier 2. Because the treated effluent is directly supplied to Barrier 3 for advanced treatment, it needs to comply with the EPA licence agreement and the supply contract with Western Corridor Pty Ltd. The key water quality parameters and their critical control limits identified in the licence agreements are summarised in Table 8. It should be noted that, in order to better safeguard the plant operation under PRW conditions, the frequency of monitoring these parameters has been increased to more than once per week. However, all parameters are still monitored using laboratory-based methods due to the lack of commercial on-line sensors that can obtain accurate measurements in these types of measurement environments.

Table 8 Important Water Quality Indicators for Supply of Treated Effluent to AWTP

Key Parameter	Compliance Limit
Temperature	30°C
Free chlorine residual	0.05 mg/L
Turbidity	100 NTU
Total Phosphorus	6.0 mg/L
Ammonia (as N)	7.5 mg/L
Total Nitrogen (as N)	15.0 mg/L
pH	6.5-8.5
TOC	40 mg/L

3.5.2.1 Physiochemical parameters

Temperature

The licence agreement requires that the temperature of treated effluent at Barrier 2 must never exceed 30oC. Figure 11 shows the recorded temperature of the treated effluent collected from Bundamba WWTP from 2004 to 2008. Analysis revealed that the temperature of the effluent varies seasonally. The recorded temperature reaches its yearly minimum value of 18°C during June/July and achieves its maximum value of 28°C during January/February. None of the recorded data exceeded the maximum compliance level of 30°C. It was also found that a brief temperature drop can occur during a heavy rainfall event. There was no noticeable impact of the different levels of water restrictions on the effluent temperature recorded.

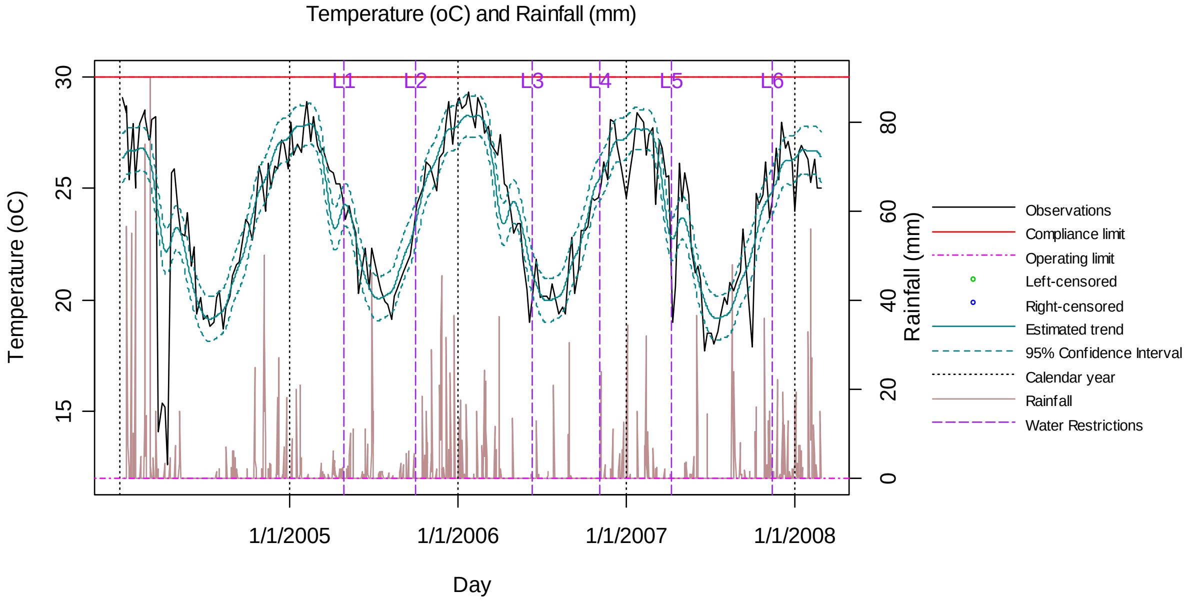

Figure 11 Plot of Effluent Temperature Recorded at Bundamba WWTP

pH

The licence agreement requires that the pH of treated effluent at Barrier 2 should be within the range of 6.5 to 8.5. The observed pH values varied between 6.3 and 8.0, with an overall mean value of pH 7.27 (see Figure 12). The recorded data indicates that only 1.4% of the measured values were outside the operational limits over the period investigated (note that the compliance limits and the operational limits for pH are the same). A clear seasonal/annual pH variation pattern was evident, in which the observed pH reached its maximum and minimum values at each year's summer and winter period, respectively. This seasonal dependence is similar to that observed for the raw influent at Barrier 1 (see discussion in section 2.53).

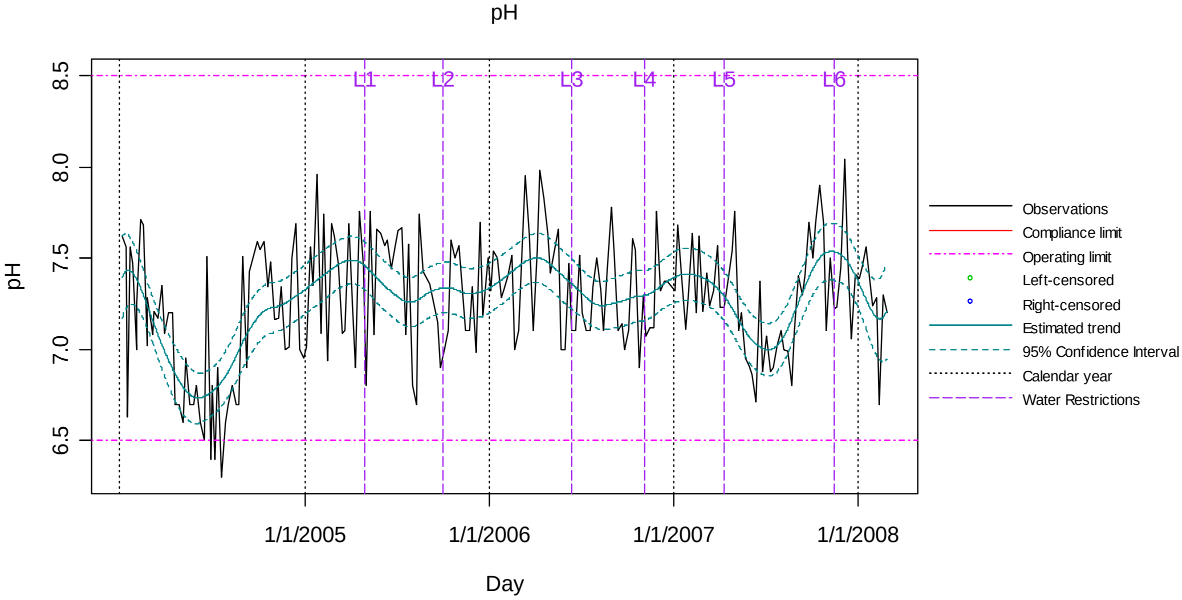

Figure 12 Plot of Effluent pH Recorded at Bundamba WWTP

Conductivity

The upper and lower operational limits for conductivity are 1160 µS/cm and 920 µS/cm respectively. The licence agreement requires the conductivity of treated effluent at Barrier 2 to be below 1600 µS/cm. Figure 13 shows the plot of measured conductivity values against time during 2004 to 2008. A clear seasonal/annual conductivity variation pattern was evident, in which the conductivity values observed during summer are higher than those observed during winter. There was also a clear increasing trend evident that correlated with the introduction of increasingly stringent levels of water restrictions. These patterns are similar to those observed for the raw influent at Barrier 1. Though nearly 57% of measured conductivity values were outside the operational limits, only 0.47% exceeded the compliance limit of 1600 µS/cm.

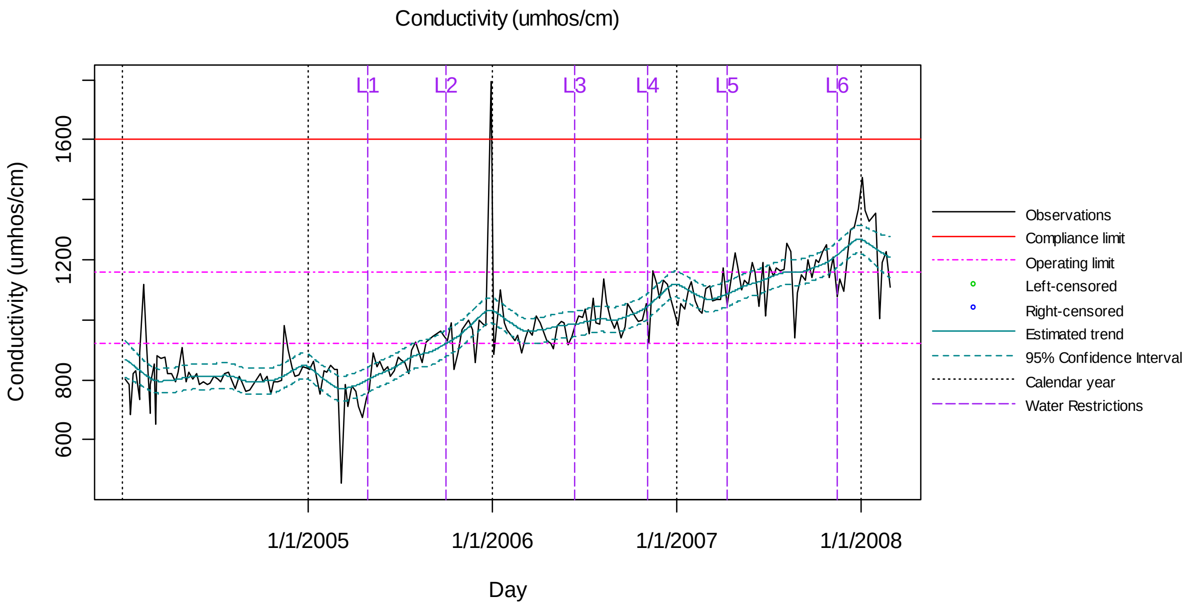

Figure 13 Plot of Effluent Conductivity Recorded at Bundamba WWTP

Turbidity

The upper and lower operational limits for turbidity are 2.9 and 1.0 NTU, respectively. The licence agreement requires a turbidity compliance limit of 100 NTU. Figure 14 shows the plot of measured turbidity values against time during 2004 to 2008. No seasonal pattern could be observed for any of the period investigated. The overall mean value was found to be 1.90 NTU and nearly 15% of recorded data were outside the operational limits. However, no data exceeded the compliance limit of 100 NTU.

Suspended Solids

The operational upper and lower limits for suspended solids are 6.0 and 4.0 mg/L, respectively. The licence agreement requires a suspended solids compliance limit of 30 mg/L. Figure 15 shows the plot of measured suspended solids values against time over the period of 2004 to 2008. The investigation did not find any clear seasonal pattern during this period. The overall mean value was found to be 4.0 mg/L and only 7.4% of recorded data were outside the operational limits, but no data exceeded the compliance limit of 30 mg/L.

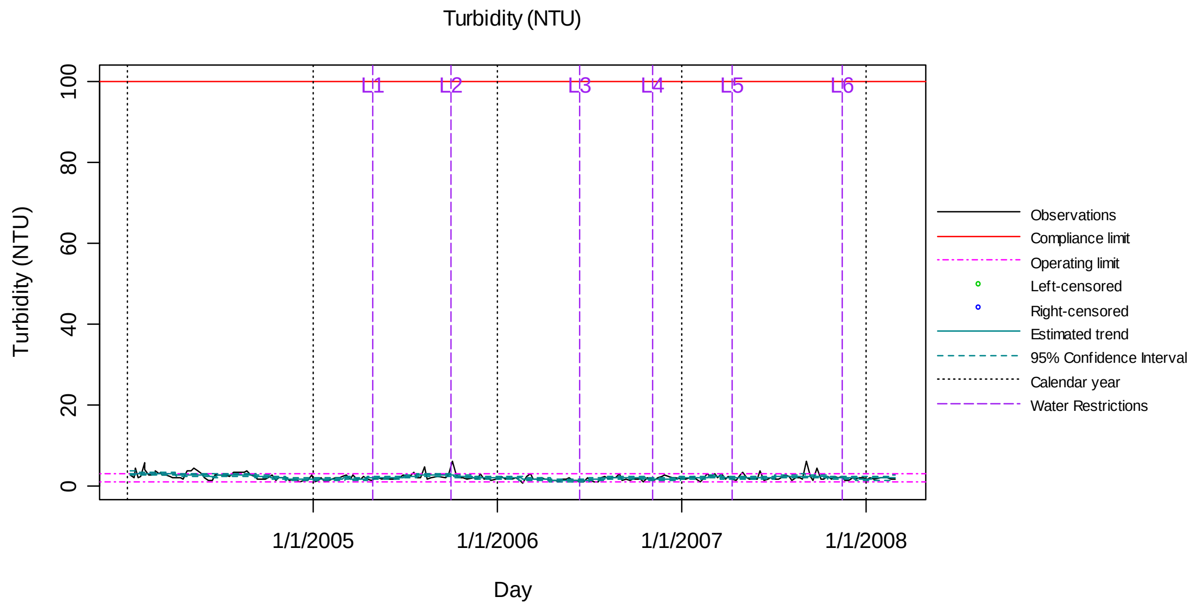

Figure 14 Plot of Effluent Turbidity Recorded at Bundamba WWTP

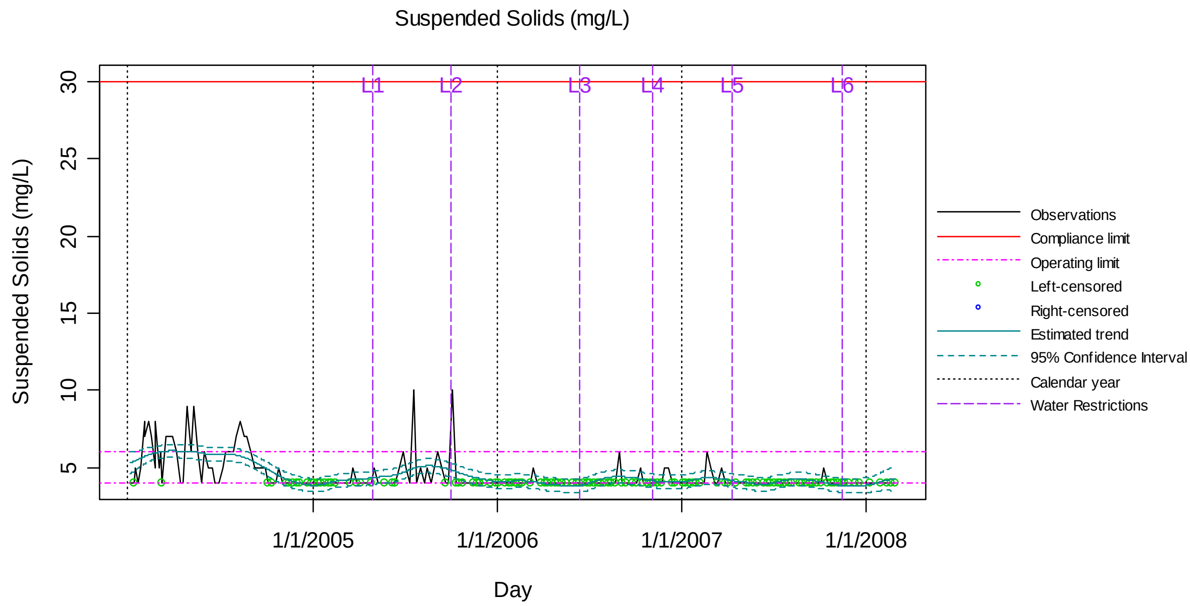

Figure 15 Plot of Effluent Suspended Solids Levels Recorded at Bundamba WWTP

Dissolved oxygen

The operational upper and lower limits for dissolved oxygen levels are 7.6 and 4.3 mg/L, respectively. The licence agreement requires a compliance limit of greater than 2.0 mg/L DO. Figure 16 shows a plot of dissolved oxygen values over the period of 2004 to 2008. Analysis of the data revealed that nearly 27% of the recorded DO levels were outside the operational limits and less than 1% were below the minimum compliance level of 2 mg/L.

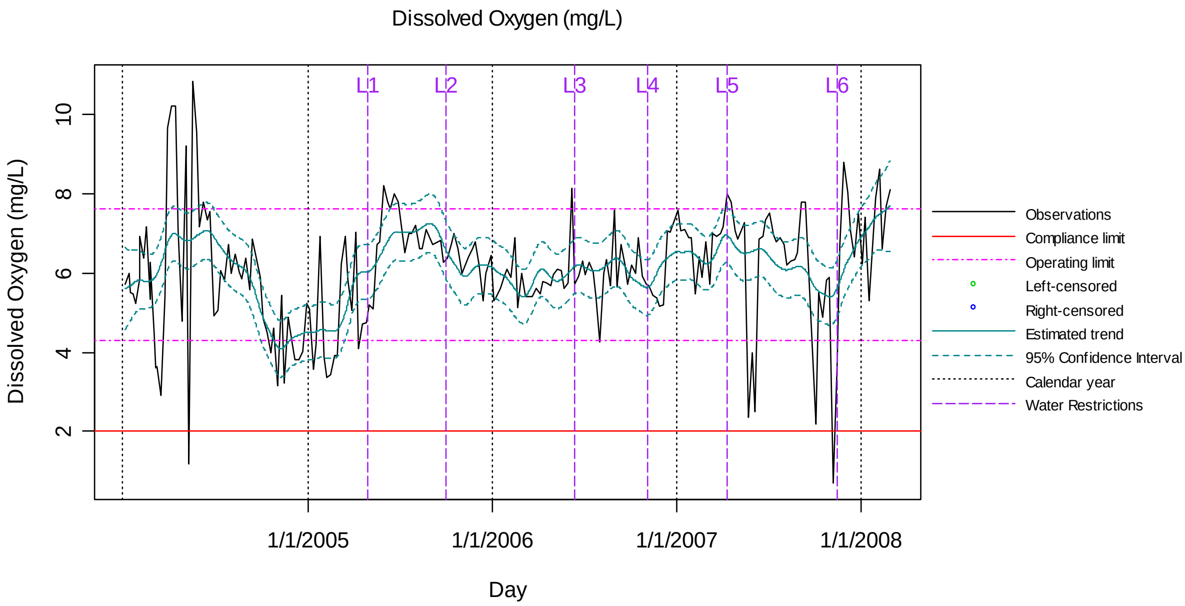

Figure 16 Plot of Effluent DO Levels Recorded at Bundamba WWTP

3.5.2.2 Nutrients

Ammonia

The operational upper and lower limits for ammonia (as N) are 2.6 and 0.1 mg/L, respectively. The licence agreement requires the ammonia of the treated effluent at Barrier 2 to be below 7.5 mg/L. Figure 17 shows the plot of measured ammonia (as N) values against time over the period of 2004 to 2008. Analysis showed that over 27% of the recorded data exceeded the operational limits, but no recorded data exceeded the compliance level of 7.5 mg/L during the period investigated. It should be noted that no conclusions could be drawn concerning the effect of water restrictions or seasonal, temporal and climatic variations on the measured ammonia levels because the available data was insufficient to establish a meaningful baseline. The previous EPA licence only required ammonia to be measured quarterly. However with the recent shift to incorporate the requirements of the PRW scheme, the frequency of ammonia measurement has been increased to >1 per week at the connection point, because the AWTP need to be notified if ammonia levels exceed 7.5 mg/L.

Nitrate

The operational upper and lower limits for nitrate (as N) are 3.6 and 1.8 mg/L, respectively. According to the compliance limit defined by the licence agreement, nitrate in the treated effluent must be below 5.0 mg/L. Figure 18 shows a plot of nitrate measured over the period of 2004 to 2008. Although 28% of the nitrate values exceeded the operational limits, none was found to have exceeded the compliance limit of 5.0 mg/L during the period investigated. The overall mean value of nitrate recorded was 2.3 mg/L, suggesting the treatment processes currently employed in Barrier 2 can effectively remove nitrate to a level that meets the requirements of the AWTP.

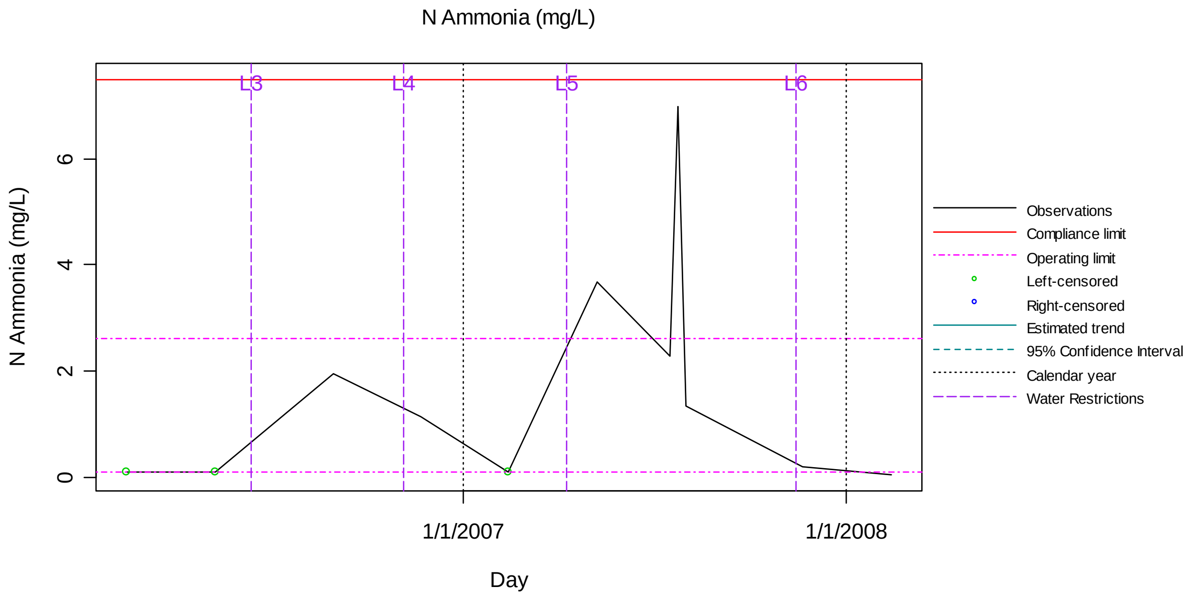

Figure 17 **Plot of Effluent Ammonia (as N) Values Recorded at Bundamba WWTP**

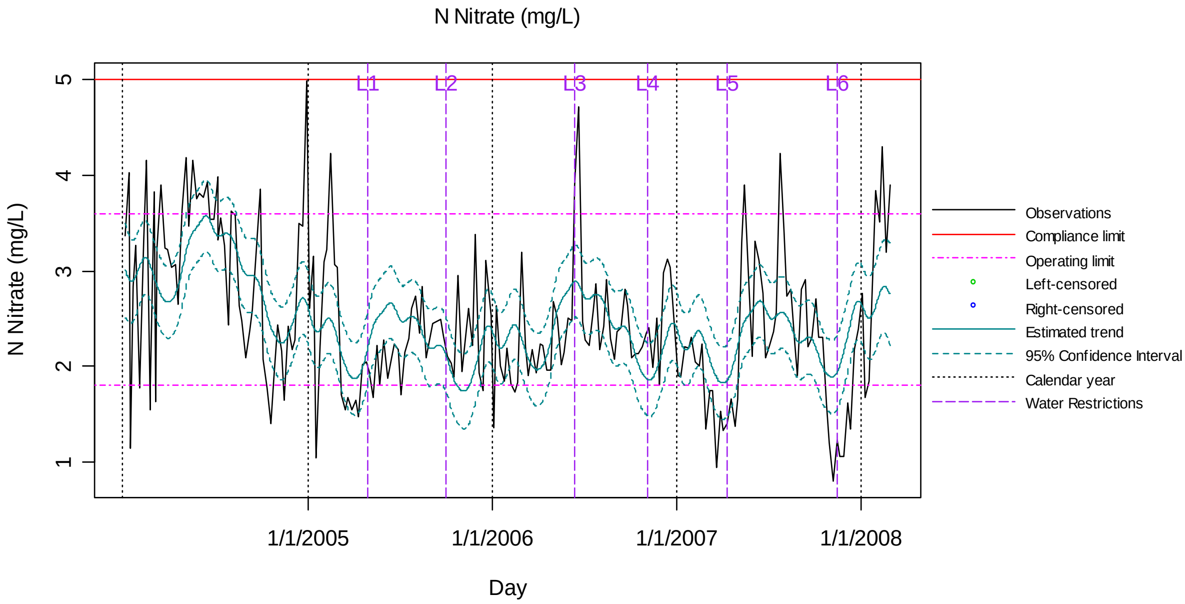

Figure 18 **Plot of Effluent Nitrate (as N) Values Recorded at Bundamba WWTP**

Total nitrogen

The upper and lower operational limits for total nitrogen are 6.6 and 0.3 mg/L, respectively. According to the compliance limit defined by the licence agreement, the total nitrogen in the treated effluent must not exceed 15.0 mg/L. Figure 19 shows a plot of measured total nitrogen values against time over the period of 2004 to 2008. Analysis revealed that only 8% of the recorded data were outside the operational limits and no recorded data exceeded the compliance limit of 15.0 mg/L during the period investigated. The overall mean value of total nitrogen recorded was 4.0 mg/L, suggesting the treatment processes currently employed in Barrier 2 can effectively remove nitrogen to a level that meets the requirements of the AWTP.

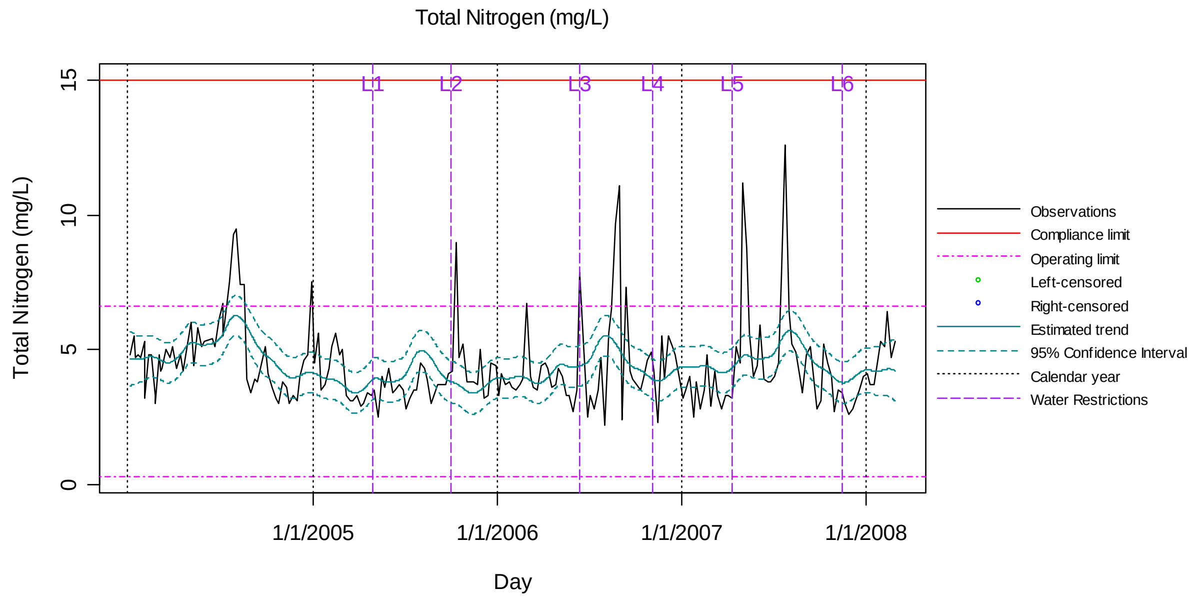

Figure 19 **Plot of Effluent Total Nitrogen Values Recorded at Bundamba WWTP**

Total phosphorus

The upper and lower operational limits for total phosphorus are 3.0 and 0.1 mg/L, respectively. According to the compliance limit defined by the licence agreement, total phosphorus in the treated effluent cannot exceed 6.0 mg/L. Figure 20 shows the plot of total phosphorus values recorded during 2004 to 2008. It was found that 6.5% and 1.4% of the recorded data were outside the operational and compliance limits, respectively during the period investigated. The overall mean value of total phosphorus recorded was 1.9 mg/L, suggesting the treatment processes currently employed in Barrier 2 can effectively remove phosphorus to a level that meets the needs of the AWTP.

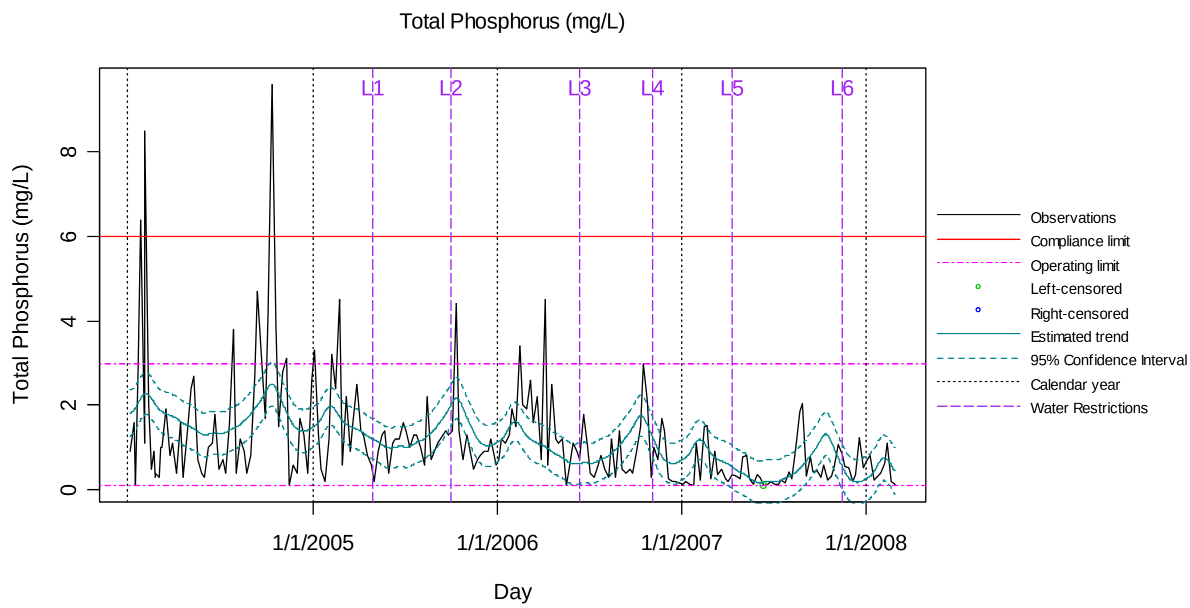

Figure 20 **Plot of Effluent Total Phosphorus Values Recorded at Bundamba WWTP**

3.5.2.3 Organic loading

Biochemical oxygen demand

Currently, the biochemical oxygen demand (BOD) is monitored using the standard 5-day biochemical oxygen demand method (BOD_5) and can be used to indicate the level of biodegradable organic pollutants. The upper and lower operational limits for BOD_5 are 5.0 and 2.0 mg/L of O2 equivalent, respectively. The compliance limit of 30 mg/L for BOD_5 in the treated effluent is defined in the licence agreement. Figure 21 shows a plot of measured BOD_5 values against time over the period of 2004 to 2008. Analysis found that only 1.2% of the data were outside the operational limits and none were outside the compliance limit of 30 mg/L during the period investigated. The overall mean value of the BOD_5 recorded was 2.0 mg/L, indicating that the treatment processes currently employed in Barrier 2 can effectively remove biodegradable organic pollutants to a level that meets the need of the AWTP. It should be noted that there was a very limited effect of seasonal, climatic and water restriction factors on the observed BOD_5 values over the period investigated, demonstrating the effectiveness and reliability of the biological primary treatment process currently in operation.

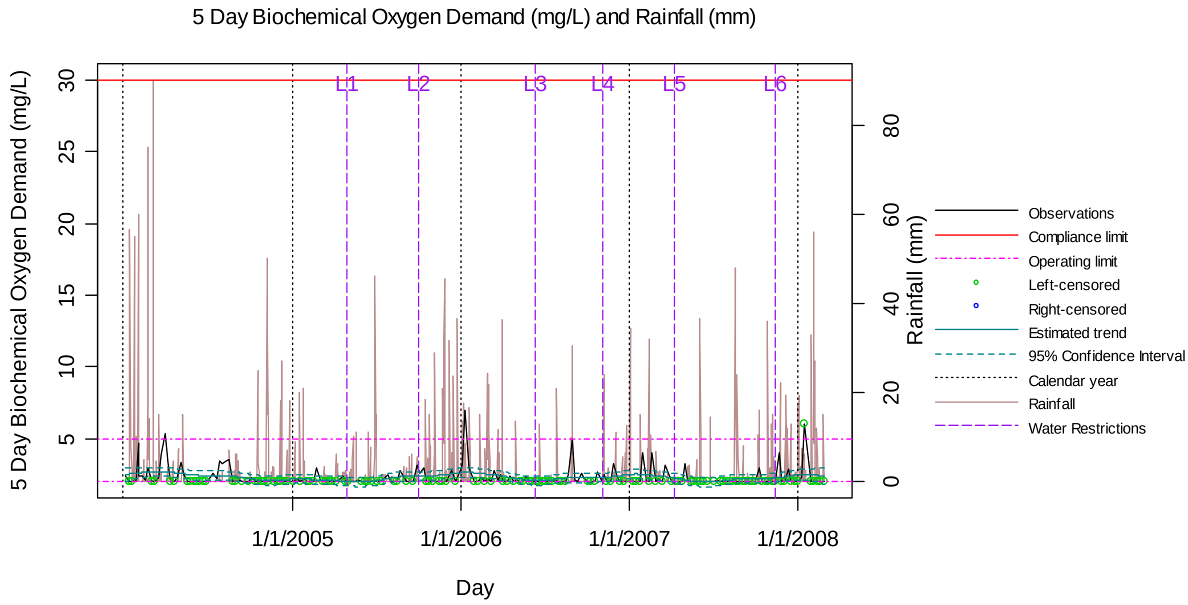

Figure 21 Plot of Effluent BOD_5 Values Recorded at Bundamba

Chemical oxygen demand

Chemical oxygen demand (COD) is currently monitored using the standard dichromate method, even though monitoring the COD of the effluent is not currently required in the licence agreement. However, because BOD_5 requires 5 days to obtain results, COD is often employed to rapidly assess the total organic pollutant levels of the treated effluent. In addition, for the purpose of assisting the PRW operation, COD may be more relevant as it provides information on the presence of organic pollutants that cannot be detected by BOD_5. BOD_5 is highly relevant for treated water to be released into the environment as it measures the level of biodegradable organic pollutants. However, with the introduction of the PRW scheme, the effluent is now destined for potable use, and therefore a more rigorous measure of any organic pollutants remaining in the treated effluent is required.

Figure 22 shows a plot of measured COD values during the period 2004 to 2008. The analysis revealed large fluctuations (with minimum value of 20 mg/L COD and maximum value of 95 mg/L of COD) over the entire period investigated. The overall mean value for COD over the period investigated was 36 mg/L. These are in stark contrast to the recorded BOD_5 data over the same period where the fluctuation was insignificant and the mean value 15 times lower. These observations are consistent with the presence of substantial but fluctuating amounts of non-biodegradable pollutants in the influent that cannot be detected by BOD_5.

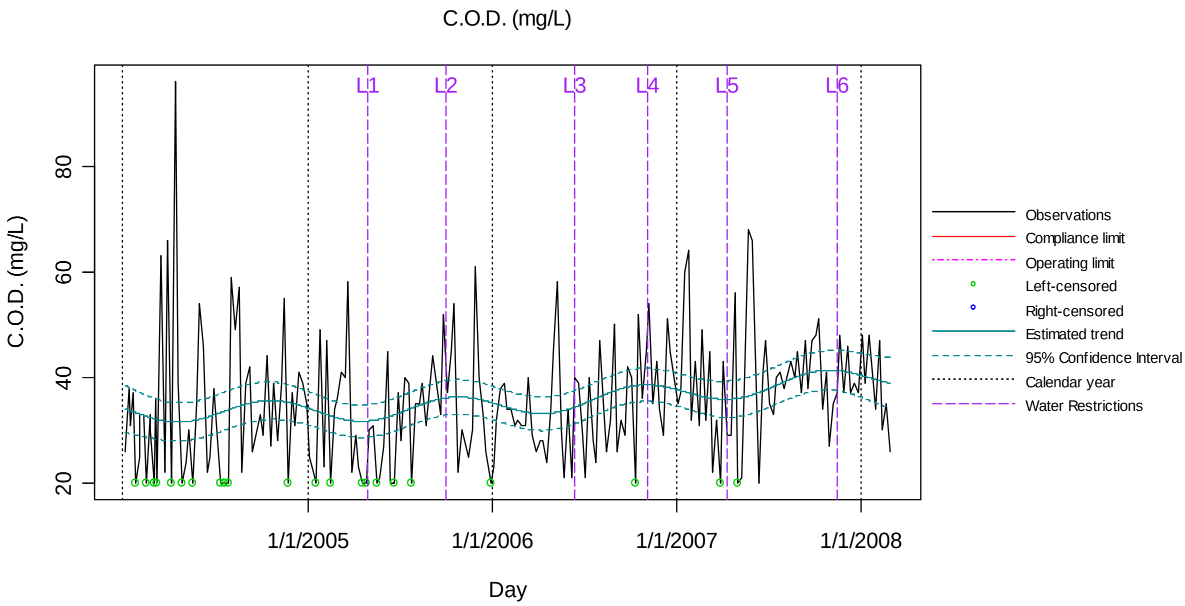

Figure 22 Plot of Effluent COD Values Recorded at Bundamba WWTP

Total organic carbon

Total organic carbon (TOC) is used to estimate the level of organic material in the treated effluent. The operational upper and lower limits for TOC of the treated effluent are 21 and 7.0 mg/L of C, respectively. The compliance limit defined in the licence agreement is 40 mg/L of C. Figure 23 shows a plot of measured TOC values against time during 2004 to 2008. Analysis revealed large fluctuations (with a minimum of 5 mg/L of C and a maximum value of 38 mg/L of C) over the period investigated. The overall mean value for the recorded TOC was 11.5 mg/L of C. As was observed for COD, these results are again in strong contrast to the recorded BOD_5 data over the same period. The observed fluctuations in TOC values confirm the observations made concerning COD, implying the presence of large but varying amounts of non-biodegradable organic pollutants in the treated effluent.

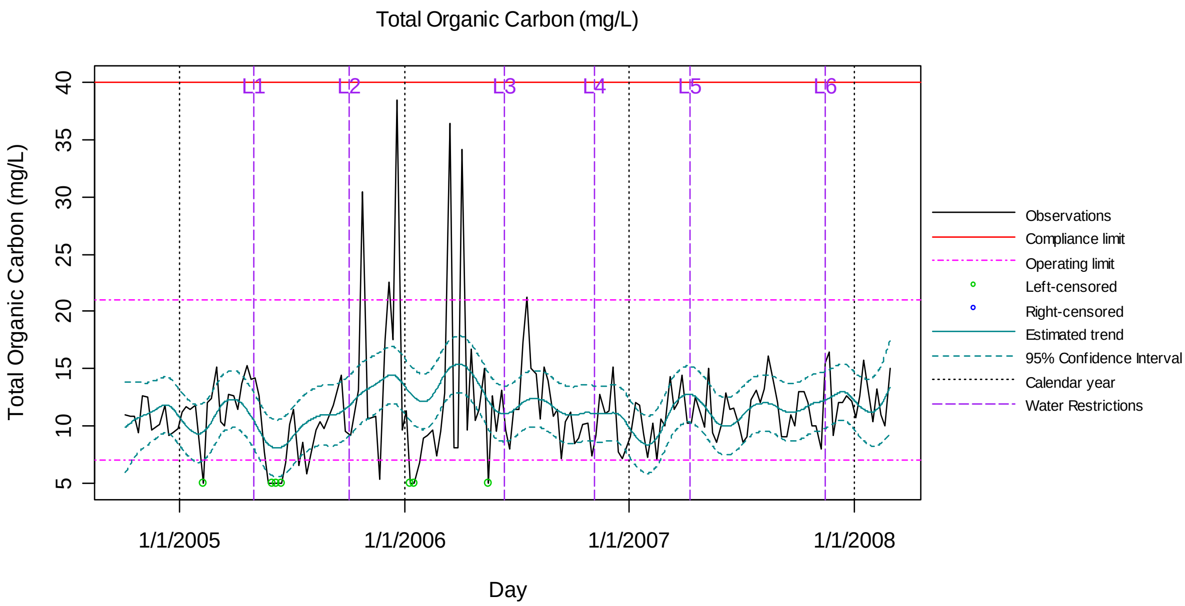

Figure 23 Plot of Effluent TOC Values Recorded at Bundamba WWTP

3.5.2.4 Chlorine

Free chlorine

Free chlorine in the treated effluent can cause damage to the membrane systems used in the AWTP at Barriers 3 and 4. The licence agreement therefore specifies that the free chlorine level in the treated effluent supplied to Barrier 3 must be less than 0.05mg/L at all times. Currently, compliance monitoring of free chlorine is performed by analysing grab samples using a laboratory-based method. However, the analytical method currently employed is incapable of detecting free chlorine concentrations below 0.1 mg/L.

Figure 24 shows the plot of the recorded free chlorine values against time over the period of 2004 to 2008. It should be noted that the compliance level used for analysis was based on the new licence agreement specifications (0.05 mg/L) prior to disinfection, but the historical data presented was recorded after disinfection according to EPA licence agreements at the time (upper limit: 0.7 mg/L and lower limit: 0.2 mg/L).

Analysis of this historical data revealed large fluctuations (with a minimum value of 0.1 mg/L and maximum value of 2.9 mg/L) over the entire period investigated. The overall mean value for the recorded free chlorine over the period investigated was 0.29 mg/L. The analysis also revealed that over 30% of historical data recorded was left censored, indicating insufficient sensitivity of the analytical method.

Total chlorine

Total chlorine is currently monitored by analysis of grab samples using a laboratory-based method. Monitoring total chlorine in the effluent is not currently required by the licence agreement. Nevertheless, the total chlorine values measured can be used to reflect the levels of free chlorine as the two parameters are closely correlated for a given type of sample. Figure 25 shows the plot of total chlorine values against time over the period of 2004 to 2008. The analysis also revealed large fluctuations (with a minimum of 0.3 mg/L and maximum of 6.7 mg/L) over the period investigated. The overall mean value for the recorded total chlorine over the period investigated was 1.1 mg/L.

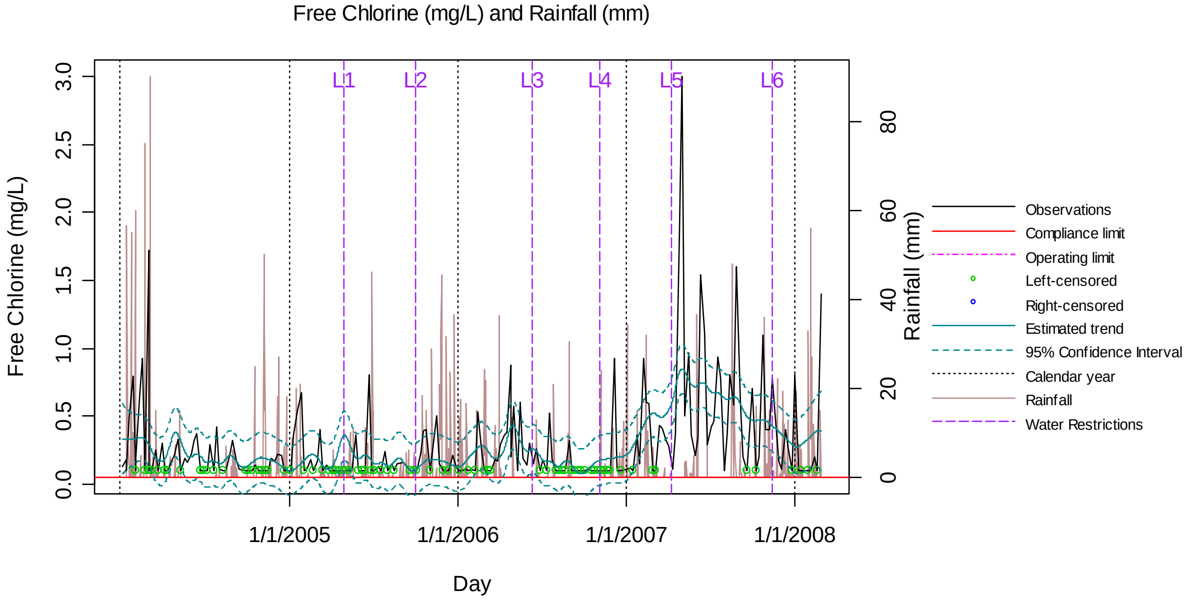

Figure 24 Plot of Effluent Free Chlorine Levels Recorded at Bundamba WWTP

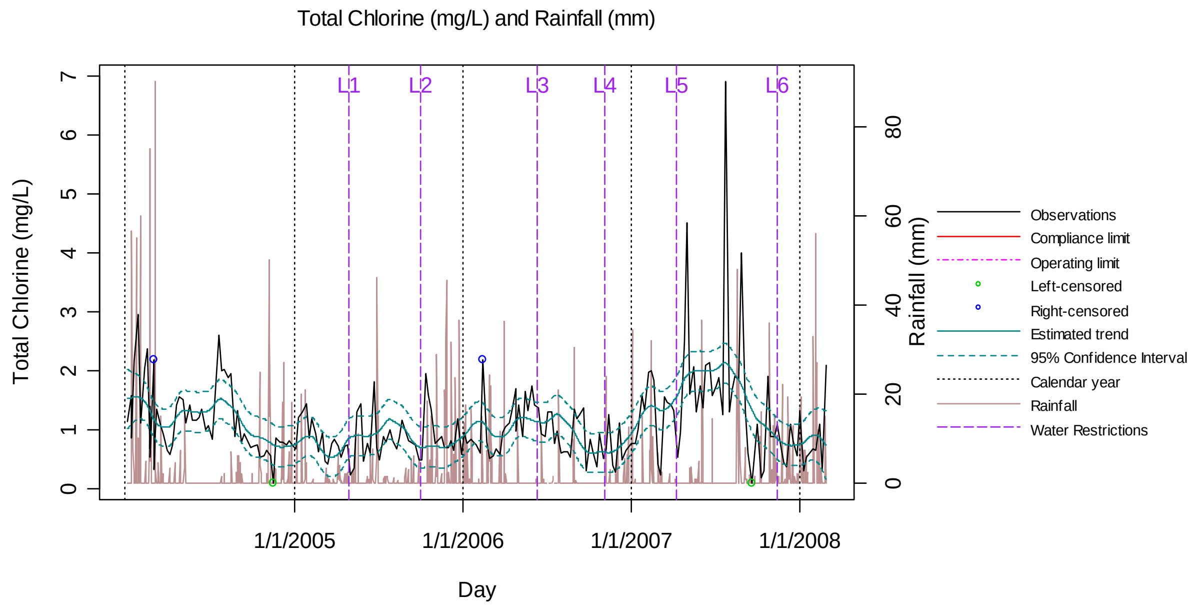

Figure 25 A Plot of Effluent Total Chlorine Levels Recorded at Bundamba WWTP

3.5.2.5 Other parameters

Anions

The licence agreement requires monitoring of a number of anionic species such as chloride, fluoride, sulphate and alkalinity. Figures 26 to 29 show time series plots of the recorded historical data. The findings of the data analysis are summarised in Table 9.

Table 9 Analysis of Historical Data Obtained for Anionic Species

Specifications	Chloride	Fluoride	Sulphate	Alkalinity
Upper/Lower limits	240/128 mg/L	0.5/0.4 mg/L	200/94 mg/L	**N/A**
Mean Value	157.4 mg/L	0.47 mg/L	108 mg/L	**171 mg/L**
Compliance limit	250 mg/L	2.0 mg/L	500 mg/L	**N/A**
Comments	**17% and 4.2% of recorded data were outside the operational and compliance limits, respectively. A clear increasing trend was observed when level 3 water restrictions were introduced.**	**69% and 0% of recorded data were outside the operational and compliance limits, respectively.** **There should be 226 data points recorded during the period investigated but only 13 were recorded.**	**40% and 0% of recorded data were outside the operational and compliance limits, respectively. A clear increasing trend was observed when level 1 water restrictions were introduced.**	**A clear increasing trend was observed when level 3 water restrictions were introduced.**

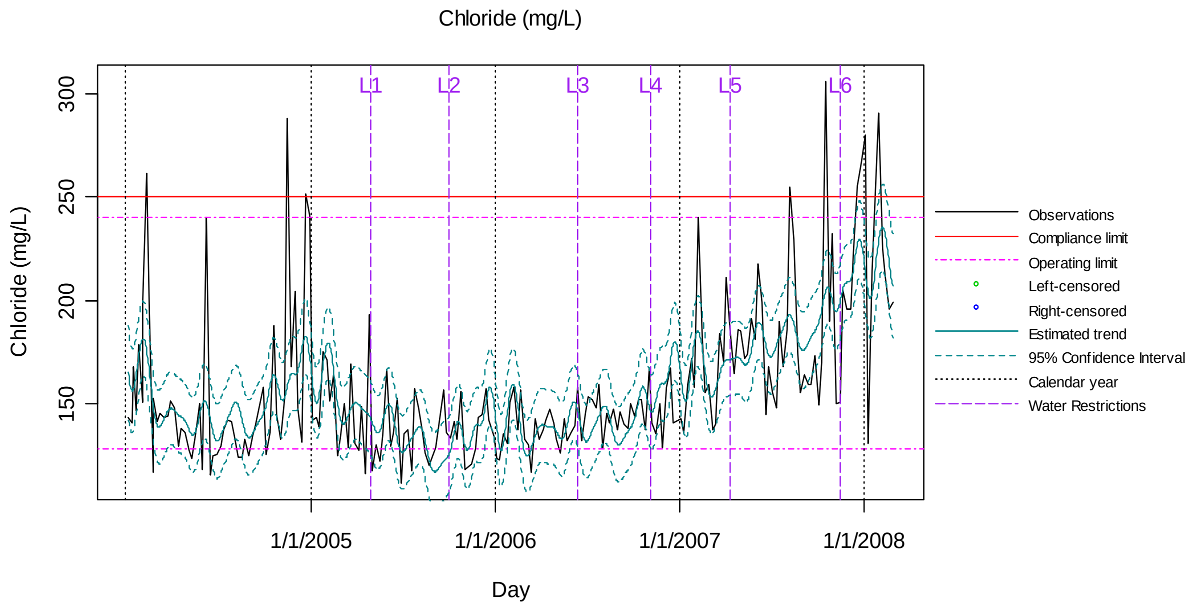

Figure 26 **Plot of Effluent Chloride Levels Recorded at Bundamba WWTP**

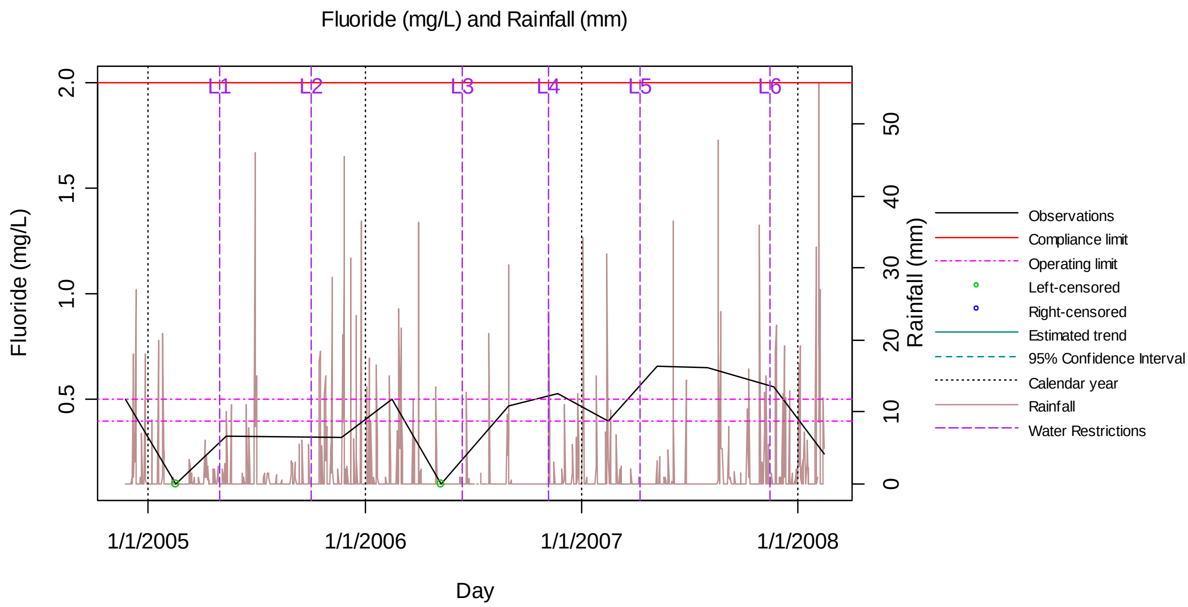

Figure 27 **Plot of Effluent Fluoride Levels Recorded at Bundamba WWTP**

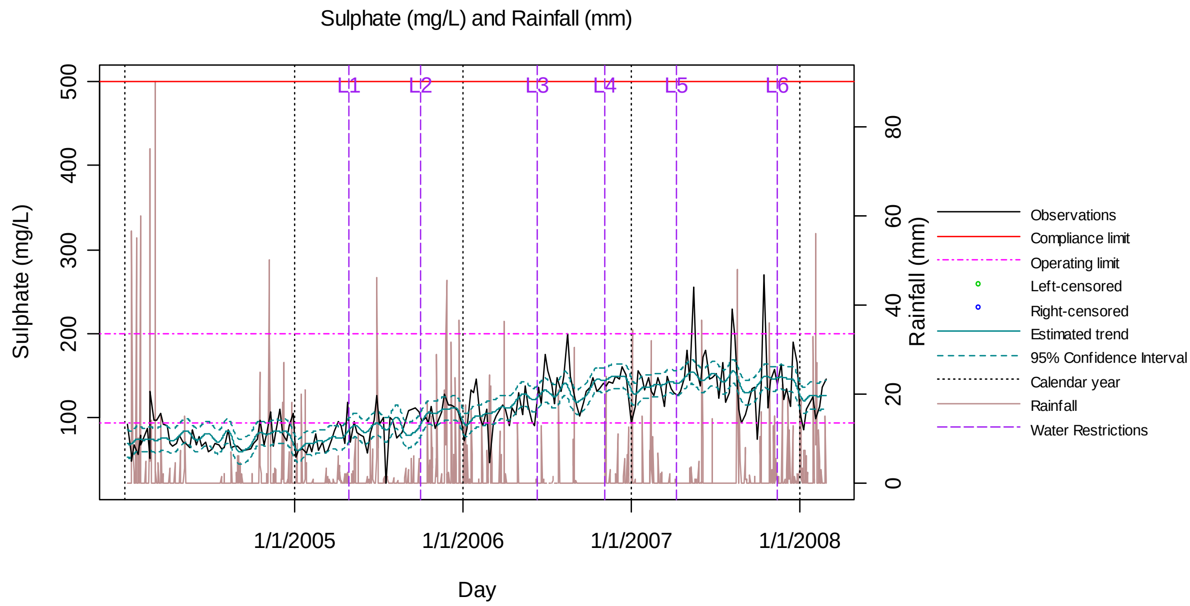

Figure 28 Plot of Effluent Sulphate Levels Recorded at Bundamba WWTP

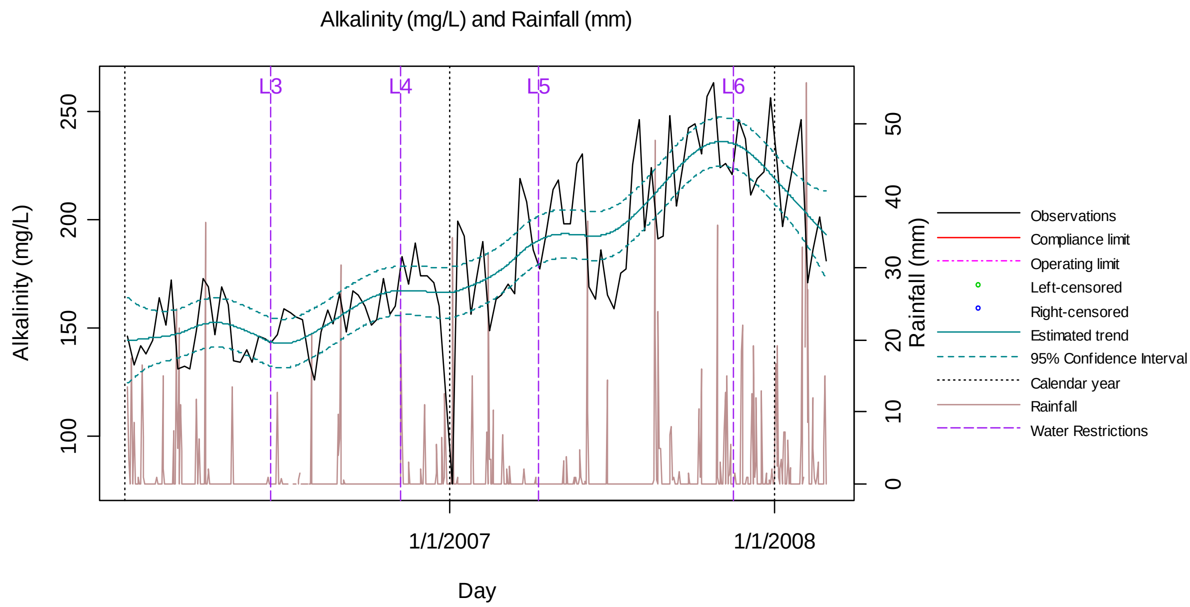

Figure 29 Plot of Effluent Alkalinity Levels Recorded at Bundamba WWTP

Alkali and alkaline earth metal ions

The licence agreement requires monitoring a number of alkali and alkaline earth metal ions such as sodium, potassium, calcium and magnesium. Figures 30 to 33 show time series plots of the recorded historical data. The findings of the data analysis are summarised in Table 10.

Table 10 Analysis of Historical Data Obtained for Alkali and Alkaline Earth Metal Ions

Specifications	Sodium	Potassium	Calcium	Magnesium
Upper/Lower limits	186/140 mg/L	22/16 mg/L	21/21 mg/L	**17/8.0 mg/L**
Mean Value	137 mg/L	18 mg/L	33 mg/L	**15 mg/L**
Compliance limit	250 mg/L	40 mg/L	30 mg/L	**50 mg/L**
Comments	**62.56% and 1% of recorded data were outside the operational and compliance limits, respectively. A clear increasing trend was observed when level 1 water restrictions were introduced.**	**44% and 0.5% of recorded data were outside the operational and compliance limits, respectively. An increasing trend was observed when level 2 water restrictions were introduced.**	**100% and 64% of recorded data were outside the operational and compliance limits, respectively. An increasing trend was observed when level 4 water restrictions were introduced.**	**16% and 0% of recorded data were outside the operational and compliance limits, respectively. An increasing trend was observed when level 4 water restrictions were introduced.**

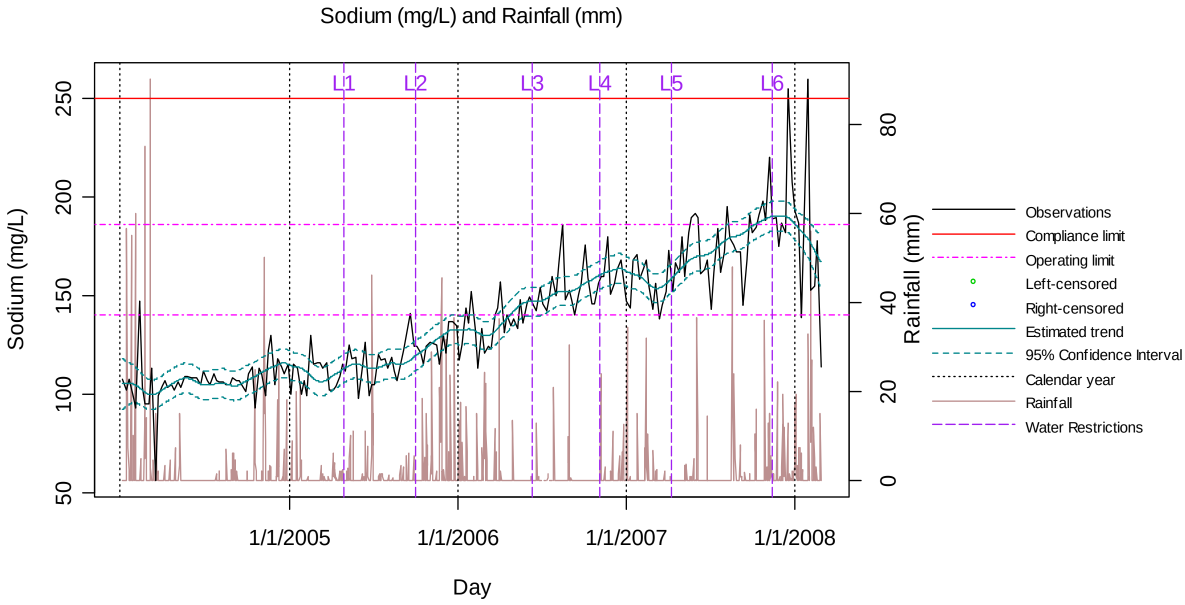

Figure 30 Plot of Effluent Sodium Levels Recorded at Bundamba WWTP

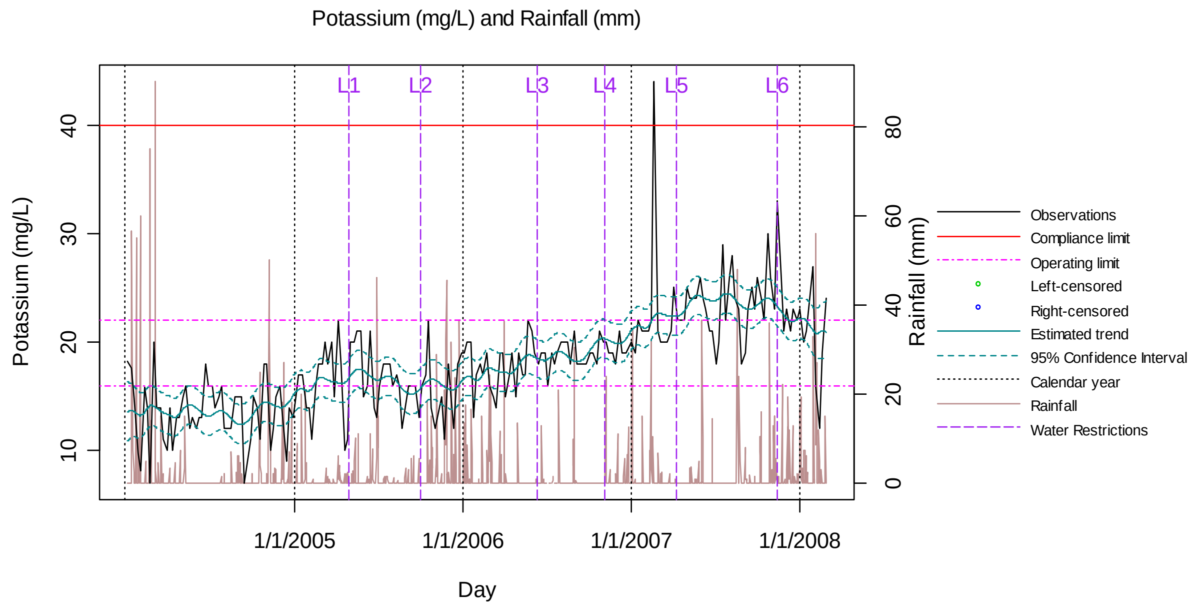

Figure 31 Plot of Effluent Potassium Levels Recorded at Bundamba WWTP

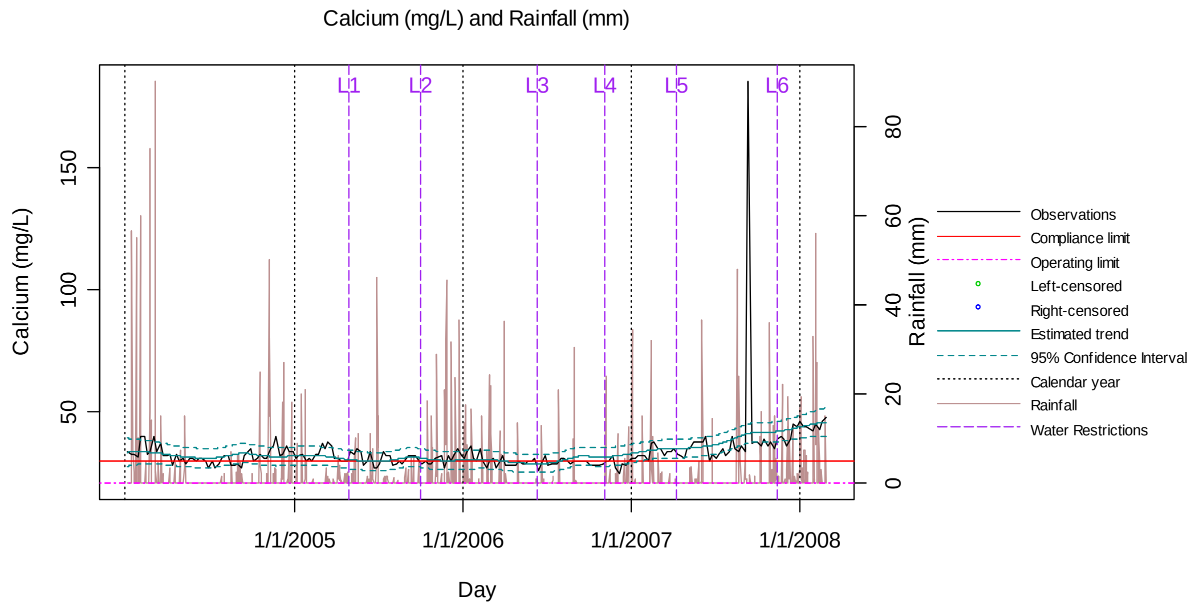

Figure 32 Plot of Effluent Calcium Levels Recorded at Bundamba WWTP

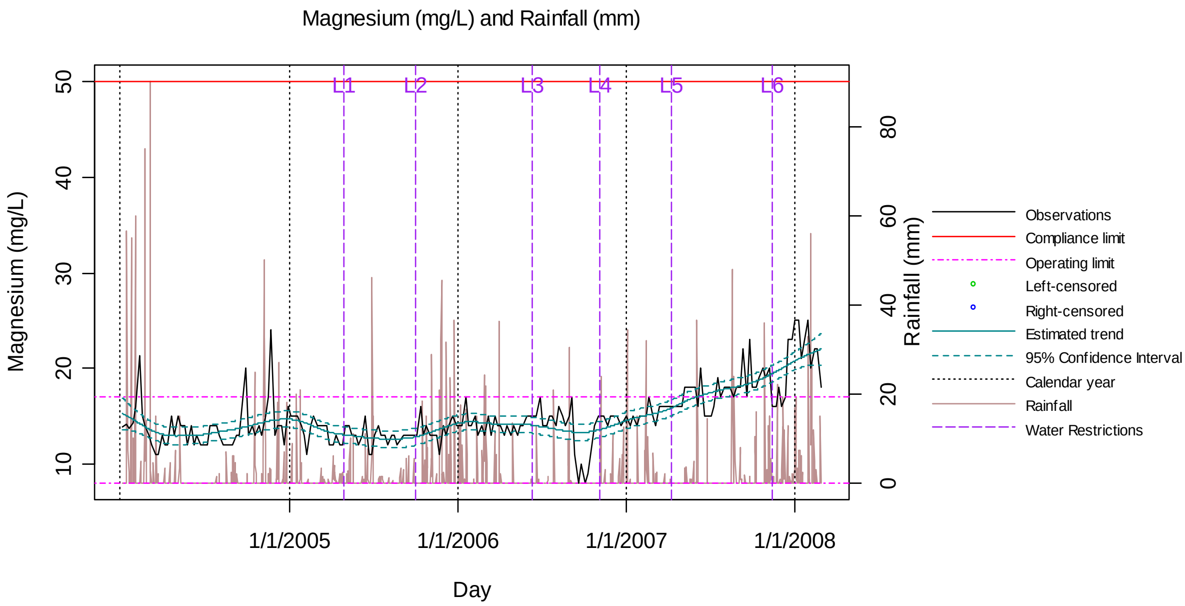

Figure 33 Plot of Effluent Magnesium Levels Recorded at Bundamba WWTP

Heavy metal ions

The licence agreement requires monitoring a number of heavy metal ions such as lead, copper, zinc and cadmium. Figures 34 to 37 show time series plots of the recorded historical data. The findings of the data analysis are summarised in Table 11.

Table 11 Analysis of Historical Data Obtained for Heavy Metal Ions

Specifications	Lead	Copper	Zinc	Cadmium
Upper/Lower limits	N/A	0.02/0.01 mg/L	0.08/0.06 mg/L	**N/A**
Mean Value	0.01 mg/L	0.012 mg/L	0.084 mg/L	**0.0032 mg/L**
Compliance limit	N/A	0.10 mg/L	0.3 mg/L	**N/A**
Comments	**There should be 226 data points recorded during the period investigated but only 15 were recorded. 100% of historical data recorded was left censored, indicating insufficient sensitivity of the analytical method used.**	**27% and 0% of recorded data were outside the operational and compliance limits, respectively. There should be 226 data points recorded during the period investigated but only 15 were recorded.**	**64% and 0% of recorded data were outside the operational and compliance limits, respectively. There should be 226 data points recorded during the period investigated but only 14 were recorded.**	**There should be 226 data points recorded during the period investigated but only 15 were recorded. 100% of historical data recorded was left censored, indicating insufficient sensitivity of the analytical method used.**

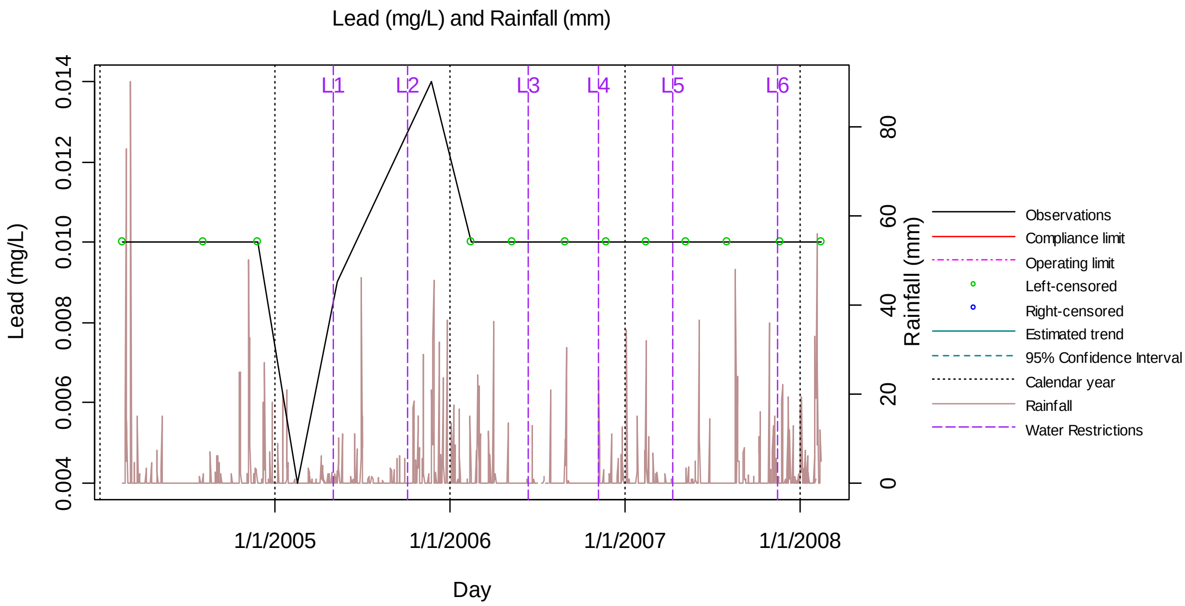

Figure 34 Plot of Effluent Lead Levels Recorded at Bundamba WWTP

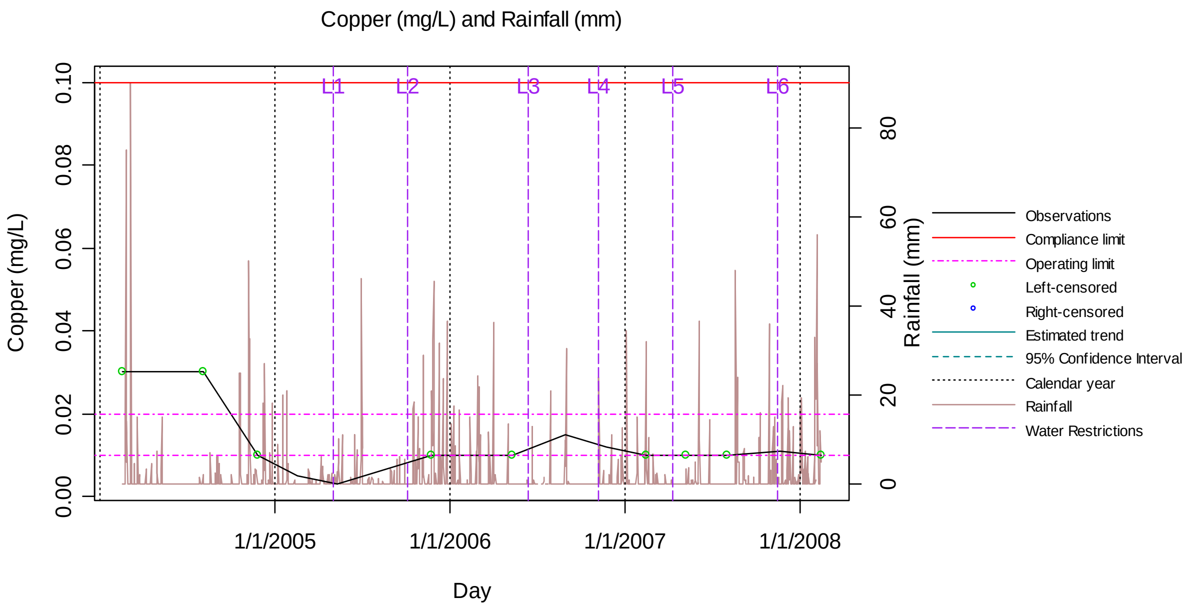

Figure 35 Plot of Effluent Copper Levels Recorded at Bundamba WWTP

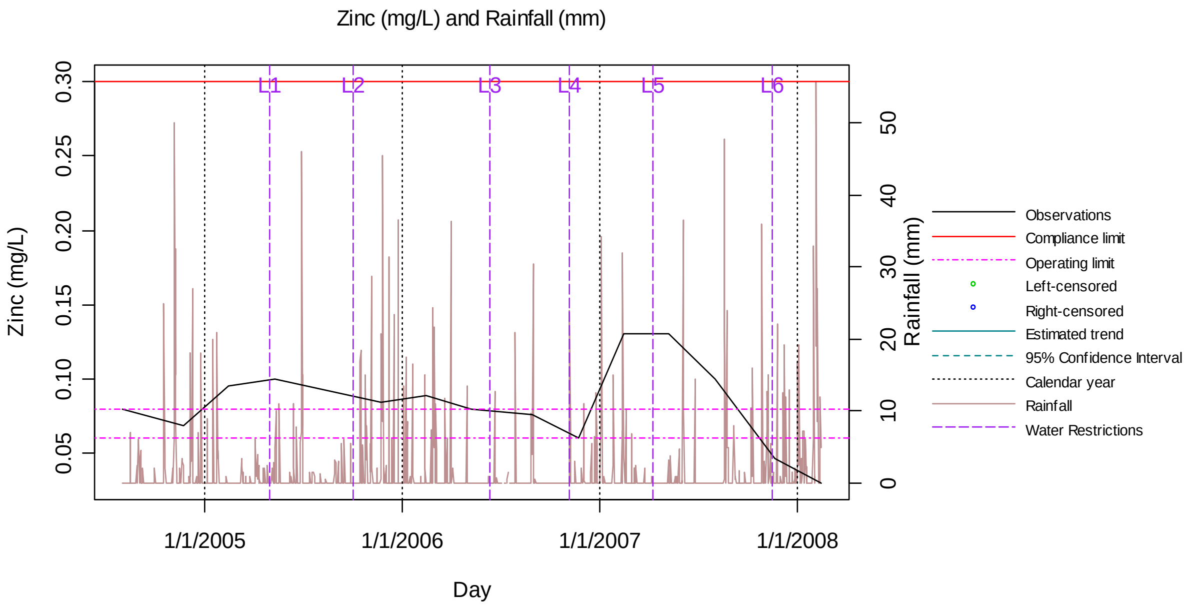

Figure 36 Plot of Effluent Zinc Levels Recorded at Bundamba WWTP

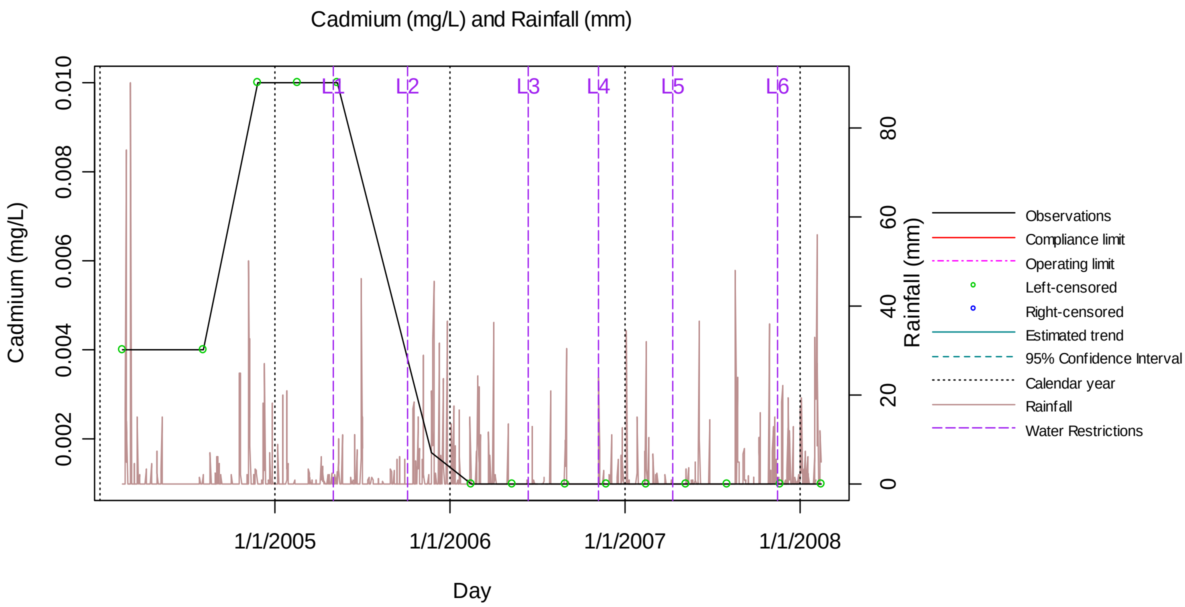

Figure 37 Plot of Effluent Cadmium Levels Recorded at Bundamba WWTP

Other metal ions

The licence agreement requires monitoring a number of other metal ions such as aluminium, barium, iron and manganese. Figures 38 to 41 show time series plots of the recorded historical data. The findings of the data analysis are summarised in Table 12.

Table 12 Analysis of Historical Data Obtained for Other Metal Ions

Specifications	Aluminium	Barium	Iron	Manganese
Upper/Lower limits	2.8/0.07 mg/L	0.01/0 mg/L	0.13/0.026 mg/L	**0.068/0.054 mg/L**
Mean Value	33.19 mg/L	0.009 mg/L	0.08 mg/L	**0.046 mg/L**
Compliance limit	3.0 mg/L	0.05 mg/L	2.0 mg/L	**0.5 mg/L**
Comments	**79% and 46% of recorded data were outside the operational and compliance limits, respectively. There should be 226 data points recorded during the period investigated but only 24 were recorded.**	**27% and 0% of recorded data were outside the operational and compliance limits, respectively. There should be 226 data points recorded during the period investigated but only 15 were recorded.**	**40% and 0% of recorded data were outside the operational and compliance limits, respectively. There should be 226 data points recorded during the period investigated but only 15 were recorded.**	**87% and 0% of recorded data were outside the operational and compliance limits, respectively. There should be 226 data points recorded during the period investigated but only 15 were recorded.**

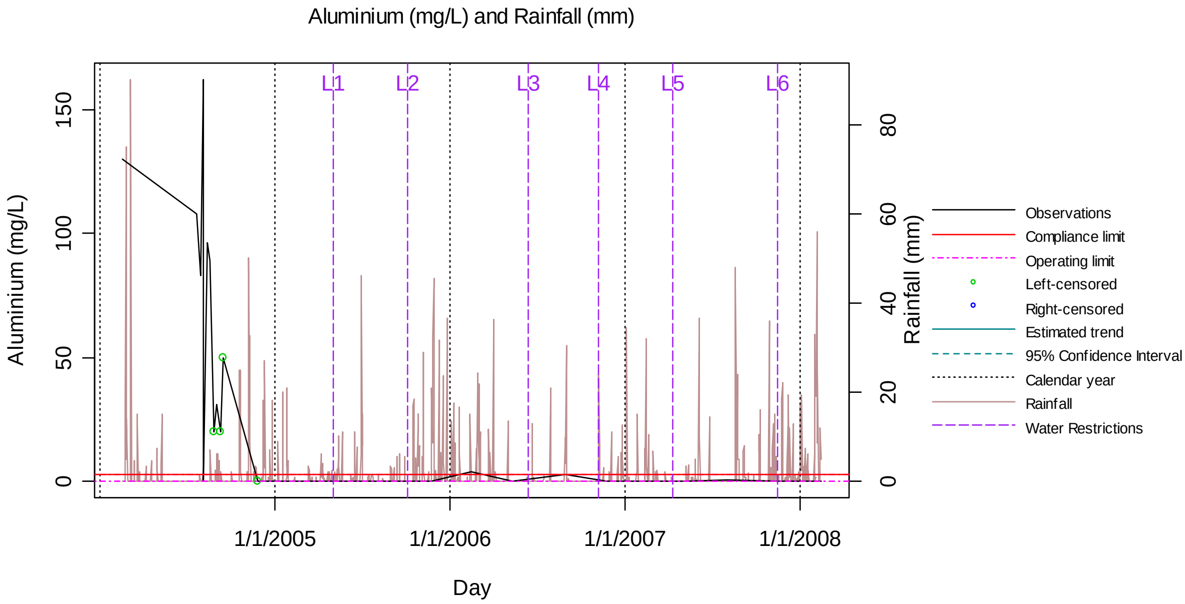

Figure 38 Plot of Effluent Aluminium Levels Recorded at Bundamba WWTP

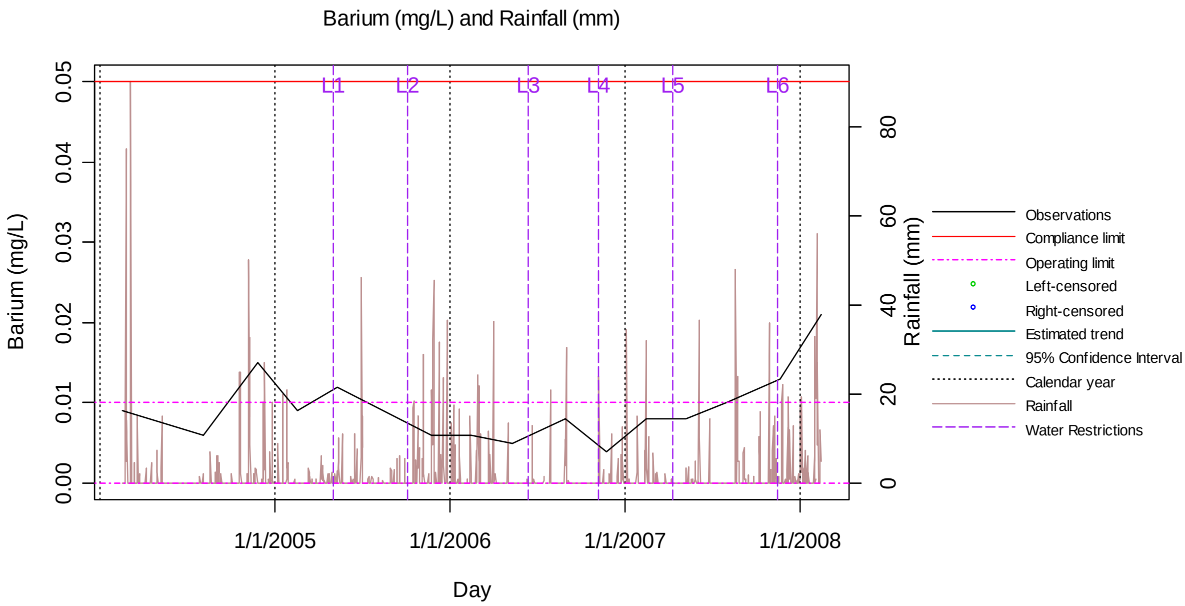

Figure 39 Plot of Effluent Barium Levels Recorded at Bundamba WWTP

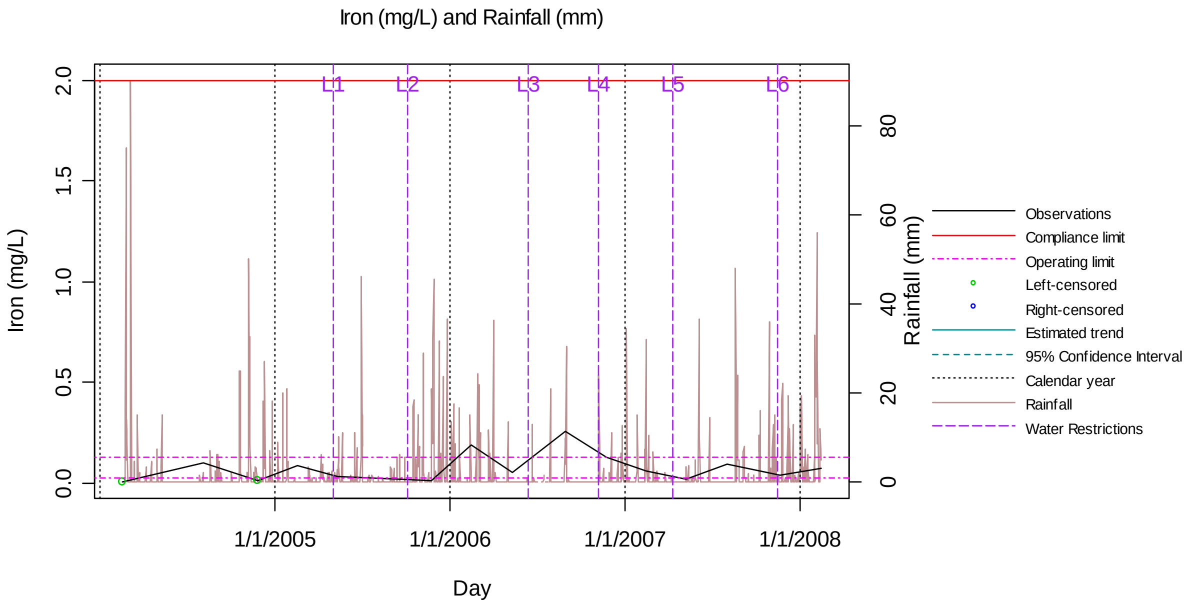

Figure 40 Plot of Effluent Iron Levels Recorded at Bundamba WWTP

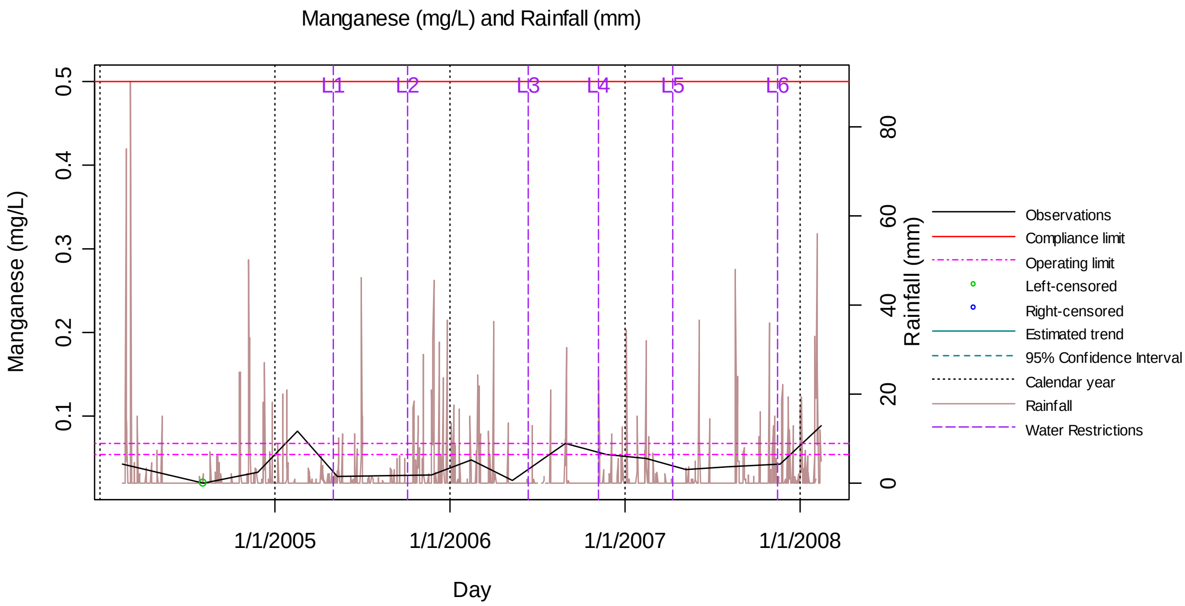

Figure 41 Plot of Effluent Manganese Levels Recorded at Bundamba WWTP

3.6 Summary of Findings and Recommended Sensor Developments for Barrier 2

This section summarises the findings made during Stage 1 investigations and makes recommendations relevant to the project.

The investigation revealed:

- The new policy documents in place have defined a range of new legislative measures to address potential risks that may be introduced by closed water loop operation.
- The current water quality monitoring practice employed was designed to serve the environmental discharge requirements existing before PRW scheme was proposed.
- The water quality monitoring regime currently in place is mainly based on traditional laboratory-based analytical methods to analyse grab or composite samples on a weekly or fortnightly basis.
- The water quality information currently collected is useful for environmental compliance assessment and long-term system performance evaluation. However, its effectiveness for closed water loop operation can only be validated after the PRW scheme is in operation.
- There is no evidence to suggest the water quality monitoring technologies in use are capable of providing real-time water quality information for source control purposes.

Under the PRW scheme, the effluent produced at Barrier 2 needs to meet the water quality specifications defined by the licence agreement for supply to Barrier 3 (AWTP). An improved water quality monitoring practice would certainly add value to better safeguard the plant operation. For this purpose, the following sensing technology developments are recommended:

- Development of an event detection system that is capable of real-time identification of any significant source water quality changes at Barrier 2.
  - The system should be developed using commercially available sensors.
  - The system should be simple, robust, reliable, low-cost and easy to operate.
  - The system should consume no reagents, generate no waste materials and require no on-going calibration.

- The system should also incur low operational costs and require little or no maintenance.
- The system should incorporate an auto-sampling device such that a detected event will automatically trigger sample collection for further investigations.
- The event detection system should be installed at the interface of the primary/secondary treatment processes and at the exit of the secondary treatment process.

* Development of an early warning system based on the event detection system which is capable of providing a real-time alarm that would enable the operator to contain the questionable source water before it enters the AWTP. The early warning system developed should be incorporated into the early warning system network at Barrier 1. Such a collective early warning system would enable more effective coordination among the barriers, especially between the up and down stream barriers. A fully developed system should be able to provide:
  - Precise time, duration and location of an event;
  - Nature of the detected event (i.e. quality and quantity);
  - Precise retention time of the questionable water by each treatment process;
  - The impact of the questionable water on the performance of the WWTP; and
  - Real-time alarm function to inform the operators/grid manager with adequate information to facilitate a decision making.
* Development of suitable on-line sensing systems capable of real-time analysis of targeted water quality parameters such as COD (which represents organic pollutant level), nutrients (i.e. organic nitrogen/ammonia and phosphorus) and free chlorine. Such systems (when they operate in parallel with the early warning system) can provide additional information that can help to characterise and identify a detected event.

4. BARRIERS 3 TO 5: ADVANCED TREATMENT PLANTS

4.1 Overview of Barriers 3 to 5

Barriers 3 to 5 cover the AWTPs of the Western Corridor Purified Recycled Water Scheme that are operated by Veolia Water Australia and governed by the Western Corridor Recycled Water Management Plan (WCRWMP). The barriers are designed to convert the effluent supplied from Barrier 2 into water of a quality that is suitable for direct industrial use and for discharge to natural environment/water catchment. The AWTPs currently in place employ a three-stage treatment strategy that consists of a primary microfiltration/ultrafiltration membrane treatment process (Barrier 3), a secondary reverse osmosis membrane treatment process (Barrier 4) and a final oxidative UV disinfection treatment process (Barrier 5).

Barrier 3 is the primary treatment step of the AWTP and is designed to remove viruses, bacteria and protozoa, as well as potential RO membrane foulants and particles. The water produced from Barrier 3 must meet the water quality specifications required by Barrier 4. The Western Corridor Purified Recycled Water Scheme currently has three AWTPs that receive treated effluent of a specified quality from six WWTPs involved in scheme. Table 13 provides a brief summary of the AWTPs involved, their treatment capacities and the WWTPs involved to supply the feedwater.

Table 13 Brief Overview of AWTPs in WCPRW Scheme

AWTP	Feed Water	Capacity of AWTP
Bundamba	Bundamba WWTP Goodna WWTP Wacol WWTP Oxley WWTP	Up to 66 ML/ day
Luggage Point	Luggage Point WWTP	66 ML/day
Gibson Island	Gibson Island WWTP	Up to 100 ML/day

Barrier 4 is the second treatment step of the AWTP and is designed to utilise the reverse osmosis membrane process to remove turbidity, inorganics, organics, pathogens and bacteria from the feedwater supplied by Barrier 3. The water produced from Barrier 4 must meet the water quality specifications required by Barrier 5.

The advanced oxidation process performed at Barrier 5 is the final treatment step of the AWTP. It is designed to destroy any potential remaining pathogenic organisms (i.e. viruses, bacteria and protozoa) in the water supplied from Barrier 4 by the use of an advanced UV disinfection technology. The water produced from Barrier 5 must meet the water quality specifications defined by the licence agreement before distribution to the end users.

The following sections summarise the water quality requirements, water quality monitoring schedules and the intended use of the collected water quality data for Barriers 3, 4 and 5. The information presented in these sections is based on the related policy documents (i.e. RWMP, ADWG, ARWG and QWRG) available to the project at the time of writing. No attempt was made to quantitatively analyse the information presented nor have recommendations been made concerning sensing technology development. A meaningful assessment will only be possible in future after the PRW is in operation and sufficient water quality data becomes available.

4.2 Water Quality Requirements and Monitoring Schedules

4.2.1 Water quality requirements and monitoring schedules for Barrier 3

The water quality specifications for Barrier 3 are defined by a number of related guidelines, licence agreements and management plans. Under the new Water Supply (Safety and Reliability) Act 2008, all stakeholders within the WCRW scheme must submit Recycled Water Management Plans for approval to ensure that they address and manage the risks associated with the related barriers. This management plan must encompass risks associated with the supply of indirect potable reuse water in accordance with requirements defined in ADWG and ARWG. The water quality specifications for Barrier 3 were based on a HACCP approach to mitigating the risks associated with human and environmental health concerns over a lifetime of consumption.

The water quality specifications for Barrier 3 include monitoring of the influent entering Barrier 3 from Barrier 2 (which is defined as a CCP) to ensure the source water received is suitable for the AWTP. With the shift to IPR, characterisation of the sewer catchment has identified over 300 IPR contaminants of concern that need to be monitored regularly in the raw water influent entering the AWTP (at the interface of Barriers 2 and 3), in addition to water quality baseline monitoring activities. The current source water monitoring schedule also encompasses species, such as free chlorine, that may impair the AWTP.

For compliance and operational control purposes, the key water quality parameters within Barrier 3 are currently monitored via a schedule that comprises a set of on-line and standard laboratory-based methods. Table 14 summarises the baseline water quality monitoring schedule employed by Veolia Water at Barrier 3. The categories of IPR contaminants of concern that are required to be measured monthly in the source water entering Barrier 3 are given in Table 15.

The investigation revealed that most of the compliance monitoring for heavy metals, inorganics and radionuclides occurs on a monthly basis, and is performed using laboratory-based methods. On the other hand, key water quality indicators that may affect the performance of the advanced treatment processes are monitored continuously by on-line analysers, in addition to being verified twice weekly by standard laboratory-based methods. The review indicated that in order to comply with the statuary obligations imposed by the PRW operation, sample collection, preservation, analysis, calibration and data reporting must be completed in accordance with the Quality Assurance and Control Framework (QACFW). All analysis included in the monitoring schedule must have NATA accreditation, and comply with Australian Guidelines for Water Monitoring and Reporting, ANZECC, ADWG, ARWG and APHA standards.

All data obtained for compliance (standard) and operational monitoring purposes are stored in a centralised reporting system under the management of Veolia Water Australia and can be accessed through the WCPRWS. The data collected are used by Veolia Water Australia to evaluate the barrier's performance against the water quality in the design specifications, contractual requirements, HACCP limits, ADWG and ARWG requirements, EPA Licence agreements, operational and CCP limits.

Table 14 Baseline Water Quality Monitoring Schedule at Barrier 3

Water Entering Barrier 3	Sampling Frequency	Guidelines	Method
Metals			
Arsenic	Monthly	ADWG	Laboratory
Antimony	Monthly	ADWG	Laboratory
Beryllium	Monthly	ADWG	Laboratory
Boron	Monthly	ADWG	Laboratory
Calcium	Twice per week	RWMP	Laboratory
Cadmium	Monthly	ADWG	Laboratory
Chromium	Monthly	ADWG	Laboratory
Cobalt	Monthly	RWMP	Laboratory
Copper	Monthly	RWMP	Laboratory
Lead	Monthly	ADWG	Laboratory
Magnesium	Monthly	RWMP	Laboratory
Manganese	Twice per week	RWMP	Laboratory
Nickel	Monthly	ADWG	Laboratory
Selenium	Monthly	ADWG	Laboratory
Sodium	Monthly	RWMP	Laboratory
Zinc	Monthly	RWMP	Laboratory
Barium	Monthly	ADWG	Laboratory
Mercury	Monthly	ADWG	Laboratory
Molybdenum	Monthly	ADWG	Laboratory
Potassium	Monthly	RWMP	Laboratory
Strontium	Monthly	ADWG	Laboratory
Vanadium	Monthly	ADWG	Laboratory
Aluminium	Monthly	RWMP	Laboratory
Iron	Monthly	RWMP	Laboratory
Inorganic Ions			
Iodide	Monthly	ADWG	Laboratory
Silica	Monthly	RWMP	Laboratory
Cyanide	Monthly	RWMP	Laboratory
Fluoride	Monthly	ADWG	Laboratory
Alkalinity	Monthly	RWMP	Laboratory
Sulphate	Monthly	RWMP	Laboratory
Chloride	Monthly	ADWG	Laboratory
Radio nuclides			
Gross Alpha/Beta	Monthly		Laboratory
Nutrients and Organics			
TOC	Twice per week/On-line	RWMP	Laboratory and On-line
Total Nitrogen	Twice per week	RWMP	Laboratory
Ammonia	Twice per week/On-line	RWMP	Laboratory and On-line
Nitrate	Twice per week/On-line	RWMP	Laboratory and On-line
Ortho-phosphorus	Twice per week/On-line	RWMP	Laboratory and On-line
Total Phosphorus	Twice per week	RWMP	Laboratory
BOD_5	Monthly	RWMP	Laboratory
Physical			
Turbidity	Twice per week/On-line	RWMP	Laboratory and On-line
Suspended Solids	Twice per week	RWMP	Laboratory
TDS	Twice per week	RWMP	Laboratory
Conductivity	Twice per week	RWMP	Laboratory
pH	Twice per week	RWMP	Laboratory

Table 15 Categories of IPR Contaminants Monitored for Source Water Entering Barrier 3

IPR Contaminants	Number of Measured Parameters	Sampling Frequency	Guidelines	Method
Phenols	16	Monthly	ADWG/AWRG if available	Laboratory
Herbicides/Pesticides	19	Monthly	ADWG/AWRG if available	Laboratory
Phenoxyacids, Dalapon	11	Monthly	ADWG/AWRG if available	Laboratory
Pesticides, Glyphosate	2	Monthly		Laboratory
Fragrances	1	Monthly		Laboratory
Nitrosamine	5	Monthly	AWRG if available	Laboratory
EDTA	1	Monthly	ADWG/AWRG	Laboratory
Endocrine Disrupting Compounds	12	Monthly	AWRG if available	Laboratory
Pharmaceuticals	52	Monthly	AWRG if available	Laboratory
PCBs and Dioxins	8	Monthly	AWRG	Laboratory
Organochlorine Pesticides	32	Monthly	ADWG if available	Laboratory
Organophosphorus Pesticides	38	Monthly	ADWG if available	Laboratory
Synthetic Pyrethroids	13	Monthly	ADWG if available	Laboratory
Polyaromatic Hydrocarbons	15	Monthly	ADWG or AWRG if available	Laboratory
Volatile Organic Compounds	59	Monthly	ADWG or AWRG if available	Laboratory
Carbamates	13	Monthly		Laboratory

4.2.2 Water quality requirements and monitoring schedules for Barrier 4

The water quality monitoring requirements at Barrier 4 are defined by the RWMP. Table 16 shows a list of water quality parameters that are monitored for operational control and compliance assessment purposes. Heavy metals, inorganic ions, selected nutrients and TDS are measured before and after RO treatment in scheduled routine testing. The RO feed water is primarily tested to verify the feed water quality against its design specifications, whilst the RO permeate is tested to evaluate the RO performance. Nutrients and organics such as TOC are measured in the RO feed water to verify the effectiveness of CCP 1 (monitoring at the inlet of Barrier 3). Nitrosamines, magnesium and calcium are also regularly monitored in the RO feed water and permeate, as they may be formed within the AWTP pre-treatment process. The other parameters such as fluoride are monitored as they could impact on the environment through the use of the product water; whereas the alkalinity of the RO permeate needs to be monitored as it will change during treatment processes.

Table 16 Water Quality Parameters Measured at Barrier 4

Parameter	RO Feed Water	RO Permeate	Guidelines	Method
Boron	Every 4 Weeks per RO unit	Every 4 Weeks per RO unit	ADWG	Laboratory
Calcium	Weekly per RO unit	1 RO unit per week – all three permeate stages tested	RWMP	Laboratory
Magnesium	Weekly per RO unit	1 RO unit per week – all three permeate stages tested	RWMP	Laboratory
Manganese	Weekly per RO unit	Every 4 Weeks per RO unit	RWMP	Laboratory
Sodium	Weekly per RO unit	1 RO unit per week – all three permeate stages tested	RWMP	Laboratory
Barium	Every 4 Weeks per RO unit	One RO unit per 4 weeks	RWMP	Laboratory
Strontium	Every 4 Weeks per RO unit	One RO unit per 4 weeks	ADWG	Laboratory
Potassium	Every 4 Weeks per RO unit	One RO unit per 4 weeks	RWMP	Laboratory
Aluminium	Weekly per RO unit	One RO unit per 4 weeks	RWMP	Laboratory
Iron	Every 4 Weeks per RO unit	One RO unit per 4 weeks	RWMP	Laboratory
Inorganic Ions				
Silica	Every 4 Weeks per RO unit	One RO unit per 4 weeks	RWMP	Laboratory
Fluoride	Every 4 Weeks per RO unit	One RO unit per 4 weeks	ADWG	Laboratory
Alkalinity	Every 4 Weeks per RO unit	One RO unit per 4 weeks	RWMP	Laboratory
Sulphate	1 RO Unit Per Week	1 RO unit per week – all three permeate stages tested	RWMP	Laboratory
Chloride	1 RO Unit Per Week	1 RO unit per week – all three permeate stages tested	ADWG	Laboratory
Nutrients/Organic Indicators				
TOC	1 RO unit per 4 weeks		RWMP	Laboratory
Total Nitrogen	1 RO unit per week	1 RO unit per week – all three permeate stages tested	RWMP	Laboratory
Ammonia	1 RO unit per week	1 RO unit per week – all three permeate stages tested	RWMP	Laboratory
Nitrate	1 RO unit per week	1 RO unit per week – all three permeate stages tested	RWMP	Laboratory
Ortho-phosphorus	1 RO unit per 4 weeks	One RO unit per 4 weeks	RWMP	Laboratory
Total Phosphorus	1 RO unit per 4 weeks	One RO unit per 4 weeks	RWMP	Laboratory
Physicochemical				
TDS	1 RO unit per 4 weeks	One RO unit per 4 weeks	RWMP	Laboratory

In addition phenolic compounds and haloacetic acids are routinely measured on a monthly basis by grab samples, as they may be formed within the AWTP pre-treatment processes and are IPR contaminants of concern that have also been found in the sewer catchment. A group of trihalomethanes are also regularly monitored on a monthly basis by grab samples, as these compounds may be formed within the AWTP pre-treatment process. These measurements are performed by conventional laboratory-based methods as summarised in Table 17.

Table 17 IPR Contaminants of Concern Measured at Barrier 4

Category	Number of Measured Parameters	Frequency	Guidelines	Method
Phenolic Compounds	16	Monthly	ADWG/ARWG if available	Laboratory (RO Feed)
Haloacetic Acids	6	Monthly	ARWG if available	Laboratory (RO Feed)
Trihalomethanes	5		ARWG/ADWG if available	Laboratory (RO Feed)
Nitrosamines	5	RO feed: 1 RO unit per 4 weeks RO Permeate: 1 RO unit per 4 weeks	ARWG if available	Laboratory

To complement discrete operational monitoring of Barrier 4, real-time continuous information is also collected before and after RO treatment. There are 6 physicochemical parameters which are monitored on-line for the RO feed. These include turbidity, conductivity, pH, total chlorine and nitrate, which are used as surrogates for the performance of MF at Barrier 3 (see Table 18).

The water quality monitoring at Barrier 4 uses both standard laboratory-based methods and on-line methods, and is completed in accordance with the QACFW, APHA standards, HACCP risk assessment model and the ADWG and ARWG limits.

All data obtained for compliance (standard) and operational monitoring purposes is stored in a centralised reporting system managed by Veolia Water Australia.

Table 18 Indicative Parameters for On-Line RO Performance Evaluation

Parameter	RO Feed	RO Permeate	Indicator
Turbidity	Yes		MF Filtration Performance
pH	Yes		Ensures suitability of feed water for RO
Conductivity	Yes	Yes	RO performance (> 90% removal efficiency)
Total Chlorine	Yes		Ensure feed water suitable for RO
Temperature	Yes		
TOC		Yes	RO performance and > 90% removal of organic compounds

4.2.3 Water quality requirements and monitoring schedules for Barrier 5

Barrier 5 is the final treatment step of the AWTP which will supply approximately 100ML/day of purified recycling water to the intended users. A large number of water quality parameters are required to be monitored at this barrier for operational control and compliance purposes.

The water quality monitoring schedule at Barrier 5 is implemented using a set of on-line and laboratory-based analyses. The on-line water quality monitoring at Barrier 5 is required for real-time information for operational control purposes. Laboratory-based analyses are employed to collect water quality data for operational control and compliance purposes. All laboratory-based analyses are performed by NATA accredited laboratories using grab or composite samples. This is to verify that the PRW produced from the AWTPs within the scheme are in accordance the ADWG and ARWG specifications.

Tables 19 and 20 list the water quality monitoring requirements at Barrier 5 that are defined by Veolia Water Australia's Baseline Purified Monitoring Schedule. It requires that phenolic compounds, haloacetic acids, glyphosate, galaxolide, EDCs and pharmaceuticals must be measured on a twice weekly or monthly basis because of their presence in the raw sewage influent. The monitoring data are used to verify the concentration levels of such species have been removed in accordance with ADWG/ARWG requirements. Nitrosamine and disinfection by-products are monitored monthly to ensure that the concentration of these species in the treatment water complies with the ADWG requirements. Heavy metals and fluoride are also measured to ensure their concentration levels are within the limits defined in ADWG/ANZECC guidelines.

Table 19 Water Quality Monitoring Schedule at Barrier 5

Parameter	Frequency	Method	Guidelines
Microbial			
F-RNA Phages	Twice per week	Laboratory	ADWG/RWMP
Somatic coliphages	Twice per week	Laboratory	ADWG/RWMP
Escherichia Coli	Twice per week	Laboratory	ADWG/RWMP
Clostridium perfringens	Twice per week	Laboratory	ADWG/RWMP
Inorganic Disinfection By-Products			
Chlorite	Twice per week	Laboratory	AWDG
Chlorate	Twice per week	Laboratory	AWDG
Perchlorate	Twice per week	Laboratory	AWDG
Bromate	Twice per week	Laboratory	AWDG
Total Chlorine	Twice per week (Lab)/ Continuous (On-line)	Laboratory/On-line	RWMP
Metals			
Arsenic	Twice per week	Laboratory	ADWG/RWMP
Antimony	Twice per week	Laboratory	ADWG
Beryllium	Twice per week	Laboratory	RWMP
Boron	Twice per week	Laboratory	ADWG/RWMP
Calcium	Twice per week	Laboratory	RWMP
Cadmium	Twice per week	Laboratory	ADWG/RWMP
Chromium	Twice per week	Laboratory	ADWG/RWMP
Cobalt	Twice per week	Laboratory	RWMP
Copper	Twice per week	Laboratory	RWMP
Lead	Twice per week	Laboratory	ADWG/RWMP
Magnesium	Twice per week	Laboratory	RWMP
Manganese	Twice per week	Laboratory	RWMP
Nickel	Twice per week	Laboratory	ADWG/RWMP
Selenium	Twice per week	Laboratory	ADWG/RWMP
Zinc	Twice per week	Laboratory	RWMP
Mercury	Twice per week	Laboratory	ADWG/RWMP
Molybdenum	Twice per week	Laboratory	ADWG/RWMP
Potassium	Twice per week	Laboratory	
Vanadium	Twice per week	Laboratory	ADWG/RWMP
Aluminium	Twice per week	Laboratory	RWMP
Iron	Twice per week	Laboratory	RWMP
Inorganic Ions			
Iodide	Twice per week	Laboratory	ADWG
Cyanide	Twice per week	Laboratory	ADWG
Fluoride	Twice per week	Laboratory	ADWG
Alkalinity	Twice per week	Laboratory	ADWG/RWMP
Sulphate	Twice per week	Laboratory	ADWG
Free chlorine	Continuous	On-line	
Radionuclides			
Gamma Alpha/beta/k40	Twice per week	Laboratory	ADWG
Gamma Spec	Twice per week	Laboratory	ADWG
Tritium	Twice per week	Laboratory	ADWG
Nutrients and Organic Indicators	**Frequency**	**Method**	**Guidelines**
TOC	Twice per week	Laboratory	RWMP
Total Nitrogen	Twice per week	Laboratory	RWMP
Ammonia	Twice per week	Laboratory	ADWG
Ortho-phosphorus	Twice per week	Laboratory	
Total Phosphorus	Twice per week	Laboratory	RWMP
Physical			
Turbidity	Twice per week (Lab)/ Continuous (On-line)	Laboratory/on-line	RWMP
TDS	Twice per week	Laboratory	RWMP
Conductivity	Twice per week (Lab)/ Continuous (On-line)	Laboratory/on-line	RWMP
pH	Twice per week (Lab)/ Continuous (On-line)	Laboratory/on-line	RWMP
CCPP	Twice per week	Laboratory	RWMP
Temperature	Continuous	On-line	RWMP

Table 20 PRW Contaminants of Concern for Compliance Monitoring at Barrier 5

Contaminants	Number of Measured Parameters	Frequency	Method	Guidelines
Phenolics	16	Twice per week	Laboratory	ADWG/ARWG if available
Pesticides and Herbicides	19	Twice per week	Laboratory	ADWG/ARWG if available
Phenoxyacid Herbicides and Dalapon	11	Twice per week	Laboratory	ADWG/ARWG if available
Pesticides, Glyphosate	2	Monthly	Laboratory	Laboratory
Nitrosamine	5	Monthly	Laboratory	AWRG if available
EDTA	1	Monthly	Laboratory	ADWG/AWRG
Endocrine Disrupting Compounds	12	Monthly	Laboratory	AWRG if available
Pharmaceuticals	52	Monthly	Laboratory	AWRG if available

Table 21 lists the key water quality parameters monitored on-line that are essential for operational control purposes. The real-time water quality data collected from the critical control points and operational points within the barrier are used as an indicator of the performance of the barrier.

All data obtained for compliance (standard) and operational monitoring purposes is stored in a centralised reporting system managed by Veolia Water Australia.

Table 21 Parameters Monitored On-Line for Operational Purposes at Barrier 5

Use of Data	Treatment Process	Parameters
Critical Control Point	Advance Oxidation	H_2O_2 flow rate and power ratio
Critical Operational Point	Stability Dosing	pH and conductivity
Critical Control Point	Disinfection – Chlorine Dosing	Free and total chlorine
Quality Control Point	PRW at pumping station, prior to release	pH, conductivity, chlorine and turbidity
Quality Operational Point	MF backwash	Turbidity
Critical Operational Point	Reverse Osmosis Concentrate (ROC) breakpoint chlorination	Chlorine and ammonia
Critical Operational Point	ROC dechlorination	Free chlorine
Critical Operational Point	ROC pH correction and phosphate coagulation	pH and phosphorus
Quality Operational Point	Trade Waste Quality	pH and conductivity
Critical Operational Point	CIP waste tank	pH

4.3 Summary of Findings for Barriers 3, 4 and 5

The AWTP has only recently been commissioned and consequently there is no long term compliance monitoring data set available for any meaningful assessment. Therefore in this section we will only summarise the findings revealed during the Stage 1 investigations, without recommendations.

- Comprehensive water quality monitoring schedules for Barriers 3, 4 and 5 defined in the RWMP have been proposed and implemented.
- Key water quality parameters essential for operational control are monitored on-line.
- Laboratory-based analyses of grab or composite samples on a twice weekly, weekly or monthly basis are employed to monitor the majority of water quality parameters for operational control purposes.
- All key water quality parameters monitored for compliance purposes are analysed by laboratory-based methods on grab or composite samples at a twice weekly, weekly or monthly basis.
- The effectiveness of the water quality monitoring practices implemented will be known after the PRW scheme is in operation and sufficient water quality data has been collected.

5. BARRIER 6: NATURAL ENVIRONMENT

5.1 Overview of Barrier 6

Barrier 6 is defined as the natural environment, and consists of rivers, wetlands, dams and reservoirs, and it currently has over 1165 GL storage capacity. It is an open barrier with multiple entry points. When fully operational, the WCPRWS has the capacity to supply up to 232 ML/day of PRW. Barrier 6 (Wivenhoe Dam) is designed to receive approximately 100 ML/day of PRW from 3 AWTPs at Barrier 5 once the PRW scheme is in full operation (see Figure 42).

The PRW produced from Luggage Point and Gibson Island advanced water treatment plans will be firstly transported to Bundamba via a 58 km pipeline. PRW will then be transported from Bundamba via the 80.4 km Western Pipeline to Lowood pumping station then to Caboonbah. The PRW will be subsequently pumped via a 16 km pipeline to the balance tank near Lake Wivenhoe and water quality parameters will be adjusted before it being released into the Wivenhoe Dam at the Logan's inlet via the Western Corridor Pipeline (see Figure 42). Wivenhoe Dam will be used as an additional environmental buffering/dilution mechanism to produce suitable quality raw drinking source water. The AWTP must ensure the PRW produced meets ADWG and ARWG standards before being released to the dam. The water will then be transported via the Brisbane River to Mt Crosby Weir for water treatment (Barrier 7).

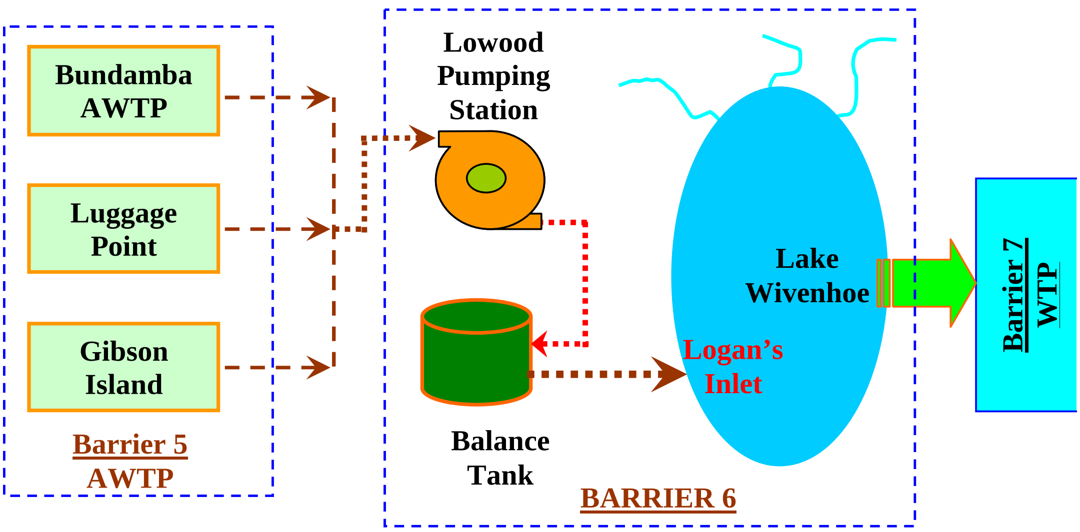

Figure 42 Schematic Diagram Illustrating Barrier 6 of the PRW Scheme

The following sections summarise the water quality requirements, water quality monitoring schedules and the intended use of the water quality data collected from Barrier 6. The information presented is based on the related policy documents (i.e. RWMP, ANZECC, ADWG, ARWG and QWRG) available to the project at the time. No recommendation is made for sensing technology development due to the lack of water quality data available to the project at the time.

5.2 Water Quality Requirements and Monitoring Schedules

The baseline water quality monitoring schedule for assessing the integrity of Barrier 6 consists of routine monthly sampling at 32 sites, with additional sampling fortnightly at major sites. Samples are analysed for a range of physical, chemical and biological parameters according to ANZECC, EPA and ADWG requirements from human and environmental health perspectives.

In the transition to a closed water loop PRW operation, Seqwater is currently in the process of expanding its baseline water quality monitoring schedule to better manage risks associated with a HACCP based management approach. In addition to the standard compliance monitoring schedule, there is an automatic weather station at the dam that records temperature, wind and evaporation.

Seqwater Water has also expanded its water quality management plant to incorporate the monitoring of pollutants during rainfall events, which is referred to as event monitoring.

Table 22 lists the water quality parameters being monitored at Barrier 6. The baseline water quality monitoring plan has been expanded to include real-time monitoring in the shift towards a closed water loop PRW operation. However, at the time of preparing this report, no information has been released by Seqwater in regards to what on-line sensors will be employed to further strengthen the integrity of Barrier 6.

Table 22 Water Quality Parameters Routinely Measured at Wivenhoe Dam

Water Quality Parameters Measured	Water Quality Parameters Measured
Dissolved Oxygen	**Pesticides**
pH	**Aldrin**
Conductivity	**Amitrole**
Turbidity	**Atrazine**
Temperature	**Chlordane**
Total Nitrogen	**Chlorpyrifos**
Total Phosphorus	**Clopyralid**
Soluble Phosphorus	**2,4-D**
Soluble Nitrogen	**DDT**
DOC	**Dieldrin**
Giardia	**Diquat**
Cryptosporidium	**Diuron**
Cyanobacteria	**Endosulfan**
Algal Counts	**Fosamine**
Escherichia Coli	**Heptachlor**
Chlorophyll a	**Hexazinone**
Alkalinity	**Lindane**
Dissolved Fe	**Molinate**
Dissolved Mn	**Paraquat**
Inorganic	**Picloram**
Arsenic	**Propiconazole**
Barium	**Temephos**
Boron	**Triclopyr**
Mercury	**Radionuclides**
Selenium	
Additional Information	
Rain fall	
Flow	
Bathymetry Information	
Evaporation	
Wind	

The majority of the parameters are monitored using laboratory-based analysis. However, for parameters such as DO, conductivity, pH, salinity and temperature, portable field analysers may also be used.

According to Seqwater's monitoring schedule, the collected data are used for the purposes of:

- Ensuring the quality of raw water is in accordance with Seqwater customer supply contracts;
- Providing information on long-term water quality trends in water storages;
- Evaluating the effect of the input PRW on physiochemical and biological characteristics within the reservoir;
- Assessing the level of species with potential significant human health effects such as pathogens, toxins and chemicals of concern;
- Monitoring of algal blooms;
- Ensuring aesthetic quality of water such as taste, odour and colour;
- Establishing baseline water quality monitoring criteria before PRW is introduced;
- Hydrodynamic modelling;
- Annual water quality reporting;
- Assessment of bioaccumulation;
- Monitoring seasonal and temporal variation in the catchment;
- Determining how seasonal variation and drought affect water quality; and
- Complying with RWMP.

A set of key water quality parameters, including temperature, pH, salinity/conductivity, turbidity, DOC, ammonia, nutrients, chlorine, pesticides, pathogens, cyanobacteria and cyanotoxins, is monitored for operational performance evaluation purposes.

5.3 Summary of Findings for Barrier 6

- The water quality monitoring schedule for Barrier 6 defined in the RWMP has been outlined.
- Key water quality parameters essential for operational performance evaluation are monitored either on-line or in situ.
- Laboratory-based analyses of grab or composite samples on a monthly basis are employed for monitoring the majority of water quality parameters for operational control purposes.
- All key water quality parameters monitored for compliance purposes are analysed by laboratory-based methods of grab or composite samples on a monthly basis.
- The effectiveness of the proposed water quality monitoring schedule cannot be assessed until after the PRW is in operation and sufficient water quality data become available.

6. BARRIER 7: WATER TREATMENT

6.1 Overview of Barrier 7

Barrier 7 covers drinking water treatment and distribution and is the last treatment process in the closed water loop PRW scheme. The barrier is designed to produce water of drinking quality from raw water received from Barrier 6. Once the PRW is in operation, the source water from Barrier 6 will contain a certain portion of blended purified recycled water. The treatment plant for Barrier 7 is operated by Brisbane Water at Mt Crosby and is governed by the RWMP. The water produced must meet the water quality requirements defined in AWDG.

The barrier operator needs to submit Recycled Water Management Plans for approval to ensure that they address and manage the risks associated with the barrier. The water quality requirements and monitoring schedules defined in the RWMP are based on ADWG and ARWG. Water quality monitoring at Barrier 3 takes a HACCP approach to mitigating the risks associated with human and environmental health concerns.

For Barrier 7, the assessment was carried out based on the policy documents and historical water quality information available to the project at the time. No recommendation is made for sensing technology development because there was insufficient water quality data available to the project.

6.2 Water Quality Requirements and Monitoring Schedules

The water quality monitoring schedules implemented by Brisbane Water and Ipswich Water are used primarily to ensure the water quality produced complies with ADWG. The water quality information monitored is also used for operational control purposes. Table 23 summarises the monitoring schedule employed at Barrier 7.

Table 23 Water Quality Requirements and Monitoring Schedule for Barrier 7

Parameter	Raw	Treated	Distribution	Delivery Point	Laboratory/On-line
Dissolved Oxygen		Yes	Yes	Yes	Laboratory or Field
pH	Yes	Yes	Yes		Laboratory or Field or on-line
Conductivity	Yes	Yes			Laboratory or Field
Turbidity		Yes	Yes	Yes	Laboratory or Field
Temperature		Yes	Yes	Yes	Field
Ammonia		Yes	Yes	Yes	Laboratory
Colour		Yes	Yes	Yes	Laboratory
Dissolved Solids		Yes	Yes	Yes	Laboratory
Hardness		Yes			Laboratory
Taste and Odour	Yes	Yes	Yes	Yes	Laboratory
DOC	Yes				Laboratory
Escherichia Coli	Yes	Yes	Yes	Yes	Laboratory
Total Coliforms	Yes	Yes	Yes	Yes	Laboratory
Inorganic					
Aluminium		Yes	Yes	Yes	Laboratory
Arsenic	Yes				Laboratory
Antimony		Yes	Yes	Yes	Laboratory
Barium	Yes				Laboratory
Boron	Yes				Laboratory
Cadmium		Yes		Yes	Laboratory
Chloride		Yes			Laboratory
Free Chlorine		Yes	Yes	Yes	Laboratory/on-line
Total Chlorine		Yes	Yes	Yes	Laboratory/on-line
Monochloramine		Yes	Yes	Yes	Laboratory
Chromium		Yes	Yes	Yes	Laboratory
Copper		Yes		Yes	Laboratory
Cyanide		Yes			Laboratory
Hydrogen Sulphide			Yes		Laboratory
Iron		Yes	Yes	Yes	Laboratory
Lead				Yes	Laboratory
Manganese		Yes	Yes		Laboratory

Mercury	Yes				Laboratory
Molybdenum	Yes			Yes	Laboratory
Nickel		Yes			Laboratory
Nitrate		Yes	Yes	Yes	Laboratory
Nitrite		Yes	Yes	Yes	Laboratory
Sodium		Yes			Laboratory
Selenium	Yes				Laboratory
Sulphate		Yes			Laboratory
Zinc		Yes	Yes	Yes	Laboratory
Organic					
Carbon tetrachloride		Yes			Laboratory
Benzo (a) pyrene				Yes	Laboratory
Di (2-ethylhexyl) phthalate		Yes			Laboratory
Disinfection Byproducts					
Trihalomethanes		Yes	Yes	Yes	Laboratory
Chemical					
Iodine				Yes	Laboratory
Pesticides					
Aldrin	Yes				Laboratory
Amitrole	Yes				Laboratory
Atrazine	Yes				Laboratory
Chlordane	Yes				Laboratory
Chlorpyrifos	Yes				Laboratory
Clopyralid	Yes				Laboratory
2,4-D	Yes				Laboratory
DDT	Yes				Laboratory
Dieldrin	Yes				Laboratory
Diquat	Yes				Laboratory
Diuron	Yes				Laboratory
Endosulfan	Yes				Laboratory
Fosamine	Yes				Laboratory
Heptachlor	Yes				Laboratory
Hexazinone	Yes				Laboratory
Lindane	Yes				Laboratory
Molinate	Yes				Laboratory
Paraquat	Yes				Laboratory
Picloram	Yes				Laboratory
Propiconazole	Yes				Laboratory
Temephos	Yes				Laboratory
Triclopyr	Yes				Laboratory
Radionuclides	Yes				Laboratory

The majority of the water quality parameters monitored are analysed using laboratory-based methods on grab or composite samples. The sampling frequency varies depending on the population size and key water quality parameters. The monitoring schedule includes four types of sampling points located at the raw water entry points (before treatment), exit points (after treatment), key monitoring points within the distribution system, and at the consumers' taps. Some water quality parameters such as pH, turbidity, free and total chlorine are monitored on-line. The sampling, analysis, data recording and reporting are performed in accordance with NATA protocols and procedures.

The raw and treated water quality data were unavailable to the project. However, some historical water quality data from the distribution system at certain delivery points were available. The assessment findings of the available data are summarised below.

Free chlorine

The level of free chlorine present in the water distribution system is used to control microbial activity. The upper and lower compliance limits defined by the new licence agreement are 1.0 mg/L and 0.20 mg/L, respectively. Figure 43 shows a plot of the recorded free chlorine values against time over the period of 2003 to 2007 at Marburg delivery point. Analysis revealed that the mean value of free chlorine was 0.24 mg/L. While, over 85% of the recorded data were outside the compliance limits during the period investigated, over 60% of recorded measurements were left censored, suggesting that most non-compliance was due to free chlorine levels that were below the compliance limit of 0.20 mg/L.

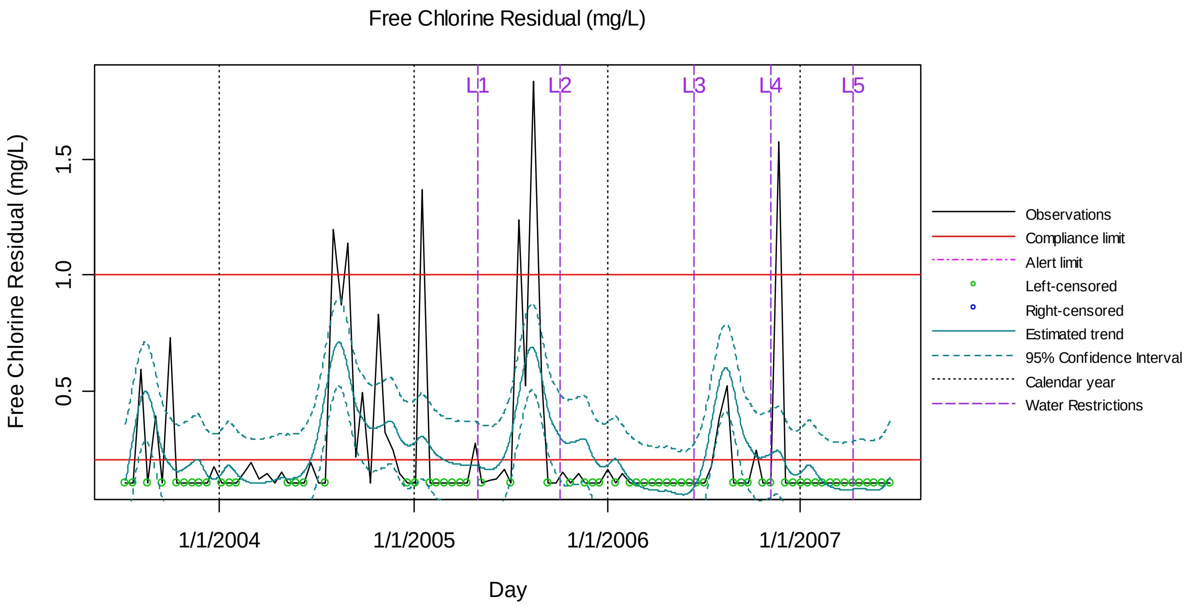

Figure 43 Free Chlorine Values Recorded at Marburg Delivery Point

Total chlorine

The upper and lower compliance limits for total chlorine defined by the new licence agreement are 3.0 mg/L and 0.20 mg/L, respectively. The lower alert limit is defined as 0.5 mg/L. Figure 44 shows the plot of the recorded total chlorine values against time over the period of 2003 to 2007 at Marburg delivery point. The analysis revealed that over 18% of the recorded data were outside the compliance limits during the period investigated. Over 47% of the recorded data were below the lower alert limit of 0.5 mg/L. The overall mean value of the recorded total chlorine was 0.72 mg/L.

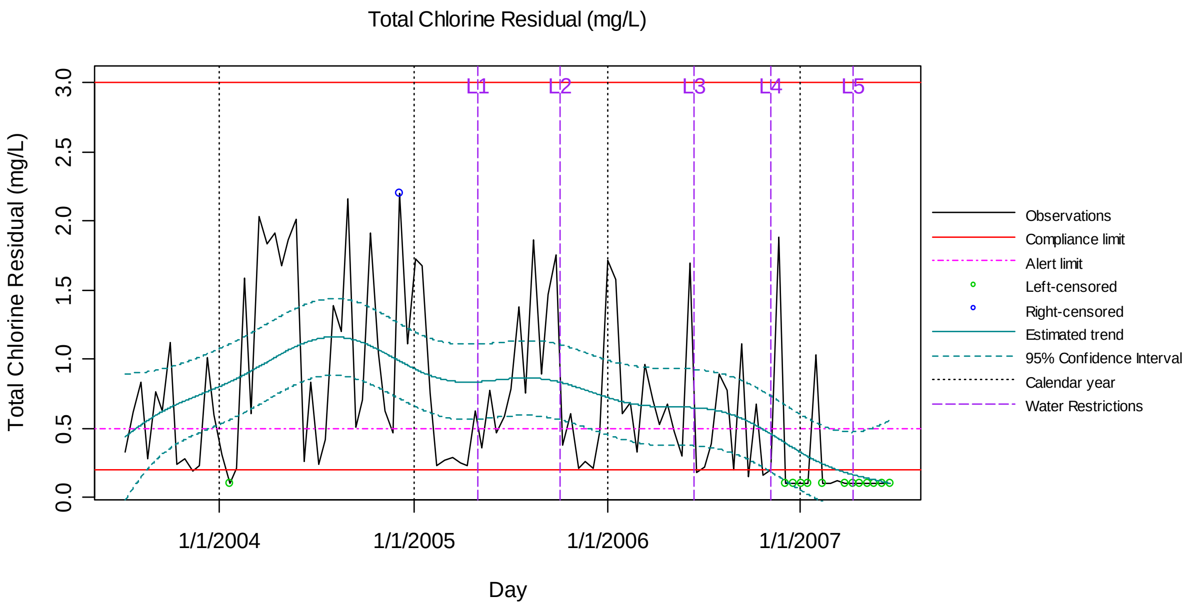

Figure 44 Total Chlorine Values Recorded at Marburg Delivery Point

Total organisms

Figure 45 shows a plot of the recorded values of total organisms against time over the period of 2003 to 2007 at Marburg delivery point. The overall mean value of the total organisms recorded was 15.6 CFU/mL. Analysis of the data found that the level of total organisms tended to be higher when the free chlorine level was below the compliance limit.

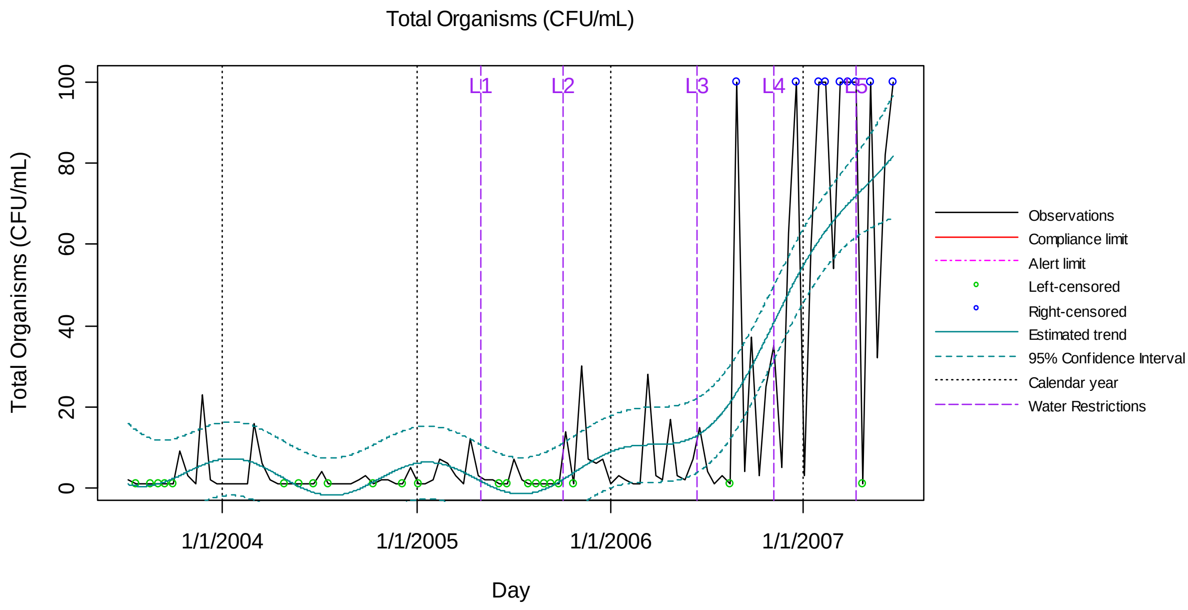

Figure 45 Plot of the Total Organisms Recorded at Marburg Delivery Point

Turbidity

The upper compliance and alert limits for turbidity defined by the new licence agreement are 5.0 NTU and 1.0 NTU, respectively. Figure 46 shows the plot of the recorded turbidity values against time over the period of 2003 to 2007 at Marburg delivery point. The analysis revealed that only 1% of the recorded data exceeded the upper alert limit during the period investigated, and no recorded data were over the compliance limit of 5.0 NTU.

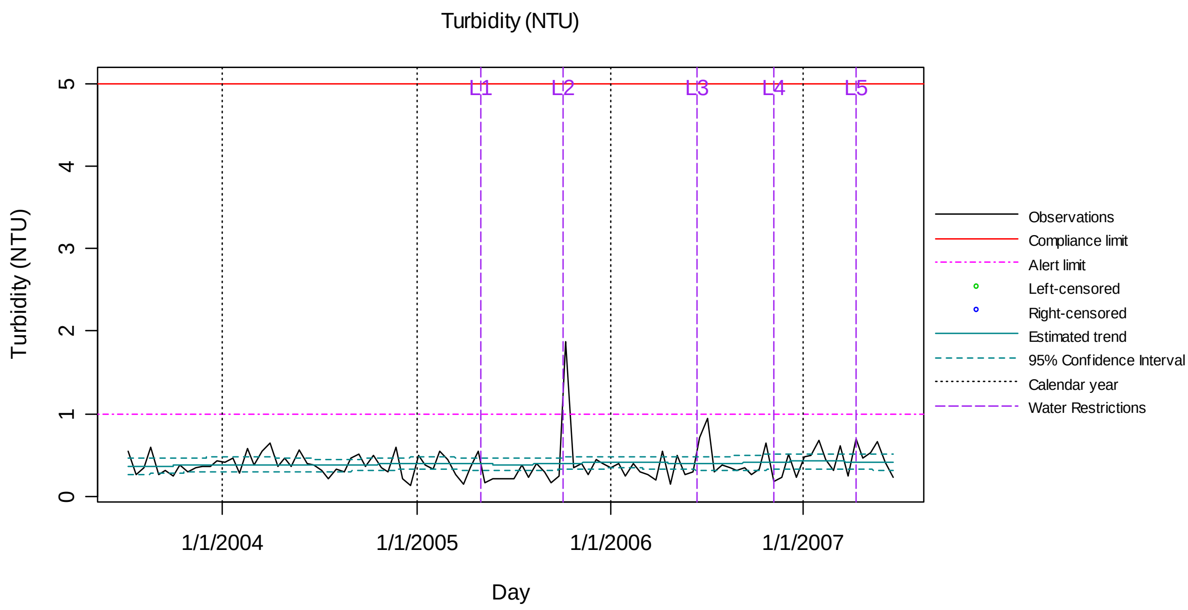

Figure 46 Plot of the Turbidity Values Recorded at Marburg Delivery Point

pH

The upper and lower compliance limits for pH defined by the new licence agreement are 8.5 and 6.5, respectively. The upper and lower alert limits are defined as pH 8.0 and 7.0, respectively. Figure 47 shows the plot of recorded pH values against time over the period of 2003 to 2007 at the Rosewood delivery point. Data analysis revealed that during the period investigated, 50% and 5.5% of the recorded data were outside the alert and compliance limits, respectively. The overall mean value was pH=8.1.

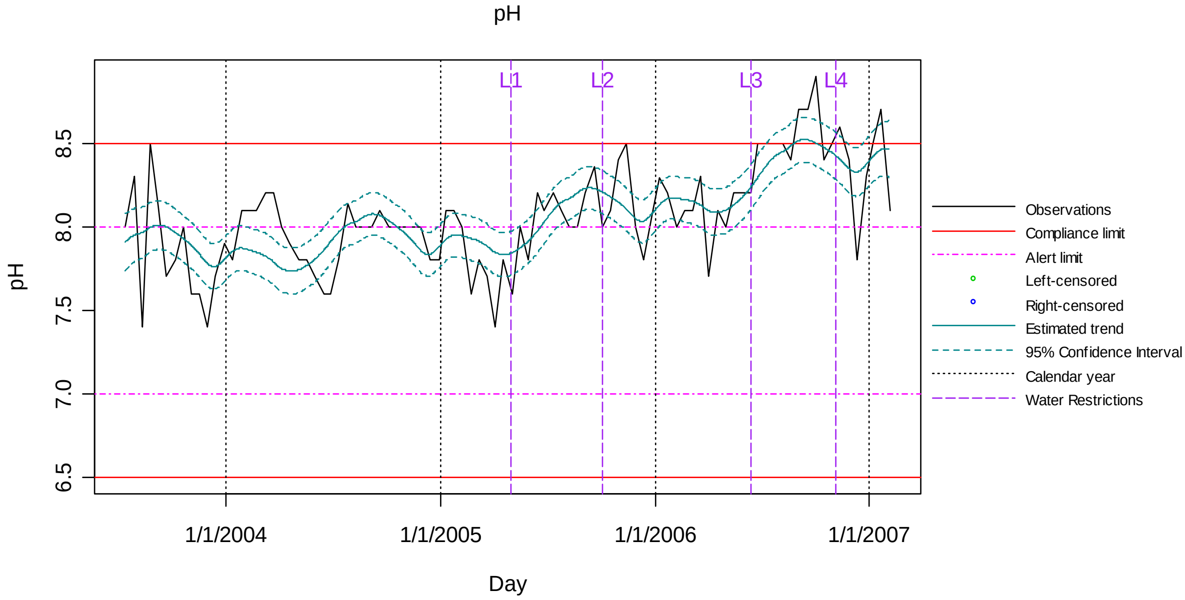

Figure 47 Plot of the pH Values Recorded at Rosewood Delivery Point

Heavy metals

Lead is used here as a typical example to represent the situation of heavy metal data recorded. Figure 48 shows the plot of recorded lead values against time over the period of 2003 to 2007 at the Marburg delivery point. The upper compliance limit defined by the licence agreement is 0.01 mg/L. Data analysis revealed that over 6% of the recorded data exceeded the upper compliance limit of 0.01 mg/L. However, over 95% of the recorded measurements were left censored, which possibly indicates that the measurement method used had insufficient sensitivity. It should be noted that the situation for other monitored heavy metals are very similar to that for lead.

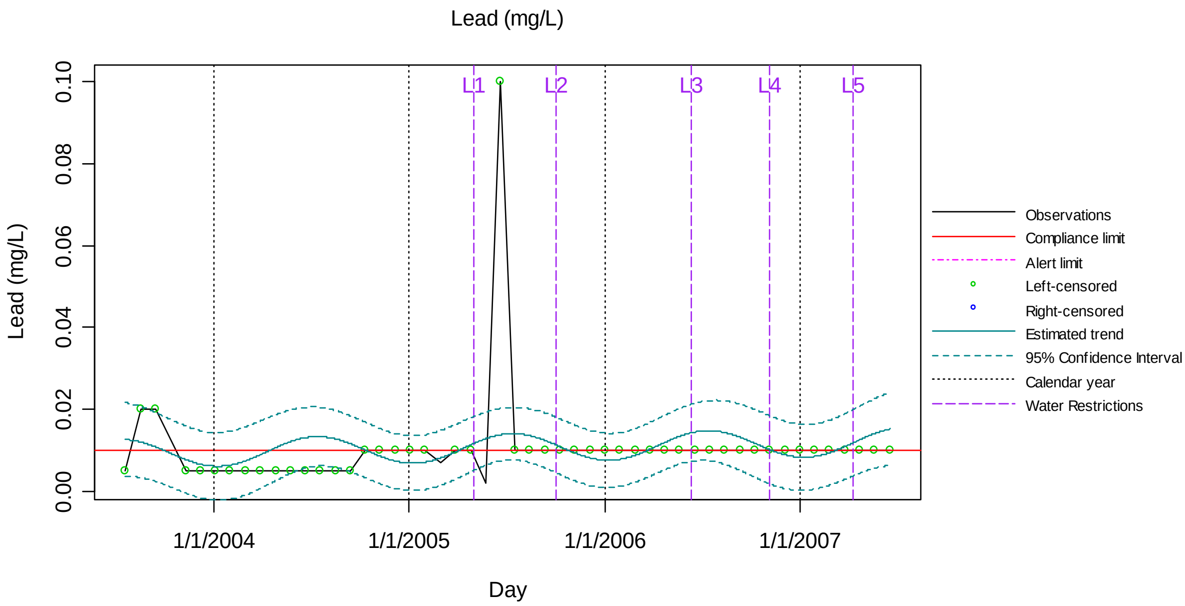

Figure 48 Plot of the Lead Values Recorded at Marburg Delivery Point

6.3 Summary of Findings for Barrier 7

- The water quality monitoring schedule for the barrier defined in the RWMP has been described.
- Some key water quality parameters essential for operational performance evaluation are monitored using on-line instrumentation.
- Laboratory-based analyses of grab or composite samples are employed for monitoring the majority of the water quality parameters for operational control purposes.
- All key water quality parameters monitored for compliance purposes are analysed by laboratory-based methods using grab or composite samples.
- For certain heavy metals, the sensitivity of the current analytical method may need to be improved.
- The effectiveness of the proposed water quality monitoring practice cannot be investigated until after the PRW scheme is in operation and sufficient water quality data become available.

7. OVERALL CONCLUSIONS

In Stage 1 of the WQICS project an evaluation was undertaken of the water quality data collected from the seven barriers of the PRW system between 2003-2007, with particular emphasis on Barriers 1 (Source Control) and 2 (Wastewater Treatment Plant). Information gathered from water policy/legislative documents, a stakeholder survey and workshop feedback was also considered. The major objective was to identify any sensing technology developments required to better safeguard system operation.

The PRW system introduces a closed water loop in which purified recycled water is fed into the water supply system. This gives rise to potential water quality risks from possible contaminants in the treated wastewaters. Consequently, new legislation governing the PRW operation has been framed to minimise the human health impact, which means that a tougher water monitoring regime is required. It is therefore essential that the water quality monitoring practices employed can service these requirements before PRW is introduced.

As the existing sewer catchments and WWTPs were not originally designed for the PRW system, an assessment was conducted to identify if the current water quality monitoring practices employed at each of the seven barriers were adequate, or if further improvements were required to better safeguard the PRW system operation.

Barriers 1 and 2

It was found that the water quality monitoring regimes currently used for Barriers 1 and 2 were based mainly on traditional laboratory-based analytical methods using grab or composite samples collected on a weekly or fortnightly basis. This gives information that is useful for environmental discharge monitoring and long-term system performance evaluation, but its effectiveness for closed water loop operation can only be validated after the PRW scheme is in operation. However, there is no evidence to suggest that the present monitoring systems are capable of providing real-time water quality information for source control purposes.

In the majority of cases, malfunction of a WWTP is caused when non-complying source water overwhelms the designed buffering capacity of the treatment plant. This risk can be greatly reduced if a source control regime is in place to ensure that only water of a suitable quality enters the WWTP. A cost-effective option to achieve effective source control would be to implement a reliable real-time event detection system to identify any significant source water quality changes, enabling any questionable source water to be contained before it entered the WWTP. However, to the best of our knowledge, there is no such commercial analytical system currently available. Therefore, it is recommended that a real-time event detection system should be developed for Barrier 1. This would form the basis of an early warning system employing event detection systems strategically located at key points in the sewer network. It is also recommended that development should commence of suitable on-line sensing systems capable of real-time analysis of targeted water quality parameters (e.g. COD, nutrients and free chlorine). Such systems provide additional information that can help to characterise and identify a detected event.

Likewise, the effluent produced at Barrier 2 needs to meet the water quality specifications defined by the licence agreement for supply to Barrier 3 (AWTP). Again, development of a real-time event detection system would add value to better safeguard plant operation and enable reliable delivery of quality effluent to the AWTP (Barrier 3). Implementation of this system will provide an essential management tool to allow the operators/grid managers to better safeguard operation of the PRW system.

For the remaining barriers, there was insufficient compliance monitoring data available at the time of writing this report for any meaningful assessment, so we have reported current monitoring practise at the barriers. The effectiveness of the proposed water quality monitoring practice cannot be investigated until after the PRW scheme is in operation and sufficient water quality data become available.

Barriers 3, 4 and 5

Comprehensive water quality monitoring schedules defined in the RWMP have been proposed and implemented, with key water quality parameters essential for operational control being monitored on-line. Laboratory-based analyses of grab or composite samples on a twice weekly, weekly or monthly basis are employed to monitor the majority of water quality parameters for operational control and compliance purposes.

Barrier 6

Key water quality parameters essential for operational performance evaluation are monitored either on-line or in situ. Laboratory-based analyses of monthly grab or composite samples are employed for monitoring most water quality parameters for operational control purposes. For compliance monitoring, all parameters are analysed by laboratory-based methods of monthly grab or composite samples.

Barrier 7

Some key water quality parameters essential for operational performance evaluation are monitored using on-line instrumentation. Laboratory-based analyses of grab or composite samples are employed for monitoring the majority of the water quality parameters for operational control purposes. All key water quality parameters monitored for compliance purposes are analysed by laboratory-based methods using grab or composite samples. For certain heavy metals, the sensitivity of the current analytical method may need to be improved.

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