

University Of Southern Queensland
Faculty of Engineering & Surveying

Investigation into the Performance of First Flush
Systems for Diesel Engine Based Pollution on Roof
Runoff

A Dissertation submitted by

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ABSTRACT

Ergon Energy has approximately 30 diesel power stations which generate electricity in isolated communities throughout Queensland. At most of these sites, rainwater tanks are located adjacent and provide water for domestic purposes to the workers' camp. The water has long been suspected of contamination, although it has not previously been tested.

The objective of this study is to assess the quality of the collected water and consider any health risks in accordance with the Australian Drinking Water Guidelines. Following initial testing, first flush devices were installed with the aim of measuring any improvement in water quality.

The study considered 25 different metals, total petroleum hydrocarbons (reported in four different carbon fractions), heterotrophic plate count and *Escherichia coli* contamination in the water. The study also included testing for polycyclic aromatic hydrocarbons which were determined to be the most likely contaminant to cause failure to comply with Australian Drinking Water Guidelines at these sites. Twenty-three different polycyclic aromatic hydrocarbons were considered, both in the collected water and the dry buildup of contaminants on the roof.

The study investigated the effects of variable parameters such as rainfall patterns, wind speed and direction, materials used in rainwater goods and detention time.

The results clearly indicated that the stored water is unfit for domestic purposes and should not be consumed. Metals concentrations were the main cause of non-compliance with Australian Drinking Water Guidelines. In most cases the study was not able to clearly define whether these contaminants originate from diesel particulate matter.

The first flush devices had little effect on harvested rainwater quality in comparison to other parameters.

Further testing would be required to assess possible health risks if rainwater harvesting is to continue at these sites, however sufficient data does exist to warrant their removal.

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CERTIFICATION

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Signature

Date

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GLEN HARDY

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ACRONYMS & ABBREVIATIONS USED IN THIS TEXT

ADWG – Australian Drinking Water Guidelines

ALS – ALS Laboratory Group

ARID – Australian Rainwater Industry Development Group

BOM – Bureau Of Meteorology

BaP – Benzo(a)pyrene

CWL – Cairns Water Laboratory

E-Coli – Escherichia coli

HFO – Heavy Fuel Oil

HPC – Heterotrophic Plate Count

ICPMS – Inductively Coupled Plasma Mass Spectroscopy

PAH – Polycyclic Aromatic Hydrocarbons

PSA – Power Station Attendant

TPH – Total Petroleum Hydrocarbons

US EPA – United States Environmental Protection Authority

WHO – World Health Organisation

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1.0 INTRODUCTION

1.1 CHAPTER OVERVIEW

This chapter discusses the background of the project and describes why the study was undertaken. It also describes the objectives and requirements for the project.

1.2 BACKGROUND

Ergon Energy has approximately 30 diesel power stations in isolated locations throughout Queensland, particularly in the Torres Strait Islands and Western Queensland areas. These stations supply electricity to remote communities of around 100 people in areas where the state power grid does not reach. The stations are typically powered by three to four continuously operated diesel generation sets (commonly known as gensets). The gensets are similar to bus or truck motors and produce electricity. The stations typically have up to seven gensets, and additional sets operate as the energy load requires. The exhaust manifold for each motor runs directly through the roof, and in most cases the stack outlet is about 1.5m above this, as shown in Figure 1.1. While most of the emissions are dispersed by passing winds, small amounts of contaminants can deposit on the roofs and in the gutters.

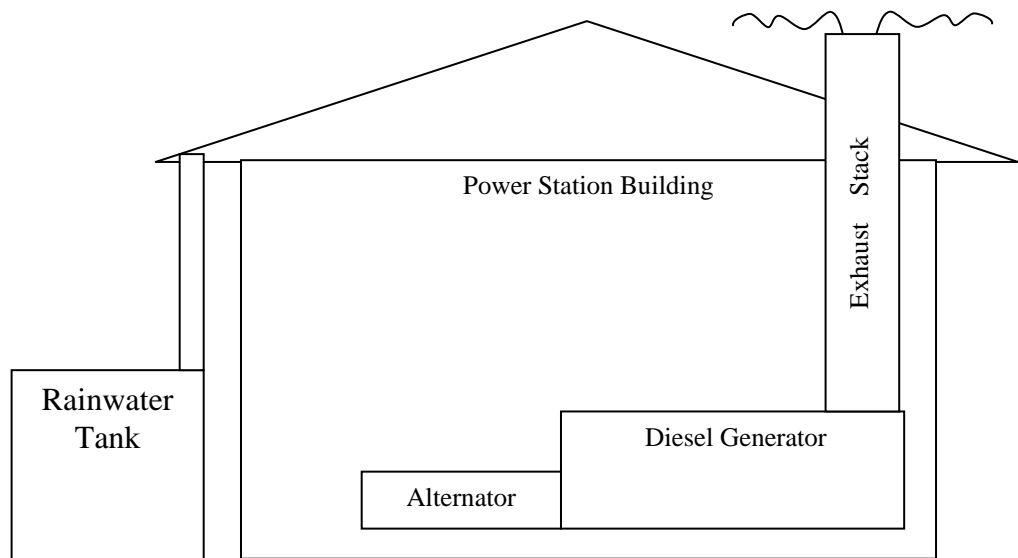


Figure 1.1 Power Station Typical Cross Section

Accommodation is limited in these areas and Ergon Energy has on site workers' camps at most of the sites. Each camp is generally located within 100m of the station.

Domestic water for use in adjacent workers' camps is a combination of municipal supply water and rainwater collected from the roofs of the power station or accommodation block. Tank water is only used when the municipal supply is unavailable; however this can occur commonly in isolated communities. There are currently no water quality testing or maintenance programs for the tanks. As per the Australian Drinking Water Guidelines (ADWG), Ergon Energy should have a Water Quality Management Plan in place to regulate testing and maintenance. This has previously been of concern to Workplace Health and Safety Officers.

Although many studies have been undertaken to examine roof runoff quality at sites adjacent highways and other pollution sources, very few, if any, have been able to separate diesel combustion based pollution from other combustion engine types. The situation at Ergon Energy offers a unique opportunity to conduct research into the effects of diesel engine based pollution on roof runoff. In these small isolated communities general traffic pollution is obviously very minimal. Therefore, one of the objective of this study is to investigate the effects of diesel engine based pollution on roof runoff.

The State Government, through the Department of Natural Resources, Mines and Water, currently offers rebates for the installation of rainwater tanks, regardless of the location. However the tanks must be plumbed internally to bathroom or laundry facilities.

With many communities currently drought stricken, many shire councils now offer rebates for the installation of rain water tanks, although few councils have definitive policies for maintenance. The Cairns City Council and similarly other councils in the area do not offer rebates for rainwater tanks and do not recommend their use, hence there are no maintenance policies for tanks in these areas. Regardless, the Building Code of Australia requires that for some classes of building, water tanks or other water saving devices are necessary. This is the case for the Ergon Energy isolated power stations and substations. The tanks involved in the study, or the whole rainwater harvesting systems for that matter, have had very little maintenance since installation. The effects of this will be considered in the study.

The power station is one of the primary pieces of infrastructure in the community and needs to be operational as often as possible, especially following cyclones or other

natural disasters. The municipal water supply in these communities is often considered unsafe for short periods following a cyclone. The light aircrafts used to carry workers and equipment into these communities are often quite restricted in terms of weight capacity and would neither have the room nor the capacity to carry the large amount of water required by workers for 3-4 days. Given that the power stations serve a post disaster function, it must be ensured that staff are able to undertake restoration operations during these times without placing themselves at risk.

This study may also be applicable to rainwater tank installations in remote construction camps adjacent to areas where diesel powered machinery is operated.

1.3 OBJECTIVES OF THIS STUDY

The aim of this project is to investigate the suitability of the collected roof water for drinking and other domestic purposes, as well as investigating the efficiency of first flush water diversion devices.

It is anticipated that the study will provide information on the effects of the following parameters, amongst others, regarding tank water quality:

- Weather & detention time;
- Different roofing materials;
- Geographical site location including distance from ocean;
- Changing volume of diverted first flush;
- Reduction in water quality associated with diesel engine based pollution; and
- Distance of collecting roof from exhaust stack.

It was also noted during initial investigations that very little definitive data is given with respect to the performance of first flush water diversion devices. The study also aims to give qualitative performance data on such systems.

Based on the findings of the above objectives, the study aims to provide a pathway towards providing a safe and reliable water supply at each of the sites, which can be implemented across all power station sites, and possibly substation sites. The possible solutions for this problem are discussed in Section 6.1

1.4 SCOPE OF THIS PROJECT

The selected sites were in the North Queensland region, particularly in the Cape York region with the exception of Palm Island. The sites are considered to be a representative sample of all the sites in the northern region of the state. It is envisaged that if the study were to be conducted in the southern sites the results, in particular biological results, may differ.

Five sites were selected as being a representative sample of all sites. The sites are:

- Aurukun
- Gununa
- Burketown
- Palm Island
- Lockhart River

Due to resource restrictions and the high costs associated with each sample, limited samples were taken.

1.5 OVERVIEW OF DISSERTATION

This dissertation has the following organisational structure:

- Chapter 2 describes the initial investigations that took place and how such investigations shaped the study. It provides information on those parameters which were expected to influence the study, and why. This chapter reviews previous research which has been completed, and identifies current knowledge gaps and inconsistencies in published literature.
- Chapter 3 describes each site and the differences between them.
- Chapter 4 describes the methodology for the study, and explains the reasoning for this. The sampling and test procedures are also described here as well as some of the logistical problems encountered.
- Chapter 5 presents the results and provides an analysis of the results on a site by site basis, as well as examining the results found for each contaminant. It also compares the results of initial testing and those results obtained after the first flush devices were installed.

- Chapter 6 concludes the results of this project, discusses the outcomes, and provides recommendations for minimising health risks to employees with regard to water quality.

2.0 LITERATURE REVIEW

2.1 CHAPTER OVERVIEW

This chapter reviews current literature applicable to the study. The information presented in this chapter largely shaped the study, in particular the contaminants examined. It provides information on those parameters which were expected to influence the results, and why. This chapter also aims to identify current knowledge gaps and inconsistencies in published literature. In the latter section, this chapter gives a brief description of first flush devices and principles involved.

2.2 WATER QUALITY PARAMETERS

The quality of roof runoff is affected each stage of the collection process. As water falls through the atmosphere it may pick up contaminants. The extent to which this occurs depends on air quality and also surrounding air patterns. As water lands on the roof, it may pick up further contamination from particles which have been transported onto the roof, or as a result of chemical processes occurring on the roof surface. This depends on the condition of the roof catchments at the time of rainfall. Additional contaminants may be picked up from gutters, downpipes and other rainwater goods as the water travels to the collection tank. Finally, as the water mixes with previously collected roof runoff, the concentration of contaminants may be increased or decreased, depending on the quality of the previously collected runoff and other processes which occur in the tank over time. The final quality of collected water is dependent on the cumulative effects of each of the above parameters, amongst others. Some of these parameters are discussed further below.

2.3 FREQUENCY OF RAINFALL

Rainfall frequency will impact on the volume of water in the tank. Provided that the layer of sludge in the bottom of the tank does not change, decreases in stored water volume should increase the concentration of contaminants. Rainfall and weather data is given in Appendix G and correlations between test results and rainfall data are discussed throughout Chapter 5.

The chosen locations are very monsoonal, receiving almost all rains during the wet summer months. Samples taken throughout the wet season would be expected to have different concentrations of contaminants to samples taken during the dry season. Due to the timelines for the study, samples were not able to be taken during the middle of the wet season.

2.4 WATER DETENTION TIME

It is expected that as water is stored over time, the quality should increase due to natural biological processes. It is also expected that many metals will settle out over time. Australian Rainwater Industry Development Group (ARID) recommends water is sourced from the aerobic zone just below the surface level using a skimmer, connected to an outlet at mid level in the tank. Outlets on most commercially available tanks are around 100 – 150mm above the bottom of the tank, representing poor design however the use of a skimmer would negate this.

The rainwater tank at Burketown Power Station has been disconnected from all plumbing, and will not be used during the period of the study. This tank will work as a controlled sample to indicate the effects of detention time, since other tanks will be used during the time of the study.

2.5 PREVAILING WINDS

As the contaminants are exhausted from the building, they are dispersed by winds. Depending on the aspect and distance of the collecting roof in relation to the exhaust stacks, contaminants will be deposited on different sections of the roof. If the contaminants are deposited onto the collecting roof area, concentrations are obviously expected to increase.

The inclination and direction of the roof also affect the amount of weathering and hence runoff quality. Slower water flows caused by small roof pitch will result in smaller contaminant particles and hence lesser amounts being picked up, however larger residence time increases the dissolution of contaminants. Gadd & Kennedy (2001) also noted higher deposition rates on the windward face of the building.

2.6 MATERIALS FOR RAINWATER GOODS

All of the tanks used in the study are fibreglass tanks from the same local manufacturer. As discovered from the first sample at Aurukun, and also in a previous studies (Magyar et al., 2008), the roofing, guttering & downpipe materials which the rainwater comes into contact with will affect the overall quality of the tank water.

The tanks were originally installed prior to the common use of polyethylene plastic tanks and rotational moulding technologies. The tanks are generally in good condition given their age and have no blistering or cracking normally associated with ageing fibreglass tanks. Fibreglass tanks offer excellent salt resistance and are ideal in coastal areas. ARID recommends that fibreglass tanks be installed in shaded areas despite UV inhibitors. The tanks themselves are classified by the Building Code of Australia as a class 10B building, therefore height and boundary setback limitations must be considered when locating the tank.

The tanks were manufactured by a local boat builder around 1990. Modern fibreglass tanks are now lined with a food grade coating on the interior surface prior to sale, however it is not known whether this was the case for the tanks under consideration.

Polyethylene tanks have become popular in recent times. These are generally fabricated from food grade polyethylene to suit AS4766. Most tanks come with assurances and guarantees to state compliance with this standard. Some of these tanks exist at other Ergon Energy sites, the majority of which are substations.

The tanks at the chosen sites are white, originally chosen to reduce heat in the tanks. Some of the tanks have yellowed slightly with age.

2.7 CONTAMINANTS

Investigations promptly indicated that the principal hazards associated with diesel emissions in regards to collected rainwater are associated with polycyclic aromatic hydrocarbons (PAH) and trace metals. Full listings of the metals and PAH, and relevant properties considered in this study are detailed in Appendices E and F respectively. PAH, metal contaminants and biological contaminants are discussed below.

2.7.1 POLYCYCLIC AROMATIC HYDROCARBONS (PAH)

It must be noted that individual PAH vary in behaviour and physical characteristics. Properties of the 23 PAH tested are tabulated in Appendix F.

Whilst PAH are found in exhausts from diesel engines, other sources include cigarette smoke, general soot, forest fires, charcoaled food and asphalt processing amongst others. This indicates that the gensets would not be the only cause of PAH concentrations. Whilst there is a test to indicate presence of PAH in urine, it does not indicate the level of contamination hence the study is unable to include human contamination since many other sources may contribute.

As noted in the US EPA technical fact sheet on PAH, there is evidence that benzo(a)pyrene (BaP) has the potential to cause cancer. Depending on the source of information, several PAH are considered possible carcinogens.

Forster (1996 and later in 1998) compared PAH concentrations in runoff from five different roof types at the same site, and showed that concentrations are similar for all different roofing materials. It was also noted that traffic emissions did not result in significant increases in PAH concentrations where PAH were examined. The distances involved between the source and the collection are not shown in this study. It is worth noting that the air quality study conducted by Ergon Energy indicates that exhaust gasses can be carried over 1km, and that US EPA technical fact sheet for PAH reported that the presence of PAH in places distant from primary sources indicate that PAH is reasonably stable and capable of long distance transport.

It may be possible to remove any PAH via an inline filter after the water leaves the tank. It was reported by US EPA that PAH will tend to absorb very strongly to any particulate matter, particularly organic matter, and be removed by filtration. It is not known whether long detention times which break down the organic matter have an effect on the PAH concentrations. The US EPA technical factsheet for PAH states that PAH are stable towards biodegradation in most waters. ADWG states that conventional water treatment processes such as coagulation, settling and filtration should reduce BaP concentrations of raw water to less than 0.000001mg/L, even if influent concentration is high. ADWG also suggests that other PAH would be similarly reduced. Although settling may occur in the rainwater tanks, the tanks will be stirred

prior to sampling to suspend any settled solids. Filtration or coagulation processes will not be undertaken for this study.

The ADWG only gives a guideline value of 0.00001mg/L for BaP, since data are inadequate to set guideline values for other PAH. It is expected that tank concentrations will not exceed this quantity. The concentration of BaP in typical drinking water from municipal supplies is estimated to be around 0.00000055 mg/L.

2.7.2 METAL CONTAMINANTS

Although many studies have investigated rainwater roof quality for metal contaminants, the majority of studies have been in relation to lead concentrations. These studies were generally undertaken to examine the presence of lead in collected runoff adjacent highways and other pollution sources. Lead was initially deemed not to be a large risk to water quality in this study due to the lack of lead in mineral diesel, however lead was included in the metals testing as a parameter in this study.

Heavy metals are defined as those metals with high molecular weights. These include mercury, chromium, cadmium, lead and zinc. These are generally harmful at low concentrations and can bioaccumulate within organisms. Heavy metals are also capable of biomagnification, the process whereby concentrations of the substance are increased as it passes up the food chain (Sinclair Knight Merz, *Airborne Contaminants or Emissions of Significance in the Kalgoorlie-Boulder, Coolgardie and Kambalda Area*, 2005) The health problems associated with exposure to high levels of metals depend on the metal under consideration, and the degree of exposure encountered. The health effects of each metal are discussed in detail in Appendix E.

Lead may also come from lead flashings, as reported by Magyar et al (2008), as well as other sources. The study by Magyar used quantities of lead flashing which were not representative of a standard roof. Hence, the study reported very high levels of lead in runoff. In documentation and specifications relating to the power station building construction, no reference to lead flashing or other lead rainwater goods were found. Magyar noted that when rainwater tanks are installed as part of a new development, the use of materials would generally be professionally assessed. Although no documentation exists to this effect, it would appear this has been the case for the subject buildings, since lead is a common flashing material.

In a second study of rainwater tanks in Melbourne, Magyar reported that tanks were commonly contaminated with lead and other heavy metals at levels exceeding the ADWG. This study was conducted many years after the removal of lead from petrol. Since the study found such alarming concentrations of contaminants, without noting any major pollutant sources nearby, it would seem doubtful that a runoff from a power station building, with continuous point source emissions, could ever comply with the ADWG.

Gadd & Kennedy (2001) did note, however, that the amount of contaminants entering the roof runoff depends on the rate of weathering of roofing materials. This should be noted when the results for the Palm Island samples are reported, as the roof at this site has weathered badly and is due for replacement. It was also noted that the geographical location, and orientation of the building will affect the weathering, as sea salt is deposited onto the roof surface by dry deposition and unless regularly washed off, it will react with moisture (particularly in humid areas) to increase the corrosion rate.

The study by Magyar did not investigate PAH or Total Petroleum Hydrocarbons (TPH), and was mainly focussed on concentrations of lead and other trace metals. The study used new materials which does not allow for corrosion or weathering & associated breakdown of roofing materials, as would be the normal situation. All samples in Magyar's study were taken 1-2 days after a rainfall event; therefore the study gave no insight into the effects of detention time.

Galvanised roofs are noted to be the highest source of zinc contamination; however the levels of zinc runoff from standard galvanised roofs are a source of debate. Gadd & Kennedy (2001) report zinc concentrations of between 1 and 44g/m³, whereas Simmons et al (2001) reported median concentrations from galvanised roofs to be 0.4g/m³. This is again in contrast with an article published in Pollution Engineering (2003) anon, which reported zinc concentrations to be as high as 3mg/l. The ADWG guideline for zinc concentration is relatively high, as the human body can tolerate high levels of zinc. The above articles did not make correlations between roof area and contamination concentrations.

Many other studies have attempted to investigate the source of contaminants in water quality. The ADWG fact sheets, WHO (World Health Organisation) Guidelines For Drinking Water Quality and United State Environmental Protection Agency (US EPA)

all give possible origins for each contaminant, however the lists of origins are neither definitive nor conclusive.

2.7.3 BIOLOGICAL CONTAMINANTS

In a recent study in New Zealand, more than half of 560 samples from private dwellings exceeded the minimal standards for contamination and 30 percent showed evidence of heavy faecal contamination (Abbott S. E., 2006). Contamination could lead to gastrointestinal diseases from pathogens including salmonella, campylobacter, giardia and cryptosporidium.

ADWG suggests that monitoring for specific pathogens is not recommended for financial reasons. The tests may also fail to detect specific pathogens. Generally, escherichia coli (E-coli) and heterotrophic plate counts (HPC) are the only tests conducted during normal operational monitoring of drinking water supplies. E-Coli is used as an indicator for faecal contamination. If E-Coli were found in high numbers in one sample, specific pathogens could be studied in detail as required. *“The presence of E-coli in water generally indicates very recent faecal contamination, since the organism does not generally multiply in drinking water systems”* (ADWG).

E-Coli bacteria originate from droppings of animals such as birds, geckos, frogs and bats. E-Coli contamination in rainwater tanks from these sources is likely given the open roof and gutters. E-Coli pose a significant risk to the very young, elderly or those with compromised immune systems.

HPC are used as an overall indicator of heterotrophic microorganisms in the sample which can grow on the growth medium used in the test.

Some enteric pathogens can occur in the absence of E-Coli and HPC indicators. Cryptosporidium and giardia, amongst other viruses, are relatively resistant to chlorination and may survive chlorination levels which would kill the indicator organism.

The majority of water borne biological contaminants tend to occur in small or very small water systems, such as water tanks (Davis & Cornwell, 2002). Table 2.1 indicates waterborne disease outbreaks in the United States from 1980 to 1996.

Illness	No. Of Outbreaks	Cases of Illness
Gastroenteritis, undefined	183	55,562
Giardiasis	84	10,262
Chemical Poisoning	46	3,097
Shingellosis	19	3,864
Gastroenteritis, Norwalk virus	15	9,437
Campylobacteriosis	15	2,480
Hepatitis A	13	412
Cryptosporidiosis	10	419,939
Salmonellosis	5	1,845
Gastroenteritis, E Coli	3	278
Yersiniosis	2	103
Cholera	2	28
Gastroenteritis, rotavirus	1	1,761
Typhoid fever	1	60
Gastroenteritis, Plesiomonas	1	60
Amoebiasis	1	4
Cyclosporiasis	1	21
Total	402	509,213

Table 2.1 Data courtesy of Water Quality & Treatment, 1999

The official figures provided in the above table are believed to be much smaller than actual cases since it is difficult to prove that gastrointestinal symptoms are related to waterborne pathogens. Since the majority of biological contaminants exist in small or very small water systems, it is believed that much of this data is relevant to rainwater tanks.

The symptoms associated with biological contamination are gastroenteritis, vomiting, stomach cramps, diarrhoea, headaches and fevers. Dr Jeffery Hanna from the Tropical Public Health Unit stated *“it is difficult to ascertain whether these symptoms relate to waterborne biological contaminants or other causes.”*

In September 2008 E-Coli was detected in seven of thirteen reservoirs in the Mossman and Mowbray region in North Queensland. During this period, the Cairns Post reported a *“notably high incidence of patients admitted to hospital with gastrointestinal*

symptoms.” Officials stated that they were unable to ascertain whether this was related to the E-Coli found in the reservoirs.

It is commonly understood that rainwater tanks sterilize the water inside, since bacteria cannot survive without UV light. Several rainwater tank manufacturers declare that UV light enters the openings in sufficient quantities to allow bacteria to survive, even with mosquito mesh guards installed. Light guards are available from tank manufacturers which ensure that an insufficient amount of light enters for many biological contaminants to exist (OzPoly Rainwater Tank Users Manual, 2008). These were not installed on the studied tanks.

It is common knowledge amongst staff working in these areas that water should be boiled when using water from the tank. Whilst this process will ensure all bacteria are destroyed, it increases the solubility of metals and hence, may increase other contamination problems.

Periods of dry / wet weather may explain patterns in biological contaminants. It is also envisaged that if the study were to be conducted at sites in the Torres Strait or Central Australia, different biological contaminants would be expected. The heterotrophic plate counts may also differ.

Other studies have revealed the presence of microbiological contaminants, and an increase in such due to lack of cleaning and maintenance.

2.8 FIRST FLUSH SYSTEMS

The background principle behind first flush devices is that the contaminant concentration decreases as rainfall quantity increases. The initial volumes of water gradually wash contaminants from the roof. The most contaminated water is theoretically captured and does not enter the tank, hence ensuring that only the cleanest water enters the tank. Roofs which are in areas heavily laden with pollutants would theoretically require larger volumes of water to be diverted, as the contaminants will take longer to be washed from the roof.

First flush devices are designed to collect and discard an initial volume of water prior to allowing water to flow through to the rainwater tank. The initial volume of water flows along the downpipe and into the diversion chamber. A valve is used to seal the

diversion chamber once it is full. Any volume of water following this runs into the rainwater tank. The diversion chamber gradually empties as water flows through an orifice designed to slowly release the water and reset the device. This ensures the diversion chamber is empty prior to the next rainfall event. The process is shown diagrammatically in Figure 2.1. In domestic applications, the diverted water could be connected to trickle irrigation or the like, however there is no purpose for the diverted water in power stations and the water falls to the ground. Ideally, the waste water should be connected to a stormwater system with bioretention systems designed to reduce metal contaminant concentrations entering waterways.

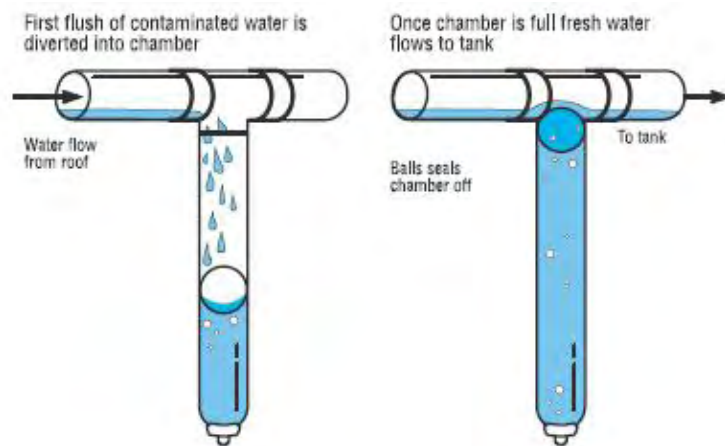


Figure 2.1 Diversion Process – Diagram Courtesy of Rain Harvest

The first flush devices chosen for the study are *First Flush Water Diverter* manufactured by *Rain Harvesting*. The model chosen is the most commonly stocked model in local plumbing & hardware stores, ensuring continual availability throughout the study. It was also recommended by local tradesman. This system utilises a plastic ball inside the diversion chamber which floats to the top of the chamber and presses against the ball seat. This blocks the diversion chamber and diverts further flow to the rainwater tank. The ball is made from very light gauge plastic and is subject to puncture or splitting if mishandled.

The manufacturer recommends that $0.5\text{L}/\text{m}^2$ of roof area be diverted in light pollution areas, as opposed to $2\text{L}/\text{m}^2$ in areas of substantial pollution. ARID recommends $0.2\text{L}/\text{m}^2$. *Domestic Rainwater Harvesting in Queensland* (Building Services Authority, 2007) states that the first 20L of water from each downpipe must be prevented from entering the tank. Installation procedures for first flush devices are discussed in section 4.5 of this document.

The systems require minor periodic maintenance. The manufacturer recommends that the hose connector (#16), flow control valve (#11), and plastic filter screen (#13), as indicated in Figure 2.2, must be removed and cleaned periodically. Specific time periods for maintenance are not stated.

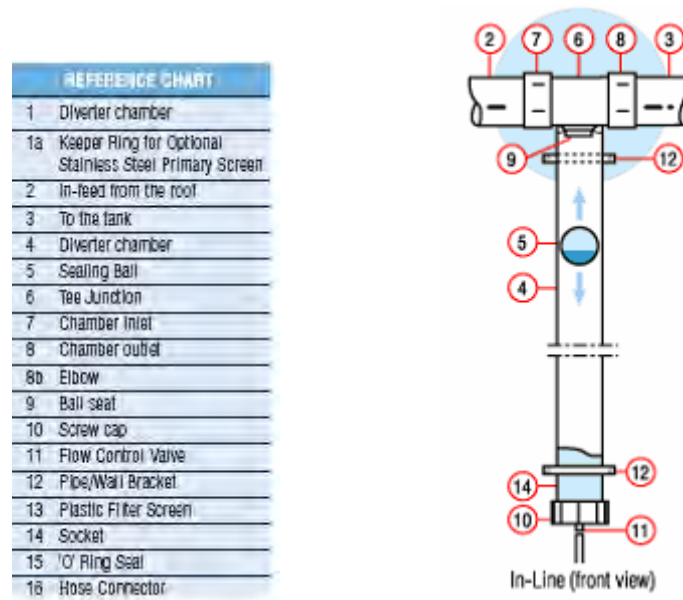


Diagram 2.2 First Flush Diverter - Diagram Courtesy of Rain Harvest

Other systems investigated were only available in one or two local stores, and in some cases were discontinued models. Most other systems involved the use of settlement tanks. Other systems investigated were typically quite expensive, required specialist maintenance contractors and were bulky to freight. Freight and maintenance costs are important factors to be considered when installing equipment into the isolated sites involved in this study.

As mentioned earlier, there is very little scientific data available to support the use of the first flush diverters, even though they are commonly recommended. Gadd & Kennedy (2001) reported that concentrations of contaminants in roof runoff demonstrate a first flush effect with an exponential decrease in concentration over time. This was said to be true for all contaminants (biological, chemical & organic). This is in contrast with a later statement by the same author that both PAH and trace metals will tend to stick to rough roof surfaces hence have no first flush effect, and the US EPA technical fact sheet on PAH, which states that most PAH have very low solubility in water. Wehrer & Totsche, 2005 analysed equilibrium and non-equilibrium

release of contaminants and noted that during the initial wave of water concentrations of contaminants were higher

Filters are another component to water harvesting systems and would normally improve water quality immensely. Typical commercial filters could be installed in line, downstream from the pressure pump. Unfortunately, the majority of commercially available filters for this purpose are only able to retain particles larger than 10 μ m. The air quality study conducted by Ergon Energy indicated that the majority of the diesel particulate released from the gensets is classed as PM_{2.5} (2.5 μ m particles). This means that the filters could not reliably remove the majority of contaminants and would be of little value. Ultra-violet in line filters are also now available for smaller systems but unfortunately are only effective in removing microbiological contaminants. Reverse osmosis filters typically have a large capital costs and require regular maintenance. Initially this study was to examine the effectiveness of in line filters, however following investigations revealed that installation and testing would be futile. As such this was not completed.

Later investigations indicated 0.5 μ m filters are available, although only exist as small models to be mounted under the sink and provide 1 tap. The flow rate from this tap is around 3L/min which is insufficient for most domestic purposes but may be acceptable for drinking water.

2.9 MATHEMATICAL MODELLING

It is anticipated that a mathematical model may be formed to predict the optimal first flush diversion volume based on several of the parameters which influence contaminant concentrations to supply water in accordance with the ADWG. This volume will be compared with the manufacturer's recommendations.

Very little data is available to predict the contamination levels in a rainwater tank. Since there are numerous variable parameters which cannot be controlled in this study, it is unlikely that a mathematical model could be compiled to accurately predict the level of contamination. This may be possible in a laboratory situation where such parameters can be accurately controlled.

Mathematical models to predict contaminants in stormwater from road runoff do exist but do not apply well to this situation. There are many mathematical models available

to predict the wind dispersion of contaminants and several computer programs freely available on the internet particularly from the US EPA website. A previous study at Thursday Island Power Station has that these models can be applied with acceptable accuracy.

In one instance at Bamaga Power Station, two separate twenty litre containers were filled with contaminants scraped from the gutters. This occurred only three days after heavy rains, indicating that it would be reasonable to assume a constant supply of contaminants in the above calculations. Visual inspections at other sites have also revealed that the contaminants are not completely removed after rainfall. This means that the solubility data, as listed for several of the contaminants, could possibly be used to calculate the concentration of contaminants in the tank, based on the amount of rainfall. Also, if it is to be assumed that there is a constant supply on contaminants, then little or no performance should be expected of the first flush devices, since this is in contrast with the principles on which first flush devices are based.

Many of the contaminants are insoluble; however the particles would still be washed into the tank. Nil information was found regarding the transport of particulate matter from roofs. This information would be necessary to undertake mathematical modelling of contaminants. It may be possible to apply soil erosion theory, however the majority of diesel particulate emitted from these gensets is PM_{2.5} (2.5 microns) and is much smaller than most soil particles so the theory may not be appropriate to the situation. Runoff and sedimentation characteristics of fine particles are different from those in the coarse fraction. Hence, it is necessary to consider particle size distributions in any runoff model for particle-bound PAH, (Murakami et al, 2003). Particle size distribution information was not available for the study.

2.10 GAPS IN CURRENT KNOWLEDGE

Due to the large rebates currently on offer, the practice of rainwater collection is becoming increasingly popular. Due to the rapid increase in the industry, design procedures, standards and maintenance practices are almost certain to change as knowledge surrounding the subject expands. ARID suggests that legislation surrounding rainwater collection is almost certainly subject to change within the coming years.

As stormwater systems are designed and built to accept periodic flushes, authorities are struggling to balance rainwater storage and stormwater capacity in new water sensitive subdivisions. In future years, as rainwater collection steadies, it is expected that stormwater system capacity will be better managed.

The WHO has indicated that an addendum to the Guidelines for Drinking Water Quality to adequately address maintenance of water tanks and associated systems. The issue is currently not addressed in either the WHO document or the ADWG. This is expected to be released early 2009.

Of interest to the study is that ADWG gives no specific guidelines for testing or maintenance regimes for water tanks in situations where runoff water is provided to workers as drinking water. Rather, the ADWG suggests the use of a risk analysis and water quality management plan. This may be addressed in a future addendum. At present, Ergon Energy does not have a water quality management plan in place. The document published by EnHealth titled Guidance on the Use of Rainwater Tanks, (2004) suggests maintenance procedures but again does not give testing requirements. Magyar et al(2008) described direct correlations between maintenance procedures and microbiological contamination.

Much of the literature available on installing water tanks indicates that tanks should ideally be connected to toilets and laundries, and state that further filtration would be required to provide drinking quality water. Generally, the literature does not offer information on such filtration or treatment.

The health effects of overexposure to chemicals are largely unknown. Many information sources state the PAH could possibly cause cancer, but do not confirm such. The health effects of chemicals are often linked to inconclusive health studies. When WHO publications were checked to confirm health effects, sources were again inconclusive, however the health limits given for drinking water quality do take this relative uncertainty into account.

2.11 CHAPTER SUMMARY

This chapter has identified some conflicting information in published literature, as well as identifying some gaps in current information. Much of this is deemed to be caused

by the large increase in rainwater harvesting in a relatively short period of time. The chapter has identified which contaminants can be expected to be found in the samples.

The chapter has also reviewed first flush devices, and identified some possible design flaws.

3.0 SITE DETAILS

As mentioned earlier, the selected sites were located in Northern and Far Northern Queensland. Figure 3.1 shows the locations of the selected sites and the extents of the Ergon Energy Network.

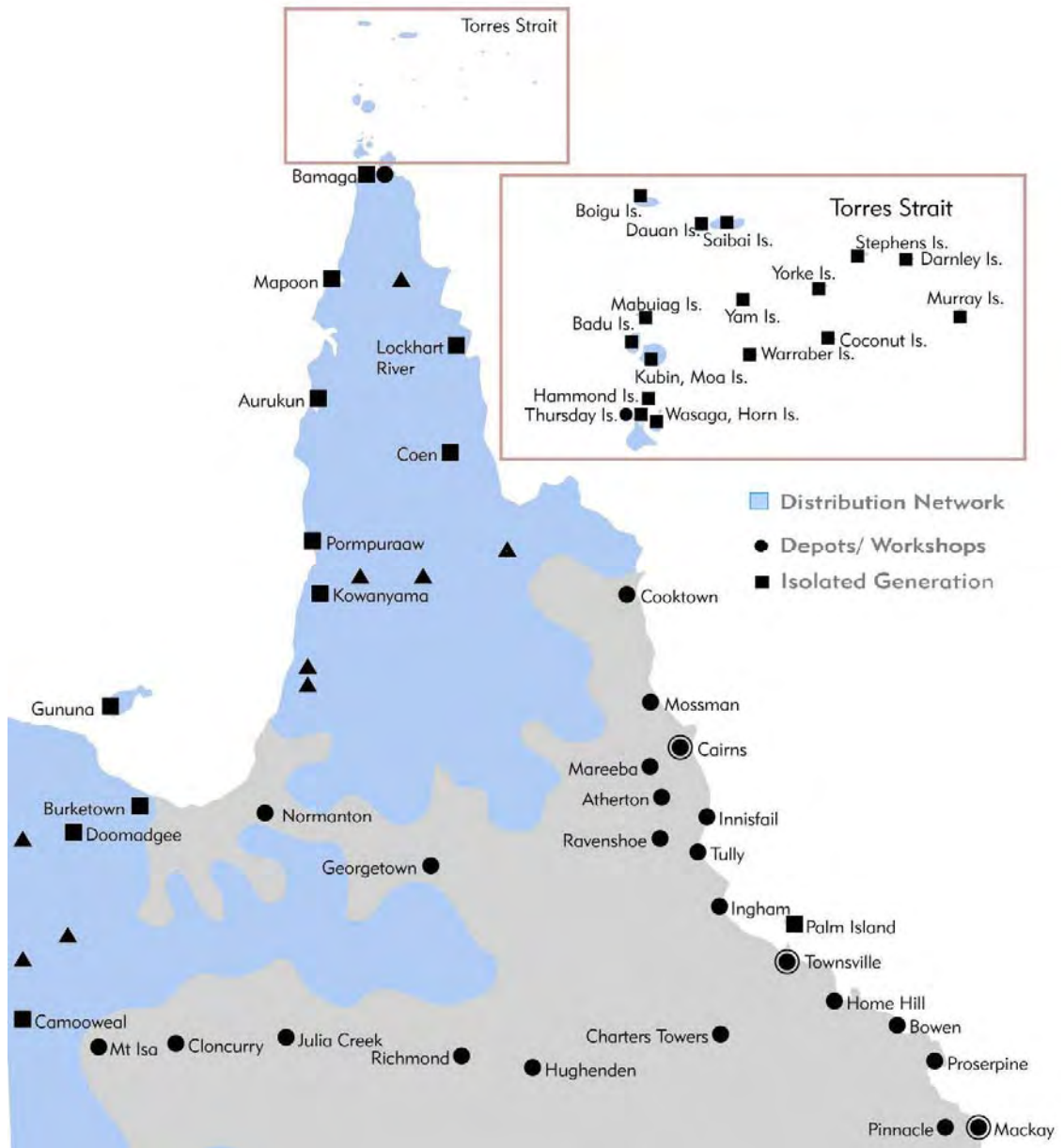


Figure 3.1 Map Indicating Study Site Locations

The sections below give detailed descriptions of each site and describe variations between sites. The hydraulic layout at each site is similar and a schematic of this is shown in Figure 3.2.

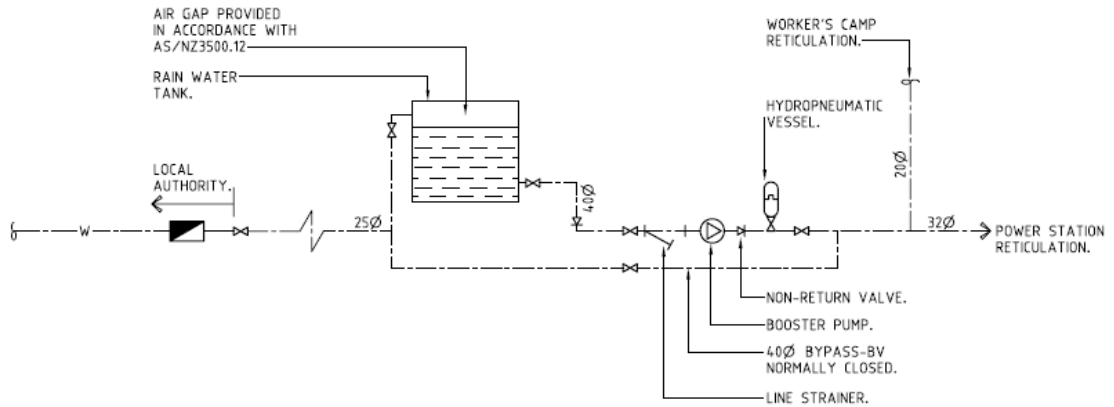


Figure 3.2 Hydraulic Schematic Layout

3.1 AURUKUN POWER STATION

The samples were taken from the tank collecting water from the accommodation block and line store roofs which are approximately 45m South East of the exhaust outlets. As noted in the weather observations in Appendix G, the prevailing wind direction is quite irregular. The roof had a visible chalky build up of contaminants prior to sampling.

The closest weather station is in Weipa, some 75km away. The area is believed to have similar weather patterns. The nearer weather station in Mapoon was damaged prior to the study. Three first flush devices had to be installed due to the layout of the downpipes as shown in Figure 3.3. The site has Zinalume roof sheeting and Zinalume gutters. The collecting roof is 144m² with a 15 degree pitch.



Figure 3.3 Aurukun Power Station – Line store and tank

3.2 BURKETOWN POWER STATION

The samples were taken from the tank fed by the power station. The centre of the collection area is no more 7m from the exhaust outlets. As noted in the weather observations in Appendix G, the prevailing wind direction is South East. This site is located around 35km inland from the coast. The roof is generally in good condition. Minor works were conducted during the study, but this is not considered to have impacted the results at all.

The weather data for this site is obtained from the weather station at Burketown Power Office in close proximity to the power station.

Only one first flush device was installed. The site has Colorbond roof sheeting and gutters. The collecting roof area is 54m² with a 10 degree pitch.

The tank at this site was not used during the period of the study, and may work as a controlled sample.

3.3 PALM ISLAND POWER STATION

The samples were taken from the tank fed by the power station roof. The centre of the collection area is approximately 25m east of the exhaust outlets. As noted in the weather observations in Appendix G, the prevailing wind direction is south south west. The site is in close proximity to the island coast and the roof has severely corroded. The roof has been nominated for replacement in the maintenance program and has some patches where previous roof penetrations have been removed.

The island does not have a weather station and the closest weather station is at Lucinda Point, around 25km away. The area is believed to have similar weather patterns. Only one first flush system was installed. The site has Colorbond roof sheeting and gutters. The collecting roof is 81m² with a 10 degree pitch. Daily flights are available to this site which increases the chances of getting samples returned with the designated timeframe.

3.4 LOCKHART RIVER POWER STATION

The samples were taken from the accommodation block which is approximately 50m South East of the exhaust outlets. As noted in the weather observations in Appendix G,

the prevailing wind direction is South East, therefore it's expected that the majority of contaminants would be blown in this direction.

The weather data shown in Appendix G is obtained from the weather station at Lockhart River Airport only a few kilometres from the power station, therefore the data should be appropriate to the site. Two first flush devices were installed on the downpipes as shown in Figure 4.2 and Figure 4.3. There are two downpipes running into the tank collecting water from each side of the building. The accommodation block has Zincalume roof sheeting and Colorbond gutters. The collecting roof is 58m² with a 15 degree pitch. The roof on the power station has aluminium sheeting and has a large surface area.

3.5 GUNUNA POWER STATION

Gununa is a small community on Mornington Island in the Gulf of Carpentaria. The samples at this site were taken from the tank fed by the accommodation block. The centre of the collection area is approximately 50m west from the exhaust outlets. As noted in the weather observations in Appendix G, the prevailing wind direction is south east. Minor extensions to the power station building were constructed during the study, but this is not considered to have impacted the results at all.

The weather data provided is taken from a weather station on the island. Only one first flush system was installed. The site has Colorbond roof sheeting and gutters. The collecting roof area is 58m² with a 15 degree pitch.

4.0 METHODOLOGY

4.1 CHAPTER OVERVIEW

The overall process of this study was to:

- 1) Undertake one initial round of contaminant testing. At the same time, site particulars were noted as well as the cleanliness of rainwater goods. This allows a snapshot of the water quality prior to installing first flush devices and cleaning the rain harvesting system.
- 2) Install first flush devices and clean rainwater goods and perform maintenance as necessary.
- 3) After leaving the systems for a period of time to collect further water, undertake a second round of testing.

Both rounds of sampling were conducted at various times at all power stations, to investigate the effects of any particular weather patterns.

This chapter describes the procedures for taking the samples and the problems involved therein. It also describes how and why the study was revised to include an analysis of the dry contaminants from the roof.

4.2 SAMPLING

Based on the literature review and discussions with the Cairns Water Laboratory (CWL) staff, it was found that metals, PAH and biological contaminants would be the most likely contaminants to cause a failure to comply with ADWG at these sites. Standard water quality parameters such as hardness, total dissolved solids, turbidity and colour were not analysed as they were not considered to be a problem based on initial research. Air particulate testing was also considered as it may provide valuable data required to fully understand the transport mode of the contaminants. As discussed further below, this was substituted for an analysis of the dry contaminants collected from the roof. The lubricant oil inside the genset is also monitored for several metals. These results are normally used to indicate engine performance, efficiency and wear. It was thought that the results of this testing may provide insight into the origin of some of the contaminants. All sampling was undertaken by the power station attendants and samples were forwarded to CWL.

4.2.1 WATER

Testing was handled by CWL throughout the study. Water samples for PAH and TPH were taken to CWL and forwarded to ALS Laboratory Group (ALS), since CWL did not have the resources to conduct these tests. ALS are NATA certified for these tests. Quality Assurance reports were attached to each water sample report to ensure accuracy of results.

During initial discussions with staff at the CWL, it was found that they were commissioning a new inductively coupled plasma mass spectroscopy (ICPMS) machine, and trial samples with various levels of metal contaminants were needed. Due to this, the Cairns Water Laboratory is not NATA accredited for the metal testing. NATA certifications are not considered essential for this study. Accuracy is monitored very frequently by the laboratory staff during the commissioning period.

The samples were analysed for the metal contaminants as listed in Table 4.1 and the PAH contaminants listed in Table 4.2. The suite of 23 PAH chosen were the only individual PAH which could be identified by ALS without incurring additional expenses and were the most likely to be detected in the samples at high concentrations. The 25 chosen metals are the most commonly analysed by CWL and were also the most likely to be detected in the samples at high concentrations.

1. Aluminium	2. Antimony	3. Arsenic
4. Barium	5. Beryllium	6. Boron
7. Cadmium	8. Calcium	9. Chromium
10. Cobalt	11. Copper	12. Iron
13. Lead	14. Magnesium	15. Manganese
16. Molybdenum	17. Nickel	18. Potassium
19. Selenium	20. Silver	21. Sodium
22. Tin	23. Titanium	24. Vanadium
25. Zinc		

Table 4.1 Metals analysed by CWL ICPMS

26. 3-Methylcholanthrene	27. 2-Methylnaphthalene	28. Dimethylbenz(a)anthracene
29. Acenaphthene	30. Acenaphthylene	31. Anthracene
32. Benz(a)anthracene	33. Benzo(a)pyrene	34. Benzo(b)fluoranthene
35. Benzo(e)pyrene	36. Benzo(g,h,i)perylene	37. Benzo(k)fluoranthene
38. Chrysene	39. Coronene	40. Dibenz(a,h)anthracene
41. Fluoranthene	42. Fluorene	43. Indeno(1.2.3.cd)pyrene
44. N-2-Fluorenyl Acetamide	45. Naphthalene	46. Perylene
47. Phenanthrene	48. Pyrene	

Table 4.2 PAH analysed by ALS Ultra Trace Machine

The metals were analysed using an ICPMS machine. The analytical procedures used at ALS Laboratory Group are those procedures published by the US EPA using an ultra trace machine. Water and samples were analysed using procedures defined in EP132B as published by the US EPA. TPH were analysed using test procedure EP080/071.

TPH were tested and were reported in separate carbon fractions as follows:

- C6-C9 Fraction
- C10 – C14 Fraction
- C15 – C28 Fraction
- C29 – C36 Fraction

In addition to these tests, general E-Coli tests and heterotrophic plate counts were conducted to monitor biological contaminants.

The tank was stirred using a clean paddle for approximately 5 minutes prior to sampling, to ensure that settled solids were suspended and the tank contents were homogenous. This was done to represent the water quality being delivered to outlets in a worst case scenario. Such a scenario may occur after heavy rainfall, cyclones, other natural disasters or natural currents which may set up within the tank. The sample was taken from the tank outlet approximately 100mm above the base of the tank. The attendants were instructed to sample immediately prior to the next flight arriving, such that samples were within the timeframes required for the relevant test.

The tank was not stirred prior to sampling at Aurukun. This was done so that samples were representative of the water which is normally being provided to the end user.

The samples were flown to Cairns, and then promptly taken to Cairns Water Laboratory. All samples which were not taken to the laboratory within 24 hours were discarded. Several samples were discarded due to arriving late.

4.2.2 AIR PARTICULATE MATTER

Ergon Energy have previously conducted an air quality study to examine the effects of using Heavy Fuel Oil (HFO) in gensets at the Thursday Island Power Station. The study was focused around several gasses emitted from the exhaust stacks, namely NO₂, SO₂ and CO. The study did not focus on PAH or metal dispersion. The manufacturer of the gensets (MAN B&W) provided initial stack emission data for the gensets when operating at 100% capacity and using HFO. This was used in a wind dispersion model and was followed by a field analysis and further dispersion modelling. The results of the two parts of the study concurred, indicating the manufacturer's information to be correct.

It was originally envisaged that this study would include air particulate sampling to find where and how far the PAH and metal contaminants would be dispersed. If possible, the concentrations would also be measured and the data from this used in a mathematical model to predict water quality.

The air quality study involved specialist equipment and expertise which could not be sourced locally. In the previous study, the equipment was out of service for several days whilst being transported to Thursday Island. This attracted large expenses. The University of Southern Queensland indicated they do not have the capacity to undertake such testing in remote locations. James Cook University in Cairns were also contacted but also had resource problems. Further discussions with a Brisbane based consultant indicated that such testing would likely involve a specialist consultant from Melbourne, and that costs involved in testing for PAH & metals would be substantial. Engaging a specialist consultant to undertake such testing at several remote locations would not fit within the scope of the project budget.

4.2.3 SOLIDS

Testing the solid matrix on the collecting roof for PAH was seen as a viable alternative to air particulate sampling. The solid matrix tests were not able to include a metals analysis since ALS was not able to undertake this at the time of initial investigations.

Solid matrix samples were analysed using similar procedures as that for water sample PAH analysis, defined in EP132B as published by the US EPA

A small area of the roof was swept using a new, clean paintbrush and the materials collected into a small sample jar. A paintbrush was used as a standard broom or dustpan and brush may contaminate the sample with particles. The sample had to be analysed at the ALS laboratory in Brisbane since CWL did not have the facilities to undertake the tests. Regrettably, the attendants were not asked to measure the area from which the sample was obtained. This information would be useful in the development of a mathematical model.

4.2.4 OIL & DIESEL

Oil samples are taken from the gensets on a quarterly basis to predict mechanical wear. The samples are tested for similar metals and contaminants as the water samples. These samples are taken by the Generation department within Ergon Energy, and only the results were provided. The sampling methodology and specific tests are not known.

4.3 LOGISTICS OF SAMPLING

The logistics involved in getting the samples to the laboratory within the specified time frames for the biological tests proved to be very difficult. Whilst there are weekly scheduled flights to most of the sites, these are subject to having sufficient passengers, good weather and no 'operational difficulties'. As such, the schedules are quite unreliable. During the second round of testing, aircraft were not able to land in Aurukun or Lockhart River for several days for a number of reasons. During the study period, two out of the three air charter companies stopped servicing these areas.

Freight to these communities is both expensive and unreliable. Parcels booked as 'Overnight or Next Available Flight' can remain at the airport for up to four days.

The heterotrophic plate count test and E-Coli test requires analysis one and two days after preparation. Since the laboratory does not operate on weekends, samples must be received by the laboratory prior to Wednesday afternoon which ruled out any flights later in the week.

For the above reasons, heterotrophic plate count tests and E-Coli tests were only conducted on a minority of samples. Also, the number of intended tests at each site was reduced, as many samples were not returned to the laboratory in the required time period. Many samples were lost in transport, returned late or not returned at all. This resulted in additional freight costs and hence the overall sampling involved in the project was reduced from the original arrangements.

4.4 DAILY WEATHER OBSERVATIONS

Weather data exists for selected locations from the Bureau of Meteorology (BOM) website. The following data is available on a daily basis:

- Maximum and Minimum Temperature;
- Recorded Rainfall; and
- Evaporation.

The following data is available at 9:00 AM and 3:00 PM daily:

- Temperature;
- Relative Humidity;
- Wind Direction;
- Wind Speed; and
- Mean Sea Level Pressure.

Weather data was considered for four weeks prior to each sample being taken. Where no rainfall occurred during this period, a reference was made to the last recorded rainfall event. The amount of rain which fell during the period between the initial sample being taken and the secondary sample being taken is also noted. Weather data is included in Appendix G.

4.5 INSTALLATION OF FIRST FLUSH SYSTEMS

The first flush devices were generally installed in accordance with the manufacturer's instructions. On a standard horizontal downpipe, a 90mm section of the downpipe was cut and removed. The T junction was inserted and glued into place. A diversion length of standard 90mm PVC stormwater pipe is attached to the bottom outlet of the T junction. The ball seat is wedged in between the diversion length and the T junction.

The diversion length must hold sufficient volume to store the recommended diversion amount. In most cases, there was insufficient space between the downpipe and the ground to install this length of pipe, and it was reduced as necessary. In future installations, additional capacity will be obtained by using larger pipe sizes for the diversion lengths, and tapered sockets to suit.

A screw socket was glued to the bottom of the diversion length. The bottom components, including screen, end cap and outlet were assembled. Once the sealing ball is inserted into the chamber, the bottom assembly can be screwed onto the socket.

Depending on the configuration of the existing downpipe and tank, other installation methods may be necessary. Three options are shown in Figure 4.1.

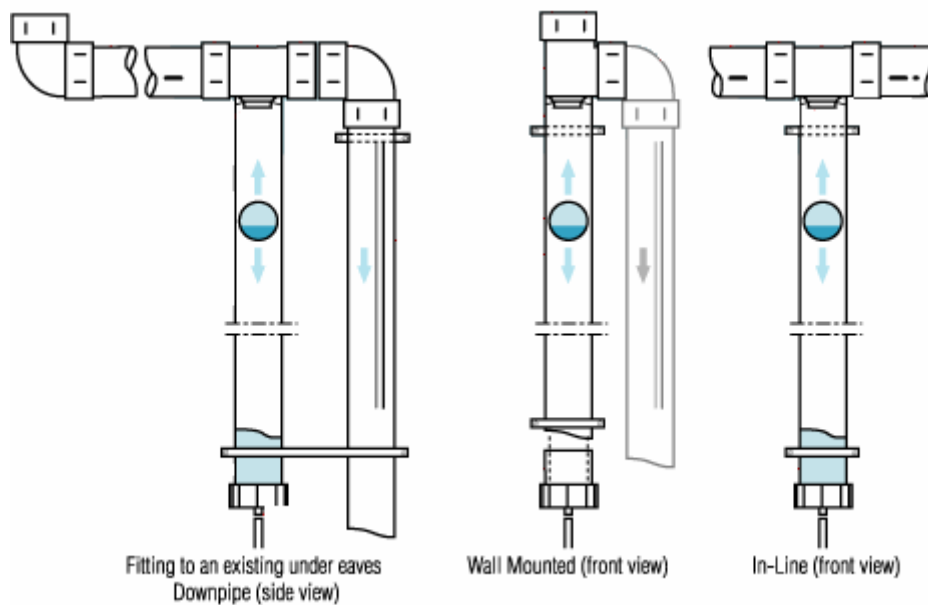


Figure 4.1 First flush installation methods - Image Courtesy of Rain Harvesting

Figures 4.2 and 4.3 show installed first flush devices at the Lockhart River site. Two devices were installed at this site. The length of the first flush system is approximately 1600mm on the windward roof side and 2100mm on the leeward roof side. Ideally the larger system would be installed on the windward side, however this was not the case as the downpipe levels did not suit.

All rainwater goods were cleaned at the time of installing the first flush device. The tank was desludged using a vacuum siphon and funnel and the majority of water remained in the tank. The roof, gutters and downpipe were cleaned as best as possible to remove contaminants.



Figure 4.2 First Flush Device - Eastern



Figure 4.3 First Flush Device - Western

4.6 CHAPTER SUMMARY

This chapter has discussed the procedures followed for the entire study. To reiterate, initial samples were taken and analysed, the first flush devices were installed, the rainwater goods were cleaned and after a period of time secondary samples were taken.

5.0 RESULTS

5.1 CHAPTER OVERVIEW

This chapter analyses the results on a site by site basis to discuss general patterns, followed by an analysis of each contaminant with respect to each site. The effects of variable parameters are discussed throughout. At the end of the chapter, the efficiency of first flush devices are discussed.

The raw data results of the testing are presented in Appendices B, C, D, G and H.

5.2 SITE RESULTS

The results found during the study differed significantly between sites for various reasons. As predicted, weather patterns greatly affected contaminants.

Only one of the initial samples met the criteria for drinking water as set by ADWG. Many of the criteria are based on aesthetic considerations as opposed to health consideration. Nevertheless, it is advisable and prudent to stick to these limits, as health based limits do not exist for many of the metals.

5.2.1 BURKETOWN

Burketown did not receive a recordable rain event in the period of time between when the initial sample and secondary sample were taken. The last recorded rain event at Burketown was nearly 8 weeks prior to taking the initial sample and was recorded to be 65.2mm. The first flush device was installed on 19/07/08. As mentioned earlier, the tank at this site has been disconnected from all downstream plumbing, and the tank was not used during the period of this study. This means that water did not enter or exit the tank during the period of this study and also that the first flush system would have had no effect. This site can be used to show the effects of detention time. Levels of boron, cobalt and magnesium increased around 25% after the period, levels of nickel increased nearly 80% whilst levels of iron decreased 80% as shown in Figure 5.1. The exact reasons for this are not fully understood but will be investigated further. It is possible that the tank simply was not stirred sufficiently prior to taking the first sample. The sample from this site was the only sample which had detectable levels of

TPH. This could possibly be for the same reasons which caused the metal concentration to rise.

Because of the long duration between rainfall events, the roof would be expected to have a high level on contaminant build up. It is possible that dew falling during the night is responsible for washing additional contaminants into the tank prior to the installation of the first flush. However, this area is quite dry during the winter months and very little, if any dew generally falls during the night. Unfortunately, the Bureau of Meteorology does not readily provide data on dew.

If the first flush system had been installed immediately after taking the first water sample, then dew would not have impacted this study since the volume would not be sufficient to fill the diversion chamber. This applies to all sites.

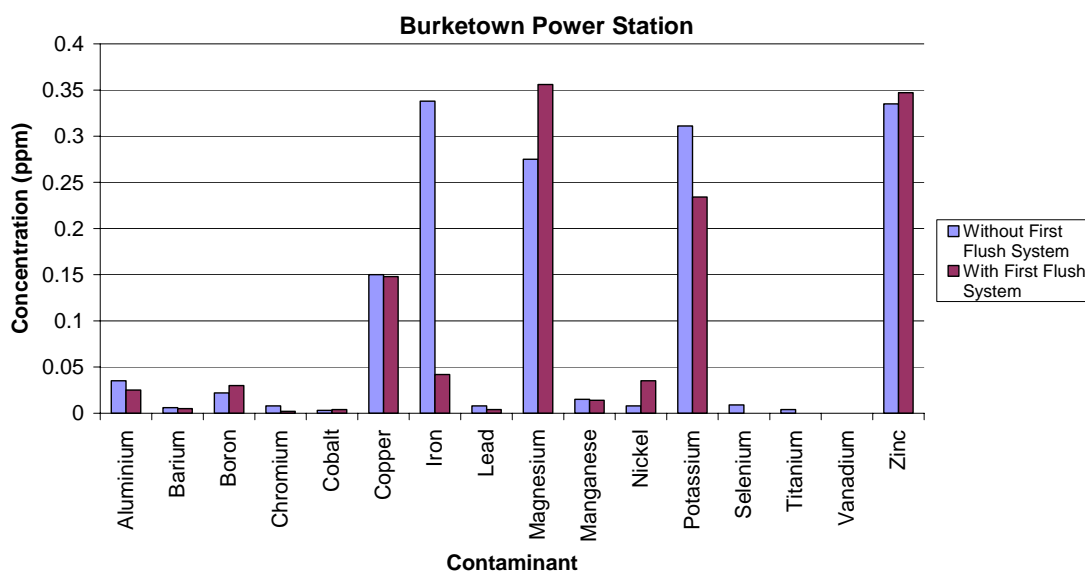


Figure 5.1 Concentrations of Metal Contaminants At Burketown Power Station

5.2.2 PALM ISLAND

The installation of the first flush system at Palm Island power station generally decreased the contaminant concentrations as shown in Figure 5.2, with the exception of potassium. The power station attendant had reported a slight rainfall event just prior to taking the sample. The BOM data states that 0.6mm fell during the day. The sample was taken early in the morning, so the actual rainfall just prior to taking the sample may be less.

The staff at this site reported that the tank is commonly used and is cleaned every year. This includes emptying and desludging the tank. The time between the tank being cleaned and the initial sample being taken is unknown. The tank was cleaned at the time the first flush system was installed.

The samples from this site failed the criteria set out by the ADWG for aluminium, iron and lead. The installation of the first flush system and cleaning of the tank apparently reduced the problem contaminants significantly, but was not able to reduce the lead concentration to below the ADWG guideline level.

Solid samples from the roof indicated the concentrations of PAH contaminants were significantly less at the time of the second test. Since PAH tend to form chemical bonds with solids of particulate matter, it may be possible that decreased PAH contaminants indicate decreased metal contaminants. Further testing would need to be undertaken before this could be considered as fully conclusive.

Wind speed and direction was very similar for the weeks preceding each test and cannot explain the difference in PAH contaminants on the roof. The reasons for the decreased contaminants on the roof are unknown.

If lower concentrations of metal contaminants were in fact present at the time of the second test, then the effects of the first flush device may be very minimal, if any.

This site was expected to have elevated concentrations of zinc in comparison to other sites because of the close proximity to the coast and accelerated corrosion rate. This was not the case.

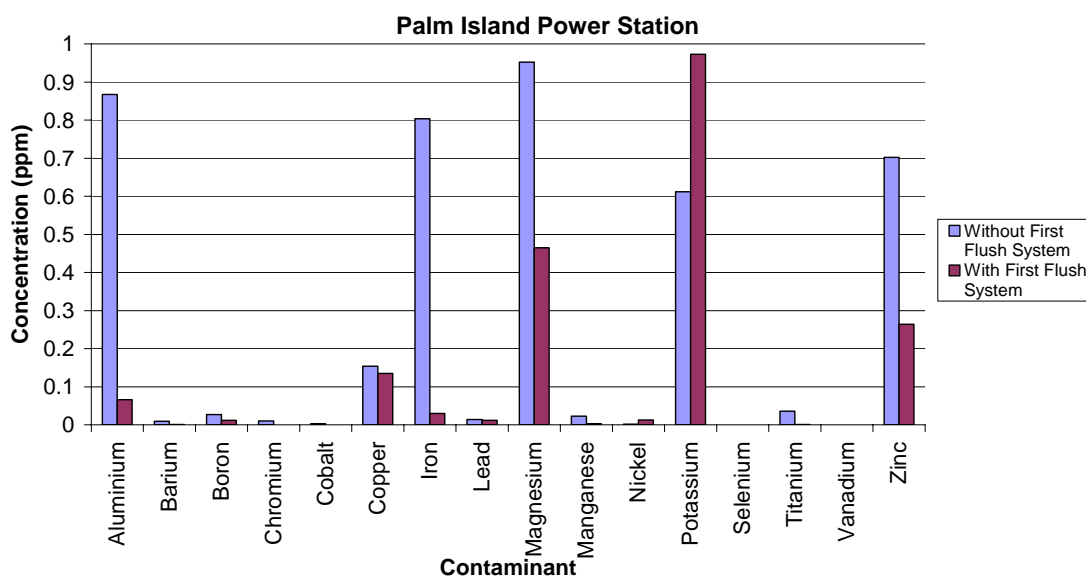


Figure 5.2 Concentrations of Metal Contaminants At Palm Island Power Station

5.2.3 GUNUNA

The initial sample taken from this site was the only sample taken during the study which passed the ADWG criteria. The first flush device was installed on 10/06/08. The tank and all rainwater goods were cleaned at the same time.

Concentrations of metal contaminants at Gununa power station actually increased during the period of the study. PAH contaminants were approximately the same for both tests.

The weather station at this site was damaged approximately two weeks prior to taking the second sample. As such, weather information during this period is not available.

An extension to the power station was constructed during the period of the study. Since the tank collects runoff from the accommodation block, some 50 metres away, the actual construction works are not believed to cause an increase to the concentrations of contaminants. During the construction period, the accommodation block was used extensively by construction workers, mechanics and commissioning staff. These staff report using the tank for various purposes.

Since there were only slight rainfalls during this period the stored volume would have significantly decreased, however the metal contaminants generally settle to the bottom of the tank below the outlet level. As such, volume of metal contaminants would not have decreased to the same extent as water volumes. This theory explains the increased

concentrations in the tank but further testing would need to be undertaken before this could be considered conclusive.

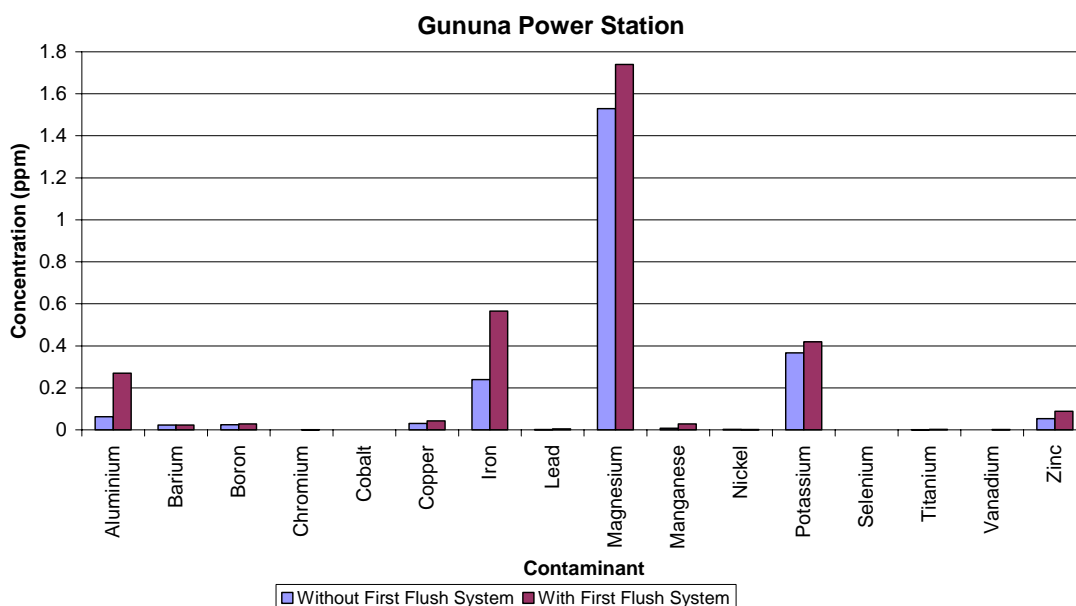


Figure 5.3 Concentrations of Metal Contaminants At Gununa Power Station

5.2.4 LOCKHART RIVER

Concentrations of both metal and PAH contaminants increased significantly at Lockhart River as indicated in Figure 5.4. During the period between the initial sample and secondary samples being taken, only 66mm of rain fell. Given that the roof area is 58m², this equates to 3,828L. This does not represent the full amount that would have entered the rainwater tank since the first flush devices would have diverted a certain quantity of this. The exact quantity is difficult to predict and depends on rainfall intensity. At the time of the installation of the first flush device, the tank was full. The tank at this site is used often for washdown and irrigation purposes which consume large amounts of water. It is generally not used for domestic purposes.

The increase in contaminant concentrations can be explained by prevailing winds blowing strongly from the exhaust stacks towards the collecting roof, dispersing contaminants on the rooftop. Also, the level of water in the tank at the time of taking the second sample was quite low (as noted by the Power Station Attendant). As explained in the Gununa Power Station results, a decreased water level corresponds to increased contaminant concentrations.

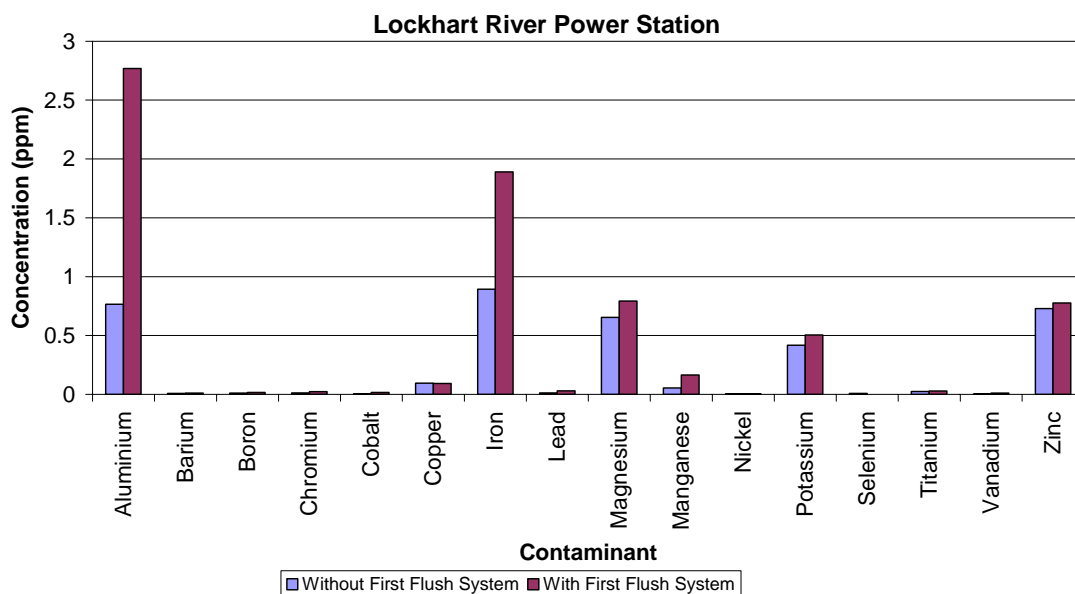


Figure 5.4 Concentrations of Metal Contaminants At Lockhart River Power Station

5.2.5 AURUKUN

When the samples were taken at Aurukun, the attendant did not stir the tank prior to taken the samples. This resulted in significantly lower metal concentrations and also in several metals not being detected at all as indicated in Figure 5.5. The results from this site are indicative of the water which is normally being provided to the outlets, but does not account for any mixing which may occur during heavy rainfall or other actions which may stir the tank.

At Aurukun, the failure to comply with ADWG was caused by biological contaminants, not metal contaminants which were the usual cause for failure.

The prevailing winds prior to the second sample were in the East South East direction.

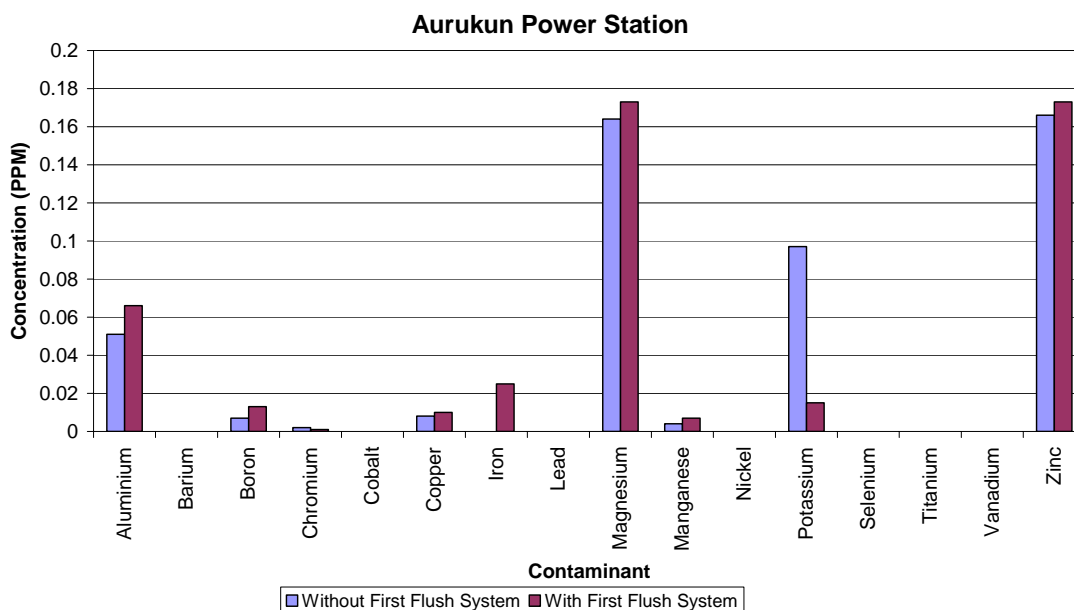


Figure 5.5 Concentrations of Metal Contaminants At Aurukun Power Station

5.3 METAL CONTAMINANTS

Metals were the main cause for water samples to fail the criteria set by ADWG. Each metal tested is analysed separately in the following sections.

5.3.1 ALUMINIUM

Aluminium concentrations at all sites are shown in Figure 5.6. The high concentrations of aluminium at both Lockhart River and Gununa are most likely caused by the aluminium roof sheeting at these sites. The other sites do not have aluminium roof sheeting. Aluminium bauxite in the Aurukun area may have elevated concentration at this site. It should be noted that bauxite mines exist in the area. Since Burketown and Palm Island do not have any aluminium rainwater goods, the aluminium concentration at these sites is believed to be the background level of pollution emitted by the diesel gensets, however many other origins are possible. The ADWG suggest that aluminium may be present in water through natural leaching from soil and rock. This may explain the concentrations of aluminium at Aurukun.

The ADWG guideline for Aluminium is 0.2 mg/L. This is based on problems associated with post-flocculation, which is not applicable to this study. No health based guideline was available at the time of writing by the ADWG or WHO *Guidelines for Drinking-Water Quality*. This remains under review. The degree of

aluminium absorption by the human body depends on pH, bioavailability and dietary factors.

Since the guideline is based on factors which do not apply to this study, it would be possible to state that the results are not of concern. However, the levels of aluminium encountered during the study exceed the guidelines by several times that amount. Since overexposure to aluminium can lead to gastrointestinal irritation, nausea and possibly lung damage, it would be prudent and advisable to adopt the 0.2mg/L limit as set out in ADWG and WHO *Guidelines for Drinking-Water Quality*.

Dwivedi, Agarwal & Sharma (2006) reported aluminium to be present in particulate emissions from diesel-fuelled compression ignition transport engines at concentrations between 0.9 to 2.2mg/g when using mineral diesel. To some extent this study explains the level of aluminium concentrations, the exact degree of which is unknown. Aluminium was also noted in several of the available oil test results in concentrations similar to that found by *Dwivedi, Agarwal & Sharma (2006)*.

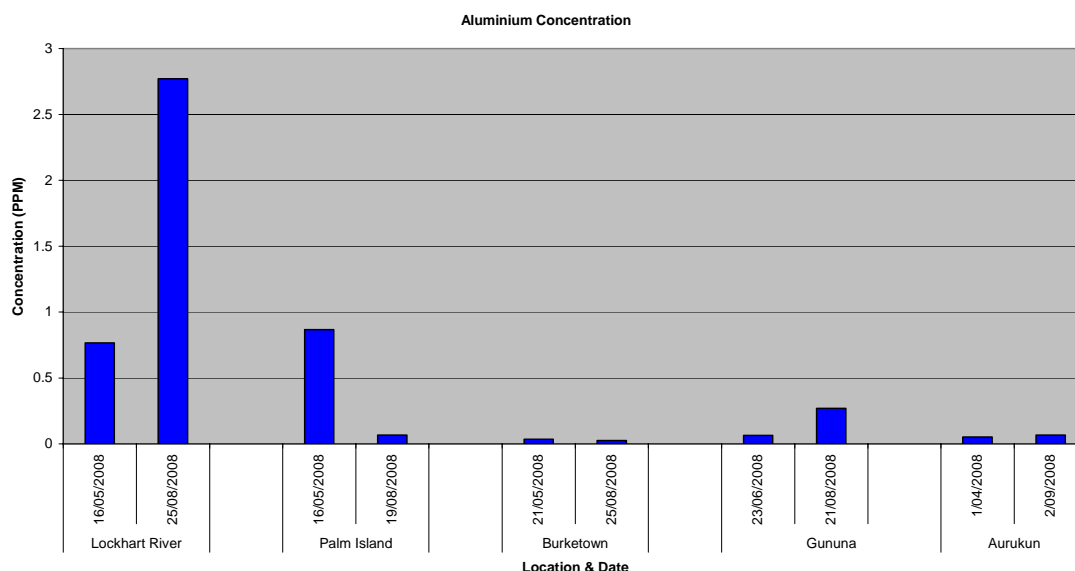


Figure 5.6 Aluminium Concentrations at Each Site

5.3.2 ANTIMONY

No antimony concentrations were found above the detection point.

5.3.3 ARSENIC

Arsenic was only found in one sample at a very minor concentration at Lockhart River. The concentration found is well below the limit and not of any concern.

5.3.4 BARIUM

The highest concentration of barium found was 0.023mg/L. The guideline values set by ADWG is 0.7mg/L. All samples had low concentrations of barium, indicating that the source of this metal is common to all sites. Oil sampling or the study conducted by Dwivedi, Agarwal & Sharma (2006) does not incorporate barium as a parameter, which means that the gensets are a possible source of this metal. There are also many other common possible sources at each site therefore any assumptions made would be inconclusive.

5.3.5 BERYLLIUM

No beryllium concentrations were found above the detection point. ADWG states that concentrations of beryllium in water may originate from atmospheric deposition where fossil fuels are burnt. For this reason the results were somewhat unexpected. The density of beryllium is quite small compared to other problem metals, which may somehow explain the results.

5.3.6 BORON

Concentrations of boron were found in all samples, however they were all well below the health based guideline set by ADWG. All results for boron were well be. The environmental chemistry of boron is not well understood, therefore the origin of the boron is difficult to identify.

It is likely that the boron originates from the genset exhausts. Boron was identified in several of the oil tests, indicating that it is most likely present (albeit in small concentrations) in the exhaust emissions. Boron was not one of the metals investigated by Dwivedi, Agarwal & Sharma (2006). Other data indicating that boron exists in diesel engine emissions was not able to be found.

ADWG indicated that higher levels of boron may be present in water sources as a result of seawater intrusion. Since the presence of boron was common to all sites this origin is unlikely as some of the sites are located away from the coast.

5.3.7 CADMIUM

Cadmium was found in two samples at a concentration of 0.0001mg/L. Cadmium was noted to be present in diesel exhaust by Dwivedi, Agarwal & Sharma (2006). This is the most likely source of cadmium, although cadmium may also originate from impurities in galvanised sheeting. The level found is not of any health concern.

5.3.8 CALCIUM

Calcium concentrations at all sites are within the aesthetic guidelines. Calcium concentrations at all sites are indicated in diagram 5.7. The reason for the particularly high concentration of calcium at Gununa Power Station is not known. No calcium build up was visible at the time of inspection. The level of calcium encountered is not hazardous to human health.

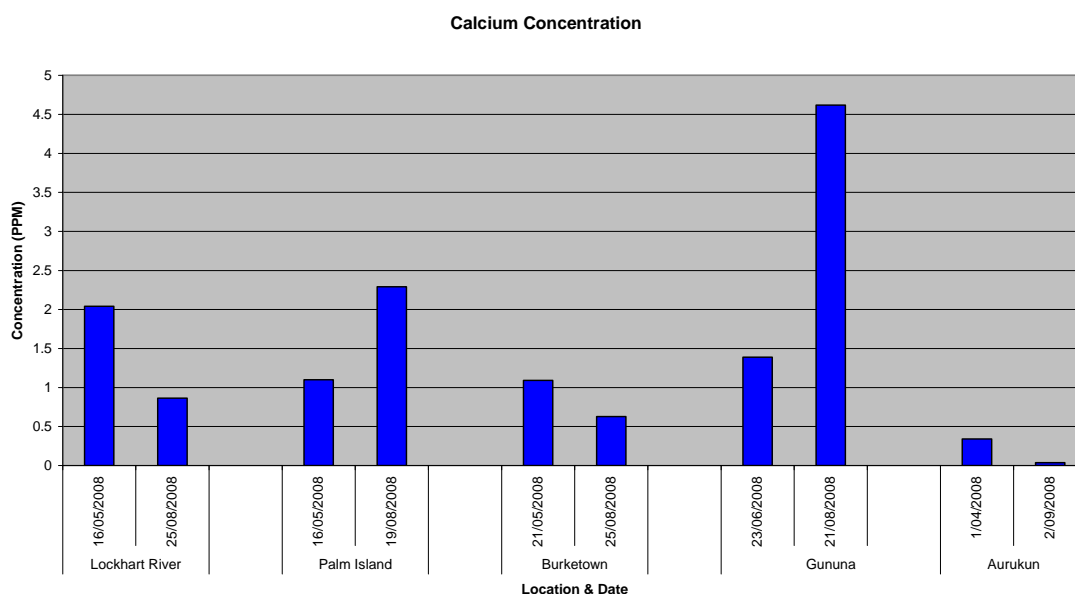


Figure 5.7 Calcium Concentrations at Each Site

5.3.9 CHROMIUM

Very low levels of chromium were encountered in nearly all samples. The study by Dwivedi, Agarwal & Sharma (2006) noted chromium presence in diesel engine

emissions. Another possible but unlikely source for chromium at this site is leachate from paint.

Further testing would be required to confirm whether trivalent, hexavalent or a combination of both types of chromium was found.

A health based guideline of 0.05mg/L was set by ADWG for chromium concentrations. Total chromium concentrations in natural drinking water are usually less than 0.005mg/L. The concentrations encountered during this study did not exceed 0.023mg/L indicating that whilst contamination is occurring, it is not of a health concern.

5.3.10 COBALT

The highest cobalt concentration detected was 0.016mg/L. Minor concentrations were detected in five out of the ten samples. No specific limits are set in ADWG for cobalt, however the concentrations encountered are not deemed to be hazardous to health.

5.3.11 COPPER

The highest concentration of copper found was 0.154mg/L. Copper was detected in every sample, indicating that the source is common to all sites. Possible copper origins in the samples include brass pipework or fittings. Copper is also contained in the emissions of diesel engines and is also contained in the lubricating oil in quite high concentrations. It is impossible to determine the contribution from each from the given results. Further testing would be required.

Higher levels of copper may lead to blue or green stains in bathroom and kitchen fittings such as the toilet or sink. This was not noticed at any of the sites.

The human body can tolerate quite high levels of copper, up to 12 times that level encountered hence copper does not pose a health risk at these sites.

5.3.12 IRON

The guideline of 0.3mg/L for iron is based on aesthetic considerations. Concentrations above this level may produce an objectionable taste. As shown in Figure 5.8, the highest concentration was well in excess of this, at 1.89mg/L. The human body's

minimum daily requirement of iron is around 7mg, however this requirement varies with age and sex. High levels of iron are not harmful to the human body and excess quantities are passed through urine. In summation, the levels of iron encountered in the study do not pose health risks, although may lead to objectionable tasting water.

Iron is present in abundance in both diesel and lubricating oils. Previous studies have noted iron in diesel particulate. The most obvious source of iron contained in the samples is from the roof sheeting and emissions from the diesel.

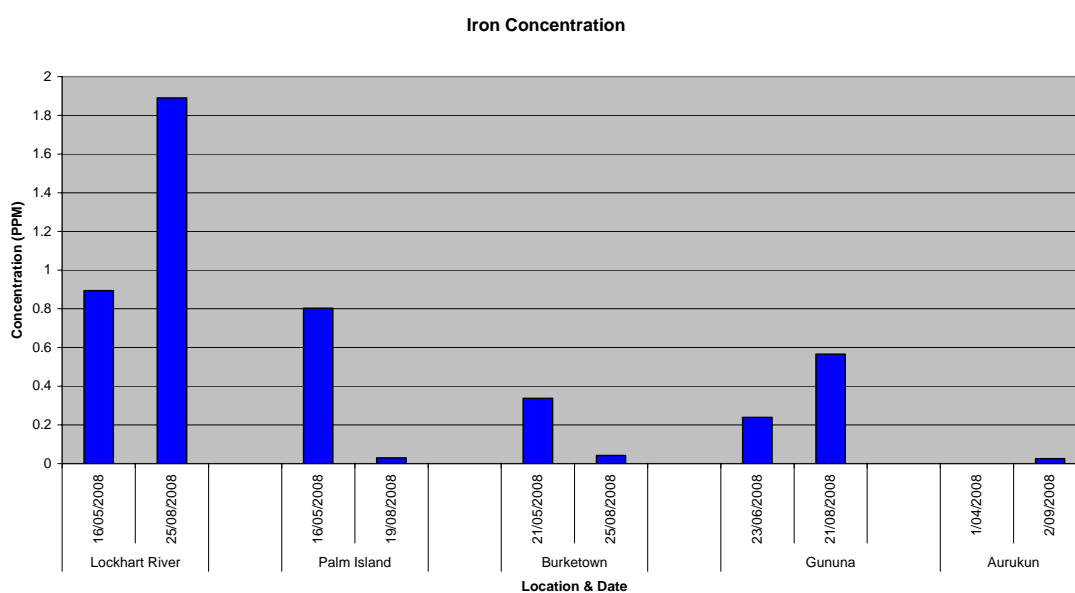


Figure 5.8 Iron Concentrations at Each Site

5.3.13 LEAD

The study by *Dwivedi, Agarwal & Sharma (2006)* identified lead as a component of diesel emission particulate. This is the most likely source of the lead encountered. Lead was also detected in several of the lubricating oil samples, which is in contradiction to the above study, which states that lead was not present in lubricating oil.

The highest concentration of lead encountered was 0.029mg/L. This is far in excess of the limit, 0.01mg/L. High levels of lead were detected in nearly all samples, with four samples above the ADWG health based limit. This would lead to significant health problems if employees were drinking this water for any considerable period of time including lead poisoning and other associated problems with the central nervous system

Lead may also be contained in some lower quality PVC. All pipes and plumbing used at these sites are high quality food grade fitting and pipes.

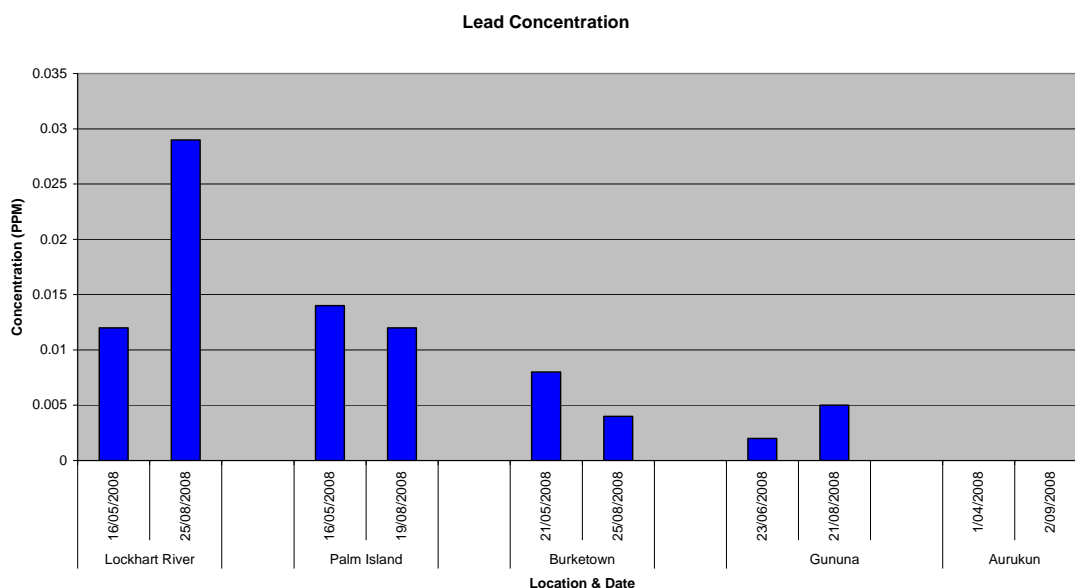


Figure 5.9 Lead Concentrations at Each Site

5.3.14 MOLYBDENUM

No molybdenum concentrations were found above the detection point. This was unexpected since molybdenum is present in the manufacture of some alloys, and is noted by WHO to be present in waters near mining sites.

5.3.15 SILVER

No silver concentrations were found above the detection point.

5.3.16 TIN

Only one sample contained detectable concentrations of tin. The concentration was 0.001mg/L. Concentrations this low may be from natural sources and do not pose health risks.

5.3.17 MAGNESIUM

The water samples taken from Gununa power station had much higher concentrations of magnesium than any of the other sites. The average magnesium concentration noted in lubricating oil samples was also slightly higher at this site. The highest concentration of magnesium detected was 1.74mg/L. No health based limit of

magnesium concentration is given by ADWG. Magnesium concentration in diesel particulate is noted to be higher as engine load increases and the magnesium concentration in lubricating oil is noted to be higher as engine wear increases. Direct correlations between water sample results and engine performance could obviously not be made due to the amount of uncontrollable variables, however it is interesting to note that the results compare so well. This may be a coincidence and further tests should be conducted to prove the correlation.

Other sources of magnesium at the sites are not known.

5.3.18 MANGANESE

Based on aesthetic considerations, ADWG states that manganese concentrations should not exceed 0.1mg/L. This was exceeded once at the Lockhart River site (concentration 0.164mg/L). All other samples had manganese concentrations well below this limit. Manganese is an essential element for humans, therefore WHO suggests a rather high limit of 0.4mg/L. Since all concentrations encountered were well below this limit, manganese concentrations do not pose a health risk at these sites.

Manganese is present in iron, steel and alloys therefore the most obvious source of this contaminant is in roof sheeting. Literature suggests that manganese is not contained in mineral diesel in large concentrations.

5.3.19 NICKEL

The highest concentration of nickel was 0.035mg/L. The limit set by ADWG is 0.02mg/L, however the limit set by WHO is significantly higher, at 0.07mg/L. It would be prudent to accept the ADWG limit.

Nickel is noted to be present in diesel particulate in relatively large concentrations (0.8–1.4mg/g). Whilst nickel is also used in the manufacture of stainless steels, the main source of nickel is expected to be from the diesel particulate since minimal stainless steel exists at these sites.

5.3.20 POTASSIUM

High levels of potassium will contribute to total dissolved solids. High levels of total dissolved solids will lead to objectionable taste and appearance but does not pose a principal health hazard.

The samples taken from the Aurukun site showed distinctly lower levels of potassium. Again, this is believed to be because the attendant did not stir the tanks prior to sampling. This indicates that most potassium lies in the layer of sludge at the bottom of the tank.

5.3.21 SODIUM

Sodium concentrations varied significantly depending on proximity to the coastline. Burketown and Aurukun are inland sites, whereas Lockhart River, Palm Island and Gununa are all coastal sites. The Gununa site, on Mornington Island, had concentrations of sodium which were three to four times higher than any of the other sites. This site is in close proximity to the coastline, however Palm Island power station is closer to the coastline. The reason for the higher concentrations at Gununa power station is believed to be because this site is directly downwind (in the prevailing wind) from the nearest coast. Palm Island power station is directly upwind from the nearest coastline in the prevailing wind.

Sodium is also present in diesel particulate in concentrations up to 12mg/g as well. It was also detected in the lubricating oil samples.

The highest level of sodium detected was 19.4mg/L. Sodium is not believed to be a health risk, therefore no guidelines are proposed by either ADWG or WHO. Concentrations of over 200mg/L will lead to objectionable taste.

5.3.22 TITANIUM

The highest concentration of titanium detected was 0.036mg/L. Very little information is available regarding the origins of titanium in drinking waters and no limits are given for drinking water concentrations. The titanium is believed to originate from the diesel particulate although this is difficult to confirm since titanium was not a parameter in the lubricant oil tests or in previous tests on diesel particulate.

5.3.23 VANADIUM

Very low concentrations of vanadium were detected in three of the samples. All concentrations were below 0.01mg/L.

5.3.24 ZINC

It is difficult to determine whether the zinc concentrations originate from breakdown of the galvanised rainwater goods or from diesel particulate. It exists in high concentrations in diesel particulate and lubricating oil, although the concentration in particulate reduces as engine load increases.

Gununa power station has aluminium roof sheeting and did show notably reduced levels of zinc concentration, indicating that the majority of zinc contamination originates from galvanised roof sheeting and other galvanised rainwater goods. This is in contrast to the samples taken from Lockhart River, which also has aluminium roof sheeting but contained zinc concentrations comparable to the other sites. This may be attributable to engine load but it is difficult to draw conclusions without additional data. Samples taken from Lockhart River power station showed elevated levels of nearly all contaminants due to reduced water levels which may also explain the additional zinc at this site.

5.4 BIOLOGICAL CONTAMINANTS

Insufficient results were obtained to be able to draw accurate conclusions regarding biological contaminants. A long term testing regime is needed to monitor HPC such that coliform numbers can be compared on a monthly basis. This would indicate any problems or failures in the collecting system.

5.4.1 E-COLI

The initial sample taken from Aurukun had 52 counts of E-Coli in the 100 mL sample. The ADWG states that E-Coli “*should not be detected in a minimum 100 mL sample of drinking water. If detected, immediate action should be taken*”. This level of contamination poses a serious health risk. It is highly likely that if this water had been consumed without prior disinfection (e.g. boiling) the consumer would have suffered gastroenteritis and / or dysentery. Based on this result, additional testing should ideally

be conducted to identify other specific coliforms, since E-coli are only an indicator of other coliforms and pathogens.

As mentioned earlier, E-coli originate from animal faeces. Possible sources of contamination at this site include faeces from frogs or mosquitoes living inside the tank, or bird droppings on the roof being washed into the tank. None were noted at the time of sampling.

As mentioned earlier, sufficient samples to draw accurate conclusions were unable to be conducted due to the logistics of obtaining samples from these sites within the required timeframe.

5.4.2 HETEROTROPHIC PLATE COUNTS

There are no specific guidelines or limits set by ADWG or WHO for plate count numbers. The value has little sanitary value unless compared with data collated over long periods. Staff at CWL indicated that the results are representative of other rainwater tanks tested, and symbolize very poor water quality.

The first HPC sample taken from Aurukun was tested undiluted and presented a lower result as such. Following HPC tests were conducted with 10 times dilution to provide more accurate results.

Given the lack of total results and the fact that most results only indicate counts > 2500, it is impossible to analyse the effects of weather, detention time or materials used in rainwater goods on heterotrophic organisms.

5.5 POLYCYCLIC AROMATIC HYDROCARBONS

Results for PAH in water and solid matrix samples are indicated in Appendices C & D respectively.

PAH were generally not found in the water samples. This was a very unexpected result, since it was initially thought that PAH would be the major contaminant in drinking water which would pose the biggest risk to health at these sites.

One of the staff at CWL had conducted significant research into this topic. The literature was not produced in English and was unable to be reviewed; however, the

author indicated that the low solubility of PAH in water would be the most likely explanation for the lack of PAH occurring in the water samples. It was later noted that PAH will also bind to the roof or other particles unless an extended period of rainfall is encountered. These two theories generally explain the results encountered.

The only two PAH which were detected in water samples were 2-Methylnaphthalene and Naphthalene at concentration of $0.3\mu\text{g/L}$ (0.0003mg/L) and $0.2\mu\text{g/L}$ (0.0002mg/L) respectively from the Burketown site. These two PAH are noted to have some of the highest solubility in water (refer Appendix F) and were detected in the second solid matrix samples taken from the roof of this site.

It is interesting to note that these PAH were not detected in the initial sample, and that Burketown had no recordable rain events during the time of the study. The metal contaminants at this site also increased during the time of the study. Again, it is reasoned that dew may have washed additional contaminants into the tank. It is also possible that a rain event occurred which was unrecorded.

Both 2-Methylnaphthalene and Naphthalene were recorded in many of the solid matrix samples at other sites, but did not present in the respective water samples. This is unexpected given the high solubility of both of these PAH. Other soluble PAH were also not detected in the water samples. The reasons for this are not fully understood. Discussions with project supervisors, ALS staff, CWL staff and a third party consultant indicated that PAH would almost certainly be present in the environment (as shown in the solid matrix results). The following suggestions were made:

- These PAH are possibly less dense than water, and would be floating on the surface similar to an oily film. By taking the samples from the lower outlet, no PAH will be found since separation would occur quickly after mixing. As shown in Appendix F, the PAH which are soluble in water also have similar densities to water, thereby discounting this theory.
- PAH may be volatile and possibly evaporate from the system after being in the tank for a period of time. This is possible, but since the sample taken from Burketown occurred after a long period without rain, it is considered unlikely.
- PAH may form a bond with the suspended solids and settle out to the bottom of the tank. As the outlet was 100mm from the base of the tank, no PAH were

found. This was noted in the literature review to be possible, although unlikely since the tanks were thoroughly stirred prior to testing.

The initial solid matrix sample taken from Palm Island power station revealed very high concentrations of PAH in comparison to other sites. Fluoranthene concentration in particular was recorded to be 106 times higher than that found in any other sample. The reasoning for this is not fully understood, however it is noted that major rainfall events had occurred within the previous days. Whilst this would be expected to having a cleansing effect on the roof, it appears to have had the opposite effect.

The high concentrations of contaminants appear to have dispersed by the time of taking the second sample. This is in contradiction to *Technical Factsheet on Polycyclic Aromatic Hydrocarbons* (US EPA 2006) which states that PAH are stable in environments for long periods of time.

The levels of PAH found in the Burketown water sample (0.000 3mg/L for 2-Methylnaphthalene and 0.000 2mg/L for Naphthalene) are far in excess of those limits given by both ADWG and WHO (0.000 01mg/L). Admittedly this limit is for BaP concentrations; however US EPA state that it is advisable to set this same limit to all PAH in the absence of other data. Since PAH are considered to be carcinogenic, further testing should be conducted to explain the Burketown sample results before risks associated with PAH can be fully and accurately assessed.

5.6 TOTAL PETROLEUM HYDROCARBONS

TPH were only detected in one sample. The sample from Burketown had 0.05mg/L of TPH in the C10 – C14 fraction. As mentioned earlier, the reasons why this occurred at the Burketown site may be associated with the causes of the increased metal concentration.

5.7 EFFICIENCY OF FIRST FLUSH SYSTEMS

Whilst the data obtained does give a slight indication, insufficient data is available to accurately assess the efficiency of the first flush devices. The results did not indicate a noticeable reduction in contamination levels. The concentrations of contaminants generally appeared to be influenced more by other parameters, such as stored water volume, weather patterns and materials used for rainwater goods. This is evident at the

Lockhart River, Gununa and Aurukun power stations where contaminants levels actually increased over the duration of the study due to other reasons.

6.0 CONCLUSIONS & RECOMMENDATIONS

The results clearly indicate that the stored water is unsuitable for the intended purposes, even with first flush devices. The concentrations of metals in the collected water pose quite serious health risks to any consumers. Whilst the concentrations of PAH were generally nil, or very low, the results did indicate that it is difficult to predict the level of contaminations which will occur, and what the causes for this are. The biological testing proved little given the limited number of tests. Since one test indicated extremely high counts of E-Coli, it should be noted that the possibility exists for biological contamination although good system design and regular maintenance should eliminate this.

The testing was quite expensive given the logistical problems encountered. If Ergon Energy elects to continue to use the harvested water for domestic purposes, they should be tested regularly and such testing should have allocated resources and funding.

It may be possible to process the water to a standard which is acceptable, however, this is not likely to be worth the expense. It is recommended that the water tanks at all power stations sites are disconnected from the domestic reticulation permanently. Due to short term budget constraints this may not be acceptable and as such, several possible solutions to provide a water supply in accordance with ADWG are discussed in Section 6.1. Each of the proposed options involve ongoing expense. It must also be kept in mind that due to the number of uncontrollable variables and gaps in this study it is possible that any measures implemented may be ineffective in producing a safe water supply and result in wasted resources.

If the tanks are to remain in use for domestic purposes, it is recommended that a Water Quality Management Plan be compiled to assess the risks of using the stored water for such purposes. The findings of this study should guide the compilation of the management plan.

Regardless of the chosen path, an immediate and temporary recommendation is that the tanks are disconnected from domestic supply, and clearly labelled as “Non Potable – Not For Drinking”. It is possible to isolate the rainwater supply from the domestic water reticulation via a valve. This action is also recommended. It may be necessary to lock / tag this valve.

If water is to be left untreated and isolated from domestic supply, any reticulation from this system must comply with the requirements of *AS3500 Plumbing And Drainage – Part 1 - Water Services – Section 9 – NON-DRINKING WATER SERVICES*.

Investigations revealed that the municipal supply in these communities is much more reliable than when the tanks were originally installed. It is considered feasible to remove the tanks from domestic service, and rely solely on the municipal supply. To this end, other water saving devices must be installed to comply with the relevant legislation. Again, this would require resources and funding.

Following cyclones and other natural disasters when the municipal supply is unlikely to be operational, it is unlikely that the rainwater tanks would not be contaminated. It is envisaged that drinking water would most likely need to be freighted to the communities in these situations anyway.

6.1 PROVIDING POTABLE WATER FROM TANKS

The first flush devices did not have a major impact on the quality of collected water. Whilst they do form part of a good water harvesting system, in this case they do not provide sufficient enhancement of the water quality. Other components recommended for a rainwater harvesting systems include:

- Rain heads on all downpipes – to divert leaves and other large debris.
- Gutter guards – to prevent leaves and other large contaminants from entering the guttering.
- 1mm stainless steel gauze screen – to prevent mosquitoes entering the tank.
- A light guard installed on the tank inlet – to reduce microbiological contamination.
- Correct gutter, downpipe and tank sizing – to ensure maximum collected water without causing gutters to overflow.
- A maintenance program - with regular inspections and cleaning to minimise contamination.
- Chlorination – to reduce biological contamination.

Given the polluting nature of diesel power stations, the results indicate that it is unlikely that the collected water will reliably comply with ADWG, even with the above measures in place.

Due to logistical problems and resource constraints, only two tests at each site were conducted. If the water is to be made suitable for domestic purposes, additional testing would be required to accurately assess the risks.

6.2 FURTHER WORKS

The study was limited to very few tests, with many uncontrollable parameters. It is suggested that a similar study could be completed in laboratory controlled conditions. The study could be completed adjacent a diesel engine or petrol engine, or both, to quantify the effects.

This study was not able to accurately define the parameters which affect PAH concentration in roof runoff. If a study were completed in controlled conditions, it behaviour of PAH may be better understood.

Following the results of the study, it would also be beneficial to consider such parameters as hardness, total dissolved solids, turbidity and colour as these may be outside the limits of the ADWG in contrary to initial assumptions.

Although in-line filters were not considered in this study, it may be valuable to investigate the efficiency of carbon, ultra violet and reverse osmosis filters with regards to improving water quality.

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APPENDIX A – PROJECT SPECIFICATION

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project
PROJECT SPECIFICATION

FOR: *Glen Hardy*

TOPIC: *Investigation into the performance of First Flush systems for Diesel Engine Based Pollution on Roof Runoff.*

SUPERVISOR: Vasantha Aravinthan & Ian Brodie (USQ Supervisors)
Principal Engineer Civil & Building (Ergon Energy Supervisor)

SPONSORSHIP: The project will be funded by my employer, Ergon Energy

PROJECT AIM: The project aims to provide accurate data regarding the performance of First Flush diversion systems at Ergon Energy Remote Powerstations. The information will be used to provide a potable water supply which meets the requirements of the Australian Drinking Water Guidelines.

PROGRAMME: Revision 2 – 29/07/08

- a) Conduct a literature review into possible contaminants emitted by continuously operated diesel engine plant and their solubility in rainwater.
- b) ~~Undertake air sampling particulate testing to confirm results of above investigations.~~
- c) *Undertake solid matrix analysis from material on rooftop to confirm results of above investigations.*
- d) Conduct an initial chemical and physical analysis of roof runoff in rainwater tanks.
- e) Install 5 first flush devices and 2 filters and then undertake further chemical and physical analysis for approximately 3 months.
- f) Conduct research into the effects on physical and chemical parameters of water quality due to changes in:
 - Frequency of rainfall
 - Water detention time
 - Brand, type and process of first flush system
- g) Compare contaminant levels to Australian Drinking Water Guidelines and performance of first flush systems to different types of filters
- h) Find an optimum volume for initial diverted flush based on above investigations
- i) Suggest modifications to existing systems based on analysis of data
- j) Compile a project dissertation

If time permits, developing a mathematical model based to predict the volume of first flush required to ensure drinking water complies with Australian Drinking Water Guidelines

Please see attached project schedule with estimated dates.

AGREED *G.H.* (student) _____ (supervisor)
 Date: *04 / 08* / 2008 Date: / / 2008

Co-examiner: _____

AGREED *[Signature]* (Principal Engineer Civil & Building)
 Date: *4 / 08* / 2008

***APPENDIX B - TABULATED WATER TESTING RESULTS
METALS & MICROBIOLOGICAL***

Chemical	Lockhart River			Palm Island			Burketown			Gununa			Aurukun		
	16/05/2008	25/08/2008	Change	16/05/2008	19/08/2008	Change	21/05/2008	25/08/2008	Change	23/06/2008	21/08/2008	Change	1/04/2008	2/09/2008	Change
Aluminium	0.766	2.77	2.004	0.867	0.066	-0.801	0.035	0.025	-0.01	0.063	0.27	0.207	0.051	0.066	0.015
Antimony	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arsenic	0	0.001	0.001	0	0	0	0	0	0	0	0	0	0	0	0
Barium	0.007	0.011	0.004	0.009	0.001	-0.008	0.006	0.005	-0.001	0.023	0.023	0	0	0	0
Beryllium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Boron	0.01	0.016	0.006	0.027	0.012	-0.015	0.022	0.03	0.008	0.025	0.028	0.003	0.007	0.013	0.006
Cadmium	0	0.0001	0.0001	0	0	0	0	0	0	0	0.0001	0.0001	0	0	0
Calcium	2.04	0.863	-1.177	1.1	2.29	1.19	1.09	0.628	-0.462	1.39	4.62	3.23	0.34	0.037	-0.303
Chromium	0.012	0.023	0.011	0.01	0	-0.01	0.008	0.002	-0.006	0	0.001	0.001	0.002	0.001	-0.001
Cobalt	0.004	0.016	0.012	0.003	0	-0.003	0.003	0.004	0.001	0	0	0	0	0	0
Copper	0.095	0.092	-0.003	0.154	0.135	-0.019	0.15	0.148	-0.002	0.031	0.043	0.012	0.008	0.01	0.002
Iron	0.894	1.89	0.996	0.803	0.03	-0.773	0.338	0.042	-0.296	0.239	0.566	0.327	0	0.025	0.025
Lead	0.012	0.029	0.017	0.014	0.012	-0.002	0.008	0.004	-0.004	0.002	0.005	0.003	0	0	0
Magnesium	0.654	0.792	0.138	0.952	0.465	-0.487	0.275	0.356	0.081	1.53	1.74	0.21	0.164	0.173	0.009
Manganese	0.054	0.164	0.11	0.023	0.003	-0.02	0.015	0.014	-0.001	0.008	0.028	0.02	0.004	0.007	0.003
Molybdenum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nickel	0.003	0.004	0.001	0.002	0.013	0.011	0.008	0.035	0.027	0.003	0.002	-0.001	0	0	0
Potassium	0.417	0.505	0.088	0.612	0.973	0.361	0.311	0.234	-0.077	0.367	0.419	0.052	0.097	0.015	-0.082
Selenium	0.007	0	-0.007	0	0	0	0.009	0	-0.009	0	0	0	0	0	0
Silver	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sodium	5.52	6.32	0.8	5.71	2.37	-3.34	0.907	0.66	-0.247	16.8	19.4	2.6	0.413	0.31	-0.103
Tin	0.001	0	-0.001	0	0	0	0	0	0	0	0	0	0	0	0
Titanium	0.025	0.028	0.003	0.036	0.001	-0.035	0.004	0	-0.004	0.001	0.003	0.002	0	0	0
Vanadium	0.002	0.01	0.008	0	0	0	0	0	0	0	0.002	0.002	0	0	0
Zinc	0.729	0.777	0.048	0.702	0.264	-0.438	0.335	0.347	0.012	0.053	0.089	0.036	0.166	0.173	0.007
E-Coli HPC	Not Tested	<1	Not Tested	<1	<1	<1	<1	<1	<1	<1	<1	<1	52	3	
		>2500		>2500	>2500	>2500	>2500	>2500	No Result	No Result	>250	>2500			

All metal concentration values expressed in mg/L.
Heterotrophic Plate Count Values expressed in CFU/mL

***APPENDIX C – TABULATED WATER TESTING RESULTS PAH
& TPH***

Polycyclic Aromatic Hydrocarbon	Lockhart River		Palm Island		Burketown		Gununa		Aurukun	
	16/05/2008	25/08/2008	16/05/2008	19/08/2008	21/05/2008	25/08/2008	23/06/2008	21/08/2008	1/04/2008	2/09/2008
3-Methylcholanthrene	0	0	0	0	0	0	0	0	0	0
2-Methylnaphthalene	0	0	0	0	0	0.3	0	0	0	0
7.12-Dimethylbenz(a)anthracene	0	0	0	0	0	0	0	0	0	0
Acenaphthene	0	0	0	0	0	0	0	0	0	0
Acenaphthylene	0	0	0	0	0	0	0	0	0	0
Anthracene	0	0	0	0	0	0	0	0	0	0
Benz(a)anthracene	0	0	0	0	0	0	0	0	0	0
Benzo(a)pyrene	0	0	0	0	0	0	0	0	0	0
Benzo(b)fluoranthene	0	0	0	0	0	0	0	0	0	0
Benzo(e)pyrene	0	0	0	0	0	0	0	0	0	0
Benzo(g,h,i)perylene	0	0	0	0	0	0	0	0	0	0
Benzo(k)fluoranthene	0	0	0	0	0	0	0	0	0	0
Chrysene	0	0	0	0	0	0	0	0	0	0
Coronene	0	0	0	0	0	0	0	0	0	0
Dibenz(a,h)anthracene	0	0	0	0	0	0	0	0	0	0
Fluoranthene	0	0	0	0	0	0	0	0	0	0
Fluorene	0	0	0	0	0	0	0	0	0	0
Indeno(1.2.3.cd)pyrene	0	0	0	0	0	0	0	0	0	0
N-2-Fluorenyl Acetamide	0	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0.2	0	0	0	0
Perylene	0	0	0	0	0	0	0	0	0	0
Phenanthrene	0	0	0	0	0	0	0	0	0	0
Pyrene	0	0	0	0	0	0	0	0	0	0
Total Petroleum Hydrocarbons										
C6 - C9 Fraction	0	0	0	0	0	0	0	0	0	0
C10 - C14 Fraction	0	0	0	0	50	0	0	0	0	0
C15 - C28 Fraction	0	0	0	0	0	0	0	0	0	0
C29 - C36 Fraction	0	0	0	0	0	0	0	0	0	0

All values expressed in µg/L.

APPENDIX D – TABULATED SOLID MATRIX RESULTS – PAH

Polycyclic Aromatic Hydrocarbon	Lockhart River		Palm Island		Burketown		Gununa		Aurukun	
	16/05/2008	25/08/2008	16/05/2008	19/08/2008	21/05/2008	25/08/2008	23/06/2008	21/08/2008	1/04/2008	2/09/2008
3-Methylcholanthrene	0	0	0	0	0	0	0	0		0
2-Methylnaphthalene	0	0	50	0	0	20	0	0		0
7.12-Dimethylbenz(a)anthracene	0	0	0	0	0	0	0	0		0
Acenaphthene	0	0	0	0	0	0	0	0	N	0
Acenaphthylene	0	0	0	0	0	0	0	0	O	0
Anthracene	0	0	0	0	0	0	0	0	T	0
Benz(a)anthracene	0	0	260	0	0	0	0	0		0
Benzo(a)pyrene	0	0	120	0	0	0	0	0	T	0
Benzo(b)fluoranthene	0	0	390	0	0	10	0	20	E	10
Benzo(e)pyrene	0	0	210	0	0	0	0	20	S	0
Benzo(g,h,i)perylene	0	0	110	0	0	0	0	0	T	0
Benzo(k)fluoranthene	0	0	180	0	0	0	0	0	E	0
Chrysene	0	20	240	0	0	0	0	0	D	0
Coronene	0	0	0	0	0	0	0	0		0
Dibenz(a,h)anthracene	0	0	0	0	0	0	0	0		0
Fluoranthene	10	20	1060	40	0	10	10	0		0
Fluorene	0	0	0	0	0	0	0	0		0
Indeno(1.2.3.cd)pyrene	0	0	100	0	0	0	0	0		0
N-2-Fluorenyl Acetamide	0	0	0	0	0	0	0	0		0
Naphthalene	0	0	0	0	0	10	30	20		10
Perylene	0	0	0	0	0	0	0	10		0
Phenanthrene	20	30	830	60	20	10	20	10		0
Pyrene	10	10	670	40	0	10	10	0		0

All values expressed in µg/kg.

APPENDIX E – METAL PROPERTIES

Metal	Cas Number	Chemical Formula	Description	Density (g/cm ³) @ 20°C	Solubility in Water (mg/L)	Melting Point (°C)	Boiling Point (°C)	Exposure Effects
Aluminium	7429-90-5	Al	Light, silvery-white to gray, odorless powder.	2.7	Insoluble	660	2327	Chronic exposure may cause lung damage. Chronic inhalation may cause pulmonary fibrosis.
Antimony	7440-36-0	Sb	A silvery or gray solid in the form of dust. Odorless.	6.684	Insoluble	630	1637	Prolonged or repeated skin contact may cause dermatitis. Chronic exposure may cause dizziness, dry throat, sleepiness, anorexia, and nausea. Chronic inhalation may result in liver, kidney, and cardiac changes.
Arsenic	7440-38-2	As	A silver-grey brittle, crystalline, metallic-looking substance odorless.	5.727	Insoluble	817		Abnormally low blood pressure and rapid heart rate are common early signs. Fever and rapid breathing may occur. Elevated blood pressure has been associated with chronic environmental arsenic exposure. Altered mental status, seizures, toxic delirium, encephalopathy, and delayed peripheral neuropathy are complications of acute arsenic poisoning. Inorganic arsenic crosses the placenta and may result in spontaneous abortion or stillbirth with either acute or chronic poisoning.
Barium	7440-39-3	Ba	A silver to white metallic solid. Odorless.	3.51	Insoluble	725	1640	Effects may be delayed.
Beryllium	7440-41-7	Be	A grayish-white hard light metal.	1.85	Insoluble	1278	2970	Chronic exposure to beryllium may cause berylliosis, a hypersensitivity pulmonary reaction. Symptoms may include delayed cutaneous hypersensitivity, depressed helper/suppressor T cell ratios
Boron	7440-42-8	B	Gray-brown powder. No odor.	3.33	Insoluble	2000	2550	Significant ingestions or dermal exposures can be associated with weak, rapid pulse, cyanosis and abnormally low blood pressure. The patient may present with reduced body temperature, elevated body temperature or normal body temperature. Headache, lethargy, restlessness, weakness, CNS irritation, and/or seizures may occur with long term or repeated exposures. There is insufficient information concerning the reproductive effects of borates in humans. Adverse testicular effects and infertility have been reported in animals. There have been limited animal studies which suggest decreased ovulation, fetotoxicity and developmental defects may occur with very high exposure levels. Maternal toxicity was present in some studies.
Cadmium	7440-43-9	Cd	Silver-white, blue-tinged, lustrous, odorless, solid.	8.642	Insoluble	321	765	May cause respiratory tract cancer. Repeated inhalation may cause chronic bronchitis. Chronic inhalation may cause nasal septum ulceration and perforation. Cadmium and compounds may cause lung, liver and kidney damage and lung and prostate cancer in humans. May cause loss of smell, emphysema, anemia, bone demineralization, and lung fibrosis.
Chromium	7440-47-3	Cr	Steel-grey, lustrous metal, odorless, available as lumps, granules, powder or high purity single crystals.	7.2	Insoluble	1840	2469	Prolonged inhalation may cause respiratory tract inflammation and lung damage.
Cobalt	7440-48-4	Co	A black powder.	8.9	Insoluble	1495	2870	Repeated exposure may cause sensitization dermatitis. Repeated exposure may cause allergic respiratory reaction (asthma). Chronic inhalation of dust may lead to restricted pulmonary function and interstitial fibrosis.
Copper	7440-50-8	Cu	Reddish, lustrous metal, odorless.	8.94	Insoluble	1083	2595	Prolonged or repeated skin contact may cause dermatitis. May cause liver and kidney damage. May cause lung damage.
Iron	7439-89-6	Fe	A gray lustrous powder.	7.86	Insoluble	1535	3000	Chronic exposure may lead to liver and lung damage. Repeated exposure may cause pancreatic damage, diabetes, and cardiac abnormalities.
Lead	7439-92-1	Pb	A bluish-white, silvery, gray heavy, ductile, soft metal, tarnishes on exposure to air.	11.3437	Insoluble	327	1740	Chronic exposure may cause reproductive disorders and teratogenic effects. Chronic exposure to lead may result in plumbism which is characterized by lead line in gum, headache, muscle weakness, mental changes,
Manganese	7439-96-5	Mn	A lustrous brittle silvery solid.	7.2	Insoluble (reacts)	1260	2097	Effects include a parkinsonism-like syndrome, muscle weakness, impairment of speech, gait disturbances, tremor, slurred speech, diminished libido and behavioral disturbances. Symptoms may last 1 to 2 months or longer. Manganese injection has produced teratogenic effects in experimental animals, although ingestion and inhalation studies showed no effect. Manganese deficiency during gestation has demonstrated adverse effects on the central nervous system of the developing fetus in experimental animals.
Molybdenum	7439-98-7	Mo	Dark-gray or black powder with metallic luster or coherent mass of silver	10.28	Insoluble	2622	3617	Anorexia and listlessness have been reported in animals.
Nickel	7440-02-0	Ni	Lustrous, silvery, odorless metallic solid.	8.9	Insoluble	1453	3007	Prolonged or repeated skin contact may cause sensitization dermatitis and possible destruction and/or ulceration. May cause respiratory tract cancer.

Metal	Cas Number	Chemical Formula	Description	Density (g/cm ³) @ 20°C	Solubility in Water (mg/L)	Melting Point (°C)	Boiling Point (°C)	Exposure Effects
Potassium	7440-09-7	K	Potassium, metal alloys is potassium mixed with some other metal, usually sodium. It is a liquid under normal conditions.	0.86	Reacts	63	760	
Selenium	7782-49-2	Se	Depending on allotropic form, the color can range from red to blue to grey to violet to black. Crystals	4.28	Insoluble	217	685	Prolonged or repeated skin contact may cause dermatitis. May cause reproductive and fetal effects. Chronic exposure to selenium may cause central nervous system effects, digestive tract disturbances, pallor, garlic breath, Chronic exposure to selenium may cause pallor, garlic breath, metallic taste, anemia, liver and spleen damage. Chronic selenium poisoning is characterized by loss of hair and nails, skin lesions, and abnormalities of the nervous system.
Silver	7440-22-4	Ag	Metal, white, lustrous solid.	10.5	Insoluble	962	2212	Chronic inhalation or ingestion may cause argyria characterized by blue-gray discoloration of the eyes, skin and mucous membranes. Chronic skin contact may cause permanent discoloration of the skin.
Tin	7440-31-5	Sn	Grey to almost silver-white, ductile, malleable lustrous solid, odorless.	7.16	Insoluble	232	2270	Prolonged or repeated skin contact may cause dermatitis. Chronic exposure to tin oxide dusts and fumes may result in stannosis (benign pneumoconiosis).
Vanadium	7440-62-2	V	Silvery-whitish powder. Resists corrosion.	6.015	Insoluble	1896	3477	CNS depression may occur, usually with fatal doses. Sensorimotor hemiparesis and aphasia developed shortly after ingestion of ammonium metavanadate. CNS manifestations include tremors, headaches, tinnitus, and changes in mental status.
Zinc	7440-66-6	Zn	Grey dust, lustrous powder or ingot, odorless.	7.14	Insoluble	420	908	Repeated inhalation may cause chronic bronchitis.

APPENDIX F – PAH PROPERTIES

PAH	Cas Number	Chemical Formula	Description	Density (g/cm ³) @ 20°C	Solubility in Water (mg/L)	Melting Point (°C)	Boiling Point (°C)	Exposure Effects
3-Methylcholanthrene	56-49-5	C ₂₁ H ₁₆	Yellow crystals or solid.	1.277	Insoluble	-	280	Effects may be delayed. Potential cancer hazard.
2-Methylnaphthalene	91-57-6	C ₁₁ H ₁₀	White crystalline solid.	1.0058	30 mg/L	32 - 35	241	Hemolytic anemia has developed in neonates following in utero exposure. In utero exposure causes cataracts in rats.
7.12-Dimethylbenz(a)anthracene	57-97-6	C ₂₀ H ₁₆	Yellow to greenish-yellow crystals or a yellow solid. Odorless.	-	Insoluble	123	440	In experimental animal studies, PAHs and metabolites cross the placenta. Female offspring of experimental animals exposed to PAHs during pregnancy have a decrease in the number of functional oocytes, sometimes such that they are infertile. PAHs are lipophilic and are excreted in breast milk, allowing for secondary exposure of nursing infants, although the potential significance of such exposure has not been determined.
Acenaphthene	83-32-9	C ₁₂ H ₁₀	White needles.	1.024	100 mg/L	90 - 93	279	In experimental animal studies, PAHs and metabolites cross the placenta. Female offspring of experimental animals exposed to PAHs during pregnancy have a decrease in the number of functional oocytes, sometimes such that they are infertile. PAHs are lipophilic and are excreted in breast milk, allowing for secondary exposure of nursing infants, although the potential significance of such exposure has not been determined.
Acenaphthylene	208-96-8	C ₁₂ H ₈	Colorless crystalline solid.	0.8988	16 mg/L	91 - 92	265	In experimental animal studies, PAHs and metabolites cross the placenta. Female offspring of experimental animals exposed to PAHs during pregnancy have a decrease in the number of functional oocytes, sometimes such that they are infertile. PAHs are lipophilic and are excreted in breast milk, allowing for secondary exposure of nursing infants, although the potential significance of such exposure has not been determined.
Anthracene	120-12-7	C ₁₄ H ₁₀	Colorless crystals when pure, Weak aromatic odor.	1.24	Insoluble	111 - 112	340	Prolonged or repeated exposure may cause thyroid damage. Effects may be delayed.
Benz(a)anthracene	56-55-3	C ₁₈ H ₁₂	Colorless leaflets or plates or coarse gold powder with a greenish-yellow fluorescence.	1.245	Insoluble	153 - 154	437	May cause cancer according to animal studies.
Benzo(a)pyrene	50-32-8	C ₂₀ H ₁₂	Pale yellow monoclinic needles from benzene & methanol. Faint aromatic odor.	1.351	3 mg/L	176 - 178	495	May cause cancer in humans.
Benzo(b)fluoranthene	205-99-2	C ₂₀ H ₁₂	Needles (recrystallized from benzene),	-	0.0012 mg/L	167	357	In experimental animal studies, PAHs and metabolites cross the placenta. Female offspring of experimental animals exposed to PAHs during pregnancy have a decrease in the number of functional oocytes, sometimes such that they are infertile. PAHs are lipophilic and are excreted in breast milk, allowing for secondary exposure of nursing infants, although the potential significance of such exposure has not been determined.
Benzo(e)pyrene	192-97-2	C ₂₀ H ₁₂	Colorless crystals or white crystalline solid.	-	Insoluble	178-179	492	Cancer suspect agent.
Benzo(g,h,i)perylene	191-24-2	C ₂₂ H ₁₂	Colorless to white crystalline solid.		Insoluble	278-280	500	In experimental animal studies, PAHs and metabolites cross the placenta. Female offspring of experimental animals exposed to PAHs during pregnancy have a decrease in the number of functional oocytes, sometimes such that they are infertile. PAHs are lipophilic and are excreted in breast milk, allowing for secondary exposure of nursing infants, although the potential significance of such exposure has not been determined.
Benzo(k)fluoranthene	207-08-9	C ₂₀ H ₁₂	Pale yellow needles or yellow crystalline solid.		Insoluble	215	480	May cause cancer according to animal studies.
Chrysene	218-01-9	C ₁₈ H ₁₂	Colorless crystals with blue fluorescence, probably odorless.	1.274	Insoluble	250 - 252	448	May cause cancer in humans. May cause cancer according to animal studies.
Coronene	191-07-1	C ₂₄ H ₁₂	Yellow to gold powder	1.371	Insoluble	437 - 440	525	
Dibenz(a,h)anthracene	53-70-3	C ₂₂ H ₁₄	White crystals or pale yellow solid. Sublimes.	1.282	Insoluble	266	524	May cause cancer in humans.
Fluoranthene	206-44-0	C ₁₆ H ₁₀	Light yellow fine crystals.	1.128	Insoluble	110	375	Prolonged or repeated skin contact may cause defatting and dermatitis.

PAH	Cas Number	Chemical Formula	Description	Density (g/cm ³) @ 20°C	Solubility in Water (mg/L)	Melting Point (°C)	Boiling Point (°C)	Exposure Effects
Fluorene	86-73-7	C ₁₃ H ₁₀	White leaflets. Fluorescent when impure.	1.203	Insoluble	113 - 115	295	May cause cancer according to animal studies.
Indeno(1.2.3.cd)pyrene	193-39-5	C ₂₂ H ₁₂	Yellow crystals.		Insoluble	163 - 164	536	In experimental animal studies, PAHs and metabolites cross the placenta. Female offspring of experimental animals exposed to PAHs during pregnancy have a decrease in the number of functional oocytes, sometimes such that they are infertile. PAHs are lipophilic and are excreted in breast milk, allowing for secondary exposure of nursing infants, although the potential significance of such exposure has not been determined.
N-2-Fluorenyl Acetamide	53-96-3	C ₁₅ H ₁₃ NO	Tan, crystalline powder.	1.27	Insoluble	190 - 193	463	Chronic ingestion may cause liver damage. May cause cancer in humans.
Naphthalene	91-20-3	C ₁₀ H ₈	White crystalline solid with distinctive odor of mothballs or coal tar.	0.979	30 mg/L	80	218	Prolonged or repeated skin contact may cause dermatitis. May cause liver and kidney damage. May cause anemia and other blood cell abnormalities. Animal studies have reported that fetal effects/abnormalities may occur when maternal toxicity is seen. Effects may be delayed. Chronic exposure may cause lung damage. Laboratory experiments have resulted in mutagenic effects. Chronic exposure may cause corneal injury, optical neuritis, blurred vision, and possible cataract formation.
Perylene	198-55-0	C ₂₀ H ₁₂	Yellow to colorless crystals from toluene.	1.362	Insoluble	273 - 278	443	May cause cancer according to animal studies.
Phenanthrene	85-01-8	C ₁₄ H ₁₀	Colorless monoclinic crystals with a faint aromatic odor. Solutions exhibit a blue fluorescence.	1.19	Insoluble	97 - 99	340	
Pyrene	129-00-0	C ₁₆ H ₁₀	Colorless or yellow crystalline solid.	1.27	1 mg/L	148 - 150	404	May cause cancer according to animal studies. Chronic effects may include leukocytosis and lengthened chronaxy of the leg muscle flexors.

APPENDIX G – WEATHER DATA

Aurukun Weather Data																			
Date	Day	Temps		Rain	Max wind gust			9:00 AM					3:00 PM						
		Min	Max		Dir	Spd	Time	Temp	RH	Cld	Dir	Spd	MSLP	Temp	RH	Cld	Dir	Spd	MSLP
		°C	°C	mm	km/h		local	°C	%	8th	km/h		hPa	°C	%	8th	km/h		hPa
4/03/2008	Tu	24	33.2	1.4	WNW	46	15:22	25.7	89	8	E	7	1011	32.3	56	6	NE	9	1006
5/03/2008	We	24	31.5	1.4	E	26	13:36	27.2	85	5	ESE	6	1011	27.4	78	7	W	9	1008
6/03/2008	Th	23	33	4	E	56	14:33	27.1	80	5	E	15	1011	25.1	94	7	ESE	24	1008
7/03/2008	Fr	23	32.7	35.4	N	48	16:16	27	80	4	ESE	15	1011	31.7	61	5	SE	9	1007
8/03/2008	Sa	23	29	38.6	ESE	26	10:42	25.9	89	7	E	7	1011	28.6	73	7	E	11	1008
9/03/2008	Su	24	32	0	NE	35	21:01	26.9	80	6	ESE	19	1012	31	59	7	ESE	13	1009
10/03/2008	Mo	23	31.6	51.6	W	24	16:23	25.7	87	7	S	6	1012	30.9	68	6	W	11	1008
11/03/2008	Tu	25	32.8	2.6	E	31	17:10	27.8	76	6	ESE	9	1011	32.3	55	5	ESE	7	1007
12/03/2008	We	24	31.9	0	SE	41	15:10	28.1	76	7	ESE	17	1009	29.9	74	8	E	20	1006
13/03/2008	Th	24	30.8	24.8	ENE	48	11:36	28.1	84	8	E	11	1011	27.5	86	8	NW	7	1008
14/03/2008	Fr	23	33	3	SE	48	15:29	27	84	5	E	15	1012	31.8	62	6	SSE	7	1007
15/03/2008	Sa	24	33.6	8.6	ENE	44	15:21	28.1	80	2	ESE	15	1011	32.3	53	6	E	17	1007
16/03/2008	Su	24	31.2	0.4	E	39	13:00	27.3	81	5	E	15	1010	30.1	67	7	ESE	17	1007
17/03/2008	Mo	23	33.4	0.2	E	41	14:17	27.8	78	7	ESE	17	1010	29.1	74	8	ESE	22	1006
18/03/2008	Tu	24	32.5	0.2	E	37	14:18	27.9	76	7	ESE	20	1010	29.4	68	7	E	15	1006
19/03/2008	We	23	33	0.8	E	43	15:10	27.5	80	7	ESE	13	1010	31.9	60	7	ESE	24	1006
20/03/2008	Th	24	33.1	3.6	ESE	28	12:38	27.7	80	7	SE	15	1008	32.3	56	7	SSE	9	1005
21/03/2008	Fr	24	32.7	2	E	26	20:00	27.8	78	2	ESE	17	1009	31.9	56	5	E	6	1005
22/03/2008	Sa	24	32.8	0	NNW	39	15:19	27.8	78	7	E	15	1010	28.6	77	8	W	9	1006
23/03/2008	Su	24	33.6	8	SSE	30	20:49	27.7	81	6	ESE	15	1011	32	55	6	SE	9	1007
24/03/2008	Mo	24	32.4	3.6	SE	26	13:15	28.2	79	6	E	7	1011	32.3	60	6	SSW	9	1007
25/03/2008	Tu	25	32.5	3	ENE	35	15:27	27.7	81	7	ESE	7	1010	32	63	6	SSW	4	1006
26/03/2008	We	24	33.1	1	E	30	13:52	27.2	80	7	ESE	11	1010	31.4	55	7	SSE	15	1006
27/03/2008	Th	22	32.9	0	E	24	9:43	26.1	81	7	ESE	9	1010	32	52	7	S	11	1007
28/03/2008	Fr	22	33.1	0	ESE	24	10:05	26.7	80	2	ESE	9	1012	32.4	51	5	E	9	1008
29/03/2008	Sa	24	32.4	0	NNE	28	14:10	27.9	72	3	E	13	1011	31.3	65	5	NW	4	1008
30/03/2008	Su	24	31.8	14.8	NNW	20	12:16	26.1	85	7	ESE	2	1011	30.9	60	6	NE	9	1007
31/03/2008	Mo	24	33.2	5	SE	30	17:40	26.2	88	6	E	7	1011	31.7	60	6	SW	7	1007
1/04/2008	Tu	24	29.1	15	ESE	33	15:16	25.5	94	8	E	6	1012	28.7	79	8	ESE	19	1008

Aurukun Weather Data																			
Date	Day	Temps		Rain mm	Max wind gust			9:00 AM						3:00 PM					
		Min	Max		Dir	Spd	Time	Temp	RH	Cld	Dir	Spd	MSLP	Temp	RH	Cld	Dir	Spd	MSLP
		°C	°C		km/h			local	°C	%	8 th	km/h			hPa	°C	%	8 th	km/h
5/08/2008	Tu	18	32.4	0	ESE	39	12:34	23.8	70	1	ESE	20	1015	31.4	34	2	ESE	17	1012
6/08/2008	We	16	33.5	0	SE	35	11:49	22.5	77	1	SSE	9	1016	30.3	51	1	WSW	13	1012
7/08/2008	Th	18	32.3	0	ESE	39	13:15	23.1	73	2	SE	17	1017	31.8	32	5	E	19	1012
8/08/2008	Fr	17	32	0	ESE	46	10:17	23.8	66	4	ESE	24	1015	31.5	30	2	ESE	20	1012
9/08/2008	Sa	20	29.6	0	ESE	46	11:46	23.7	66	7	SE	20	1015	28.5	50	7	ESE	20	1012
10/08/2008	Su	23	30.7	0	SE	43	11:10	24.4	65	7	SE	19	1016	28.2	53	7	SE	15	1012
11/08/2008	Mo	22	32.8	0	ESE	39	14:27	25	68	7	SE	15	1015	31.3	34	7	ESE	20	1011
12/08/2008	Tu	20	32.2	0	E	43	11:59	24.6	65	5	ESE	19	1015	31	39	5	ESE	26	1012
13/08/2008	We	21	31.8	0	ESE	46	13:16	24.7	60	1	SE	22	1016	30.4	42	4	E	28	1012
14/08/2008	Th	19	33	0	ESE	48	10:20	24	65	4	ESE	24	1015	31.8	37	6	ESE	22	1011
15/08/2008	Fr	20	31.5	0	ESE	31	9:55	24.4	67	2	ESE	15	1014	30.3	45	7	SE	13	1010
16/08/2008	Sa	20	31.8	0	SE	37	12:04	25.4	68	1	ESE	17	1014	29.7	48	8	E	9	1011
17/08/2008	Su	23	32.3	0	E	35	21:00	23.8	73	8	ESE	13	1016	31.4	43	7	E	9	1012
18/08/2008	Mo	21	31.9	0	ESE	43	10:53	23.6	68	7	SE	11	1017	30	43	7	ESE	11	1014
19/08/2008	Tu	19	31.9	0	ESE	57	14:58	24.7	59	1	ESE	22	1016	30.8	36	1	E	30	1013
20/08/2008	We	21	30.7	0	ESE	57	11:01	25.7	62	7	ESE	24	1016	29.4	46	7	E	30	1014
21/08/2008	Th	22	29.1	0	ESE	41	16:37	24.1	69	7	SE	9	1016	27.2	63	7	SE	22	1014
22/08/2008	Fr	23	32.6	0	SE	46	15:33	25	69	7	SE	17	1015	32	47	6	ESE	20	1011
23/08/2008	Sa	23	32.1	0.2	ESE	54	13:51	25.9	73	7	ESE	19	1014	30.4	50	6	ESE	26	1011
24/08/2008	Su	22	29.9	0	ESE	57	16:46	25	70	7	SE	19	1015	26.2	63	7	ESE	31	1013
25/08/2008	Mo	23	31.2	0	ESE	61	14:15	25.1	69	7	E	24	1015	29.1	51	7	E	28	1011
26/08/2008	Tu	24	30.4	0	ESE	48	16:35	25.4	69	8	ESE	24	1014	28.5	59	7	ESE	31	1011
27/08/2008	We	23	32.2	0	ESE	54	11:59	26.6	60	7	ESE	28	1015	30.7	47	6	E	26	1012
28/08/2008	Th	21	32.9	0	E	50	9:58	26.2	62	2	ESE	22	1014	31.8	39	5	ESE	30	1010
29/08/2008	Fr	21	33.7	0	E	56	13:56	26.4	62	3	ESE	24	1013	32	43	7	E	26	1010
30/08/2008	Sa	23	30.5	0	ENE	48	14:39	26.5	67	5	ESE	22	1014	28.6	63	7	E	22	1011
31/08/2008	Su	24	33.3	0.2	ESE	50	12:13	26.6	68	5	ESE	20	1014	32.4	43	5	ESE	26	1011
1/09/2008	Mo	24	34.6	0.2	E	56	10:17	27.5	62	7	ESE	30	1014	33.4	35	1	E	28	1010
2/09/2008	Tu	20	33.5	0	ESE	61	9:36	26.8	59	3	E	20	1015	32.2	34	6	ESE	26	1011

Gununa Weather Data																			
Date	Day	Temps		Rain mm	Max wind gust			9:00 AM					3:00 PM						
		Min	Max		Dir	Spd	Time	Temp	RH	Cld	Dir	Spd	MSLP	Temp	RH	Cld	Dir	Spd	MSLP
		°C	°C			km/h	local	°C	%	g th		km/h	hPa	°C	%	g th		km/h	hPa
26/05/2008	Mo	20	29.9	0	ENE	31	11:10	25.7	71		E	13	1019	28.2	48		ESE	15	1016
27/05/2008	Tu	18	28.2	0	ESE	30	6:30	25.3	59		SE	15	1019	27.3	36		ESE	15	1015
28/05/2008	We	19	26.7	0	SE	33	12:15	23.4	59		SE	19	1018	26	56		SE	17	1016
29/05/2008	Th	19	27	0	ESE	48	10:56	24.2	45		SE	22	1018	25.4	34		SE	17	1016
30/05/2008	Fr	21	25.6	0	SE	46	9:53	22.9	46		ESE	24	1018	24.2	33		SE	24	1016
31/05/2008	Sa	16	26.4	0	SE	37	10:24	22.1	51		SE	19	1017	26	32		SE	17	1014
1/06/2008	Su	13	26.3	0	SE	30	9:02	23.7	59		SE	17	1015	25.9	47		SSE	13	1013
2/06/2008	Mo	16	27.2	0	SSE	31	11:41	23.5	67		SE	17	1016	26.4	55		SSE	11	1013
3/06/2008	Tu	16	27.1	0	ESE	39	9:41	22.9	61		SE	20	1017	26.3	44		SE	15	1014
4/06/2008	We	18	27.1	0	SE	31	9:30	23.5	62		SE	19	1015	26.2	59		SSE	11	1013
5/06/2008	Th	20	29.4	0	SSE	30	9:18	25.7	58		SE	17	1015	28.8	48		SE	15	1012
6/06/2008	Fr	21	28.7	0	ESE	35	8:32	25.7	60		SE	17	1015	28.4	63		SW	11	1012
7/06/2008	Sa	21	27.6	0	ESE	35	6:22	25.9	71		E	9	1015	26.7	56		SSE	9	1013
8/06/2008	Su	22	26.3	0	SE	26	7:38	23	58		SSE	9	1016	24.7	72		SSE	6	1013
9/06/2008	Mo	19	29.6	0	E	28	10:53	25.7	68		E	9	1017	27.4	57		WSW	15	1014
10/06/2008	Tu	18	29.7	0	ENE	33	13:36	25.6	71		ENE	15	1017	28.3	52		E	13	1014
11/06/2008	We	18	29.5	0	ESE	30	12:33	25.5	66		ENE	17	1017	27.6	57		SSE	9	1015
12/06/2008	Th	20	29.1	0	E	33	10:42	26.4	65		ENE	13	1017	27.3	55		SE	15	1015
13/06/2008	Fr	18	29.1	0	ESE	31	11:40	26.2	64		E	17	1017	27.3	55		SE	15	1015
14/06/2008	Sa	23	28.3	0	SE	44	10:20	25	58		SE	22	1018	27.1	33		ESE	19	1014
15/06/2008	Su	19	25.3	0	SE	44	2:28	22.1	49		SE	19	1017	25.1	48		SE	19	1014
16/06/2008	Mo	19	26.1	0	SE	30	10:44	21.1	49		SSE	13	1016	25.5	46		SSE	9	1013
17/06/2008	Tu	15	29.7	0	ENE	26	13:12	23.4	66		Calm		1016	28.3	47		N	11	1014
18/06/2008	We	19	28.9	0	S	20	13:00	24.3	71		SSE	7	1016	28.4	51		SSE	11	1014
19/06/2008	Th	19	28.5	0	ESE	44	9:47	24.3	64		SSE	15	1016	28	40		SE	19	1014
20/06/2008	Fr	20	26.8	0	SE	50	6:26	21.2	38		SSE	24	1020	26.3	32		SSE	17	1016
21/06/2008	Sa	19	26	0	SE	59	9:43	20.4	47		SE	33	1020	25.7	38		SSE	17	1017
22/06/2008	Su	19	24.9	0	SE	54	6:06	20	45		SE	31	1020	24.6	34		SE	22	1018
23/06/2008	Mo	18	24.6	0	SE	44	10:53	20	48		SE	26	1020	23.7	27		SE	19	1017

Lucinda Point Weather Data (Palm Island)																
Date	Day	Temps		Rain mm	9:00 AM						3:00 PM					
		Min	Max		Temp		Cld	Dir	Spd	MSLP	Temp	RH	Cld	Dir	Spd	MSLP
		°C	°C		°C	%	g th		km/h	hPa	°C	%	g th		km/h	hPa
18/04/2008	Fr	20	25.6	4.2	23.6	60		S	24	1013	25.1	51		ESE	24	1010
19/04/2008	Sa	21	25.4	0	23.8	64		S	22	1014	25	61		ESE	17	1011
20/04/2008	Su	23	25.6	0	23.6	65		S	20	1014	24.9	65		SE	20	1011
21/04/2008	Mo	23	25.7	0	23.5	71		S	28	1015	25.4	61		ESE	24	1012
22/04/2008	Tu	22	25.8	0	23	78		SW	19	1016	25.2	64		ESE	13	1013
23/04/2008	We	21	26.1	0	22.8	76		SW	15	1015	25.1	64		Calm		1012
24/04/2008	Th	21	26.6	0	22.8	80		WSW	17	1016	24.9	66		ENE	13	1013
25/04/2008	Fr	22	26.8	0	23.4	77		SW	13	1015	25.2	62		ENE	13	1012
26/04/2008	Sa	21	26.6	0	22.1	75		SW	15	1014	25.8	61		ESE	11	1011
27/04/2008	Su	22	26.8	0	22.9	78		SW	13	1014	25.7	64		ENE	15	1011
28/04/2008	Mo	20	26.3	0	22.8	72		WSW	19	1014	25.2	65		NNE	20	1011
29/04/2008	Tu	20	28.3	0	22.2	75		SW	22	1016	27.7	34		S	11	1013
30/04/2008	We	22	25.7	0	24.4	70		SE	20	1017	25.5	56		SE	17	1015
1/05/2008	Th	23	24.9	0	23	71		S	28	1017	24.6	67		ESE	22	1014
2/05/2008	Fr	22	25.3	0.2	24.3	68		S	19	1015	23.9	77		SSE	7	1013
3/05/2008	Sa	23	25.6	0	23.6	70		S	26	1016	25.2	54		SE	17	1013
4/05/2008	Su	21	25.8	0	23.9	70		S	20	1016	25	62		SE	13	1013
5/05/2008	Mo	20	25.6	0	23.4	73		S	24	1016	24.5	63		SE	19	1013
6/05/2008	Tu	21	25	1	23.4	73		S	24	1016	24.6	54		SE	17	1014
7/05/2008	We	20	25.5	0	21.7	73		SW	19	1016	24.7	50		SE	15	1014
8/05/2008	Th	20	25.5	0	20.9	71		SW	17	1015	24.6	54		SE	15	1014
9/05/2008	Fr	21	24.7	0	23.5	61		S	17	1016	23.8	60		SSW	17	1014
10/05/2008	Sa	22	24.9	0.8	23.3	69		S	13	1016	24.6	65		SSE	15	1014
11/05/2008	Su	23	25	0	22.9	77		S	31	1016	24.7	64		ESE	17	1014
12/05/2008	Mo	22	24.8	1.2	23	74		S	19	1016	24.3	69		ESE	19	1014
13/05/2008	Tu	22	23.5	1.2	22.2	80		S	19	1017	21.6	80		SE	15	1015
14/05/2008	We	19	25.3	44.8	23	81		SSE	19	1018	24.9	65		ESE	24	1015
15/05/2008	Th	19	23.1	15.6	19.2	87		SSW	19	1020	22.1	71		SW	9	1016
16/05/2008	Fr	19	25.5	0.4	21.5	81		WSW	15	1019	25.1	67		ESE	7	1015

Lucinda Point Weather Data (Palm Island)																
Date	Day	Temps		Rain mm	9:00 AM						3:00 PM					
		Min	Max		Temp	RH	Cld	Dir	Spd	MSLP	Temp	RH	Cld	Dir	Spd	MSLP
		°C	°C		°C	%	8 th	km/h	hPa	°C	%	8 th	km/h	hPa		
22/07/2008	Tu	20	21.6	3.2	21.2	79		SSW	26	1017	20.9	82		S	30	1015
23/07/2008	We	18	21.6	5.4	19	77		S	26	1016	17.5	95		SW	33	1013
24/07/2008	Th	16	22.1													
25/07/2008	Fr	16	22.1	0.2	17.7	65		WSW	24	1016	21	57		S	13	1012
26/07/2008	Sa	16	20.6	0	17.1	67		SW	24	1018	20.2	47		ESE	11	1015
27/07/2008	Su	14	21.5	0	16.9	72		WSW	19	1017	19.6	66		NE	20	1012
28/07/2008	Mo	16	23.4								22.9	44		ESE	11	1010
29/07/2008	Tu	16	18.9	0	15.7	33		S	24	1018	18.5	29		Calm		1015
30/07/2008	We	13	20.3	0	15.1	66		Calm		1019	19.8	45		Calm		1017
31/07/2008	Th	14	20.9	0	16.2	71		Calm		1021	20.2	62		Calm		1018
1/08/2008	Fr	16	22.6	0	17.4	85		WSW	20	1020	22.4	61		SE	2	1016
2/08/2008	Sa	17	22.6	0	18.3	86		Calm		1018	22.3	63		NNE	19	1014
3/08/2008	Su	16	22.3	0	18.2	82		Calm		1019	21.3	79		S	17	1016
4/08/2008	Mo	18	23.6	0	20.4	83		Calm		1020	22.1	71		ESE	15	1017
5/08/2008	Tu	18	23.4	0	19.4	93		SW	15	1018	21.9	73		E	13	1016
6/08/2008	We	18	23.7	0	19.2	58		WSW	24	1019	22.9	42		SE	9	1016
7/08/2008	Th	17	22	0	19	62		SW	2	1021	21.2	58		SE	13	1018
8/08/2008	Fr	16	21.3	0	17.8	72		SW	6	1021	20.9	38		SE	20	1018
9/08/2008	Sa	17	20.1	0	18.8	65		S	13	1022	19.4	60		S	20	1018
10/08/2008	Su	15	21.4	0	17.5	79		Calm		1020	20.4	55		SSW	2	1017
11/08/2008	Mo	15	22.4	0	18.1	69		WSW	2	1020	22.2	41		Calm		1016
12/08/2008	Tu	16	20.5	0	19.2	59		S	15	1021	19.6	63		SSE	6	1019
13/08/2008	We	18	20.2	0	18.8	65		Calm		1022	19.3	66		S	4	1020
14/08/2008	Th	16	21.2	0	19	72		Calm		1021	20.5	66		Calm		1017
15/08/2008	Fr	17	21.6	0	19.6	76		S	19	1019	21.3	64		SE	4	1014
16/08/2008	Sa	17	22.7	0	18	79		SW	17	1018	22.3	44		E	7	1015
17/08/2008	Su	17	21.2	0	17.9	42		SW	2	1021	20.3	38		Calm		1018
18/08/2008	Mo	15	20.3	0	17	70		Calm		1023	19.8	53		Calm		1021
19/08/2008	Tu	17	20.5	0	18.4	60		Calm		1024	19.2	64		ESE	7	1022

Burketown Weather Data																
Date	Day	Temps		Rain mm	9:00 AM						3:00 PM					
		Min	Max		Temp	RH	Cld	Dir	Spd	MSLP	Temp	RH	Cld	Dir	Spd	MSLP
		°C	°C		°C	%	8 th		km/h	hPa	°C	%	8 th		km/h	hPa
23/04/2008	We	19	31.4	0	25.5	31	0	SE	15	1014	30.9	40	5	NNE	13	1011
24/04/2008	Th	20	33.9	0	25.2	21	4	SE	13	1015	32.9	16	5	SE	9	1012
25/04/2008	Fr	19	32.3	0	25	22	1	SE	15	1015	31.6	12	0	SSW	11	1012
26/04/2008	Sa	16	33	0	23.7	24	7	SE	9	1013	32.5	15	5	E	7	1009
27/04/2008	Su	15	33.3	0	24	36	5	SSW	4	1013	31	25	5	NNE	24	1009
28/04/2008	Mo	18	34	0	23	66	2	SSE	7	1014	33.7	12	1	ESE	11	1011
29/04/2008	Tu	19	34	0	23	25	1	SSE	17	1016	33.8		0	E	4	1012
30/04/2008	We	17	32	0	21.5	25	0	SE	11	1016	31.6	20	0	N	7	1012
1/05/2008	Th	16	30.2	0	23.5	49	0	E	11	1014	30.1	45	1	N	11	1011
2/05/2008	Fr	18	30.1	0	23.8	63	1	E	11	1014	29.6	44	1	N	9	1011
3/05/2008	Sa	18	33	0	24.1	35	1	E	9	1015	32.7	26	1	E	4	1011
4/05/2008	Su	20	32.2	0	24.9	27	1	ESE	4	1017	31.6	16	0	SSE	11	1012
5/05/2008	Mo	18	30.8	0	21.1	17	5	SE	15	1015	30.5	29	7	N	6	1012
6/05/2008	Tu	17	32	0	22.7	29	7	SE	9	1016	31	32	7	NNE	9	1012
7/05/2008	We	17	31.7	0	21.7		0	SSE	7	1016	31.5	21	0	E	15	1012
8/05/2008	Th	15	31	0	21.8	24	1	SE	7	1015	29.7	29	1	N	9	1011
9/05/2008	Fr	18	29	0	24.6	58	6	E	9	1014	28.5	41	6	NNE	9	1012
10/05/2008	Sa	16	29.1	0	22.5	48	0	E	13	1014	23.9	77	1	NNE	9	1011
11/05/2008	Su	16	30.5	0	22	39	0	SSE	13	1015	23.8	78	1	NNE	15	1012
12/05/2008	Mo	18	29.1	0	23.3	40	1	ESE	13	1015	29	48	1	ESE	13	1013
13/05/2008	Tu	18	29.7	0	23.8	47	1	SE	7	1015	28.5	57	1	SE	15	1013
14/05/2008	We	17	30.2	0	22.6	71	0	SSE	13	1016	29.6	39	1	NNE	15	1013
15/05/2008	Th	17	31.7	0	22.7	63	1	SSE	7	1018	31	33	2	ENE	9	1014
16/05/2008	Fr	18	31	0	25	47	1	SSW	11	1017	30.6	36	1	NNE	6	1014
17/05/2008	Sa	18	33.5	0	23.3	62	0	S	9	1017	32.9	18	1	S	6	1013
18/05/2008	Su	17	26.5	0	19.8	34	0	SE	15	1020	26	19	0	S	20	1016
19/05/2008	Mo	13	27.6	0	17.1	33	0	NNE	22	1020	26.6	17	0	ESE	6	1016
20/05/2008	Tu	14	29	0	19.3	32	0	SE	15	1018	28.9	21	0	NW	4	1015
21/05/2008	We	14	29.6	0	19	31	0	SE	9	1017	28.9	22	0	N	9	1015

Burketown Weather Data																
Date	Day	Temps		Rain mm	9:00 AM						3:00 PM					
		Min	Max		Temp	RH	Cld	Dir	Spd	MSLP	Temp	RH	Cld	Dir	Spd	MSLP
		°C	°C		°C	%	8 th		km/h	hPa	°C	%	8 th		km/h	hPa
28/07/2008	Mo	11	28.6	0	19.6	27	0	SSE	15	1017	28	13	0	S	17	1014
29/07/2008	Tu	12	23.5	0	15.1	24	0	SE	15	1019	23.2	13	6	SSE	17	1014
30/07/2008	We	9.2	26.7	0	17	23	0	SE	11	1018	24.9	21	0	N	4	1015
31/07/2008	Th	11	26.8	0	19.2	33	0	SSE	6	1019	26	36	0	NNE	9	1016
1/08/2008	Fr	13	26.7	0	18.6	75	4	E	6	1019	26	57	2	N	9	1015
2/08/2008	Sa	14	31.2	0	20.8	41	2	SSE	20	1019	30.9	19	2	SSE	13	1014
3/08/2008	Su	15	33.2	0	20.5	29	2	SE	11	1018	33	14	2	SSE	9	1013
4/08/2008	Mo	16	30.8	0	20	25	3	SE	9	1019	28.8	25	0	N	7	1015
5/08/2008	Tu	15	29.5	0	22	23	5	SE	22	1018	29.2	17	5	S	20	1016
6/08/2008	We	16	26.9	0	18.7	26	0	SSE	31	1021	26	13	0	SE	31	1017
7/08/2008	Th	12	27.3	0	17.2	24	0	SE	22	1021	27	14	0	SSE	22	1017
8/08/2008	Fr	13	27.8	0	17.7	21	2	SE	26	1020	27.3	13	2	SSE	9	1016
9/08/2008	Sa	14	28.8	0	17.8	20	0	SSE	11	1020	28	16	0	S	15	1015
10/08/2008	Su	15	28.3	0	19.5	14	0	SSE	28	1020	28.2	14	0	SE	11	1016
11/08/2008	Mo	15	25.4	0	16.5	23	5	SE	30	1021	24.8	13	5	SSE	19	1016
12/08/2008	Tu	12	27.8	0	14.9	20	5	S	19	1020	27	16	0	SSE	9	1016
13/08/2008	We	14	29.8	0	17.3	22	5	SE	15	1020	28.7	26	5	SE	6	1016
14/08/2008	Th	15	29.1	0	17.9	18	7	SSE	22	1019	28.7	22	0	S	11	1015
15/08/2008	Fr	16	28.3	0	17.9	27	4	SSE	30	1018	28	22	0	SSE	13	1013
16/08/2008	Sa	15	25.5	0	17.2	19	5	SSE	31	1020	25.1	12	2	SE	17	1016
17/08/2008	Su	14	25.2	0	16.6	19	2	SE	20	1022	24.5	12	5	S	17	1018
18/08/2008	Mo	15	26.9	0	19.6	23	6	SSE	26	1022	26.5	15	4	E	9	1019
19/08/2008	Tu	11	28.8	0	17.1	30	5	SE	15	1021	27.5	18	2	E	9	1017
20/08/2008	We	16	27.8	0	20.3	31	1	SE	9	1020	27.3	40	5	N	6	1017
21/08/2008	Th	16	28.8	0	23	50	0	ENE	7	1020	28.5	43	0	ENE	7	1017
22/08/2008	Fr	18	25.7	0	19.6	27	7	S	24	1022	25.5	15	7	S	22	1018
23/08/2008	Sa	15	26.2	0	17.2	23	3	SSE	28	1021	25.3	15	6	SE	22	1016
24/08/2008	Su	17	30.2	0	20.8	15	7	SSE	17	1019	30	25	7	SE	6	1015
25/08/2008	Mo	18	29.3	0	22	20	2	SE	13	1018	28.7	41	1	NE	9	1014

Lockhart River Weather Data																
Date	Day	Temps		Rain mm	9:00 AM						3:00 PM					
		Min	Max		Temp	RH	Cld	Dir	Spd	MSLP	Temp	RH	Cld	Dir	Spd	MSLP
		°C	°C		°C	%	8 th		km/h	hPa	°C	%	8 th		km/h	hPa
18/04/2008	Fr	23	29.2	0	27.1	69	7	SE	28	1010	27.8	62		SE	24	1008
19/04/2008	Sa	21	29.5	0.2	26.4	66		ESE	24	1011	28	60		SE	24	1008
20/04/2008	Su	20	29.5	0	26.9	69		ESE	20	1011	28	62		ESE	22	1008
21/04/2008	Mo	24	29.9	0	27.2	68		ESE	19	1012	28.7	65		ESE	26	1009
22/04/2008	Tu	24	29.7	0	27.6	68		SE	22	1012	28	65		ESE	24	1010
23/04/2008	We	24	29.5	0	26.8	70		SE	24	1013	28.4	66		ESE	24	1010
24/04/2008	Th	22	29.7	0	27.2	72		SE	22	1013	28.3	69	4	ESE	17	1011
25/04/2008	Fr	19	29.3	0	25.6	76	6	SSE	11	1013	28.1	63	5	ESE	19	1010
26/04/2008	Sa	19	29.5	0	25.7	79	5	SSE	11	1012	28.1	64	3	E	19	1009
27/04/2008	Su	19	29.2	0	25.1	84	6	SSE	9	1012	27.7	68	7	ESE	17	1009
28/04/2008	Mo	20	29.3	0	26.3	80	4	SSE	13	1013	28.2	65	7	ESE	19	1010
29/04/2008	Tu	19	30	0	26.2	79	6	SE	13	1013	28.9	62	3	ESE	26	1011
30/04/2008	We	25	28.7	0	26.5	76	8	SE	28	1013	27.1	74	8	SE	28	1011
1/05/2008	Th	25	29	0	26.6	74	6	SE	31	1013	27	73	8	ESE	31	1010
2/05/2008	Fr	23	29.4	0	28	69	5	SE	24	1012	28.6	61		SE	24	1010
3/05/2008	Sa	20	29	0	26.4	74	6	SSE	22	1012	27.8	68	5	SE	30	1009
4/05/2008	Su	24	29.7	0	26.5	69	6	SE	24	1013	27.2	70	7	SE	24	1010
5/05/2008	Mo	23	29.3	0	27.1	66	5	SE	28	1012	28.4	60	6	SE	30	1010
6/05/2008	Tu	24	29.3	0	24.8	76	7	S	13	1013	27.7	63	5	SE	28	1010
7/05/2008	We	24	28.8	0	25.6	65	6	SE	28	1013	26.8	64	7	ESE	22	1010
8/05/2008	Th	23	27.1	0	25.4	68		SE	20	1012	24.9	78	7	SE	19	1010
9/05/2008	Fr	22	28.8	0.4	25.7	71	5	SE	26	1013	26.8	63	6	SE	22	1011
10/05/2008	Sa	24	27.4	0	25.4	81		SSE	13	1013	23.5	88		ESE	20	1011
11/05/2008	Su	23	29.1	5.4	26.1	78	5	ESE	22	1013	26.7	71		SE	24	1011
12/05/2008	Mo	24		0	25.9	76	7	SE	20	1013	27.1	66		ESE	24	1011
13/05/2008	Tu		29.1	0							27	67		ESE	24	1012
14/05/2008	We	21	29.1	0	26.1	77		SE	19	1015	27.5	69	4	SE	28	1012
15/05/2008	Th	20	29.3	0	25.6	80		SE	13	1016	28	68		ESE	20	1013
16/05/2008	Fr	22	29.2	0.6	26.7	73		SE	20	1016	27.1	67		SE	24	1013

Lockhart River Weather Data																
Date	Day	Temps		Rain mm	9:00 AM					3:00 PM						
		Min	Max		Temp	RH	Cld	Dir	Spd	MSLP	Temp	RH	Cld	Dir	Spd	MSLP
		°C	°C		°C	%	8 th		km/h	hPa	°C	%	8 th		km/h	hPa
28/07/2008	Mo	14	28.3	0	21	87	1	Calm		1015	27	56	3	E	17	1010
29/07/2008	Tu	10	28	0	18.7	65	2	N	2	1015	25.7	59	1	E	19	1012
30/07/2008	We	17	27.2	0	21.3	84		W	4	1016	24.1	64		SE	22	1014
31/07/2008	Th	17	27.5	0	24.3	57	5	ESE	24	1018	25.3	54		ESE	28	1015
1/08/2008	Fr	17	28.1	0	24.3	64		SE	26	1017	25.9	57		SE	26	1014
2/08/2008	Sa	14	28.2	0	21.6	81		SSE	11	1016	26.4	59		ESE	20	1013
3/08/2008	Su	17	28.3	0	25	64		SE	22	1016	26.4	59		SE	24	1013
4/08/2008	Mo	16	28.8	0	25.4	69		ESE	20	1017	27.2	62		SE	24	1015
5/08/2008	Tu	19	29	0	24.8	67		ESE	24	1016	27.2	59	4	ESE	26	1014
6/08/2008	We	17	27.9	0	23.6	79	3	SE	13	1016	26.9	66	3	ESE	24	1014
7/08/2008	Th	17	28.3	0	23.8	79	6	SE	24	1017	27.4	60	5	SE	28	1014
8/08/2008	Fr	22	26.3	0	24.5	69		SE	28	1016	24.8	65	8	SE	30	1014
9/08/2008	Sa	21	23.5	0.6	20.7	96	8	SSE	17	1016	23.1	76		SE	28	1013
10/08/2008	Su	20	25.4	4	20.9	96		SE	15	1016	24.3	73		SE	28	1013
11/08/2008	Mo	21	26.4	0.2	22.8	81	7	SSE	17	1016	24.8	71		SE	24	1013
12/08/2008	Tu	22	28	0	23.7	71		SE	26	1016	25.7	62		SE	33	1014
13/08/2008	We		25.7								24.4	72		SE	30	1014
14/08/2008	Th	21	28	0.4	23.9	72	7	SE	22	1016	24.2	73		SE	22	1013
15/08/2008	Fr	22	28	0	23.2	80	8	SSE	22	1015	26.3	64		SE	20	1011
16/08/2008	Sa	22	28.7	0	23.9	83	6	SSE	11	1015	25.8	68	5	ESE	26	1012
17/08/2008	Su	22	28.6	0	24.7	70	3	SE	28	1016	25.7	60		E	26	1015
18/08/2008	Mo	23	27.3	0	24.6	66	8	SE	28	1018	24.9	65	5	ESE	24	1016
19/08/2008	Tu	23	28	0	25.4	67		ESE	28	1017	25.9	59		SE	33	1016
20/08/2008	We	22	27.7	0.2	24.9	73	6	SE	31	1017	24.6	74	7	SE	30	1016
21/08/2008	Th	22	24.9	0	22.6	89		SE	20	1017	23.8	89		SE	24	1014
22/08/2008	Fr	22	26.1	1.4	22.5	92		SSE	11	1016	24.9	84		SE	20	1013
23/08/2008	Sa	22	24.2	0.6	23.2	89	8	SE	24	1015	23.3	82	8	SE	30	1012
24/08/2008	Su	22	23.8	0.4	23.1	90	8	SE	26	1016	22.8	85	8	SE	28	1014
25/08/2008	Mo	21	26	2	23	92	8	SE	24	1016	24.9	77	8	SE	28	1013

APPENDIX H – OIL SAMPLING DATA

WEAR CHECK

Your Specialist in Oil, Fuel, Grease & Coolant Analysis

Diesel Engine



OIL AND EQUIPMENT CONDITION REPORT

UNIT NO.	Auru ENG1	DATE SAMPLED	14/02/08	COMPARTMENT NAME	Engine 1
UNIT MAKE	Cummins	DATE RECEIVED	18/02/08	COMPARTMENT MAKE	Cummins
UNIT MODEL	855	DATE REPORTED	18/02/08	COMPARTMENT MODEL	NTA-855-G2
UNIT SERIAL NO.				COMPARTMENT SERIAL NO.	23237049
SYSTEM CAPACITY	36.0 Ltrs			MACHINE LOCATION	Aurukun Power House

UIN 1F100

DIAGNOSIS

Current Sample :
All wear rates normal. Abrasive and other contaminant levels acceptable. Viscosity within specified operating range.

Action: As oil and filter(s) already changed, resample next service interval to further monitor.

Last Sample :
Lead level (bearing material) at tolerance limit. All other wear levels within limits. Abrasive and other contaminant levels acceptable. Viscosity within specified operating range.

Action: As oil already changed and if visible metal/debris was acceptable. Recommend checking if system oil pressures are within normal parameters. Check for excessive engine knock at stall speed. Resample and examine filter debris in 250 hrs to further monitor.

	14/02/08	18/12/07	07/11/07	22/09/07	27/04/07	12/02/07
DATE SAMPLED	14/02/08	18/12/07	07/11/07	22/09/07	27/04/07	12/02/07
SAMPLE NO.	6443391	5996792	5996797	5854969	5956468	5956499
COMPONENT	Hrs 26447	25922	25342	24805	24280	23239
MACHINE	Hrs 26447	25922	25342	24805	24280	23239
OIL	Hrs 525	579	530		500	500
OIL MAKE	Shell	Shell	Shell	Shell	Shell	Shell
OIL TYPE	Rimula Super	Rimula Super	Rimula Super	Rimula Super	Rimula Super	Rimula Super
OIL GRADE	15W40	15W40	15W40	15W40	15W40	15W40
OIL ADDED	Ltrs 20.0					150.0
FILTER	Hrs 525	579	530		500	500
OIL CHANGED	Changed	Changed	Changed	Changed	Changed	Changed
Metals (ppm)						
Aluminium (Al)	2	2	1	2	1	4
Nickel (Ni)	<1	1	1	<1	<1	1
Copper (Cu)	3	5	5	7	2	2
Chromium (Cr)	2	2	2	1	1	2
Iron (Fe)	46	51	51	48	26	26
Lead (Pb)	21	31	29	16	10	11
Tin (Sn)	1	1	1	1	<1	<1
Contaminants and Additives (ppm)						
Silicon (Si)	4	4	4	4	3	3
Boron (B)	<5	<5	<5	<5	<5	<5
Sodium (Na)	2	4	3	3	2	<1
Potassium (K)	2	3	2	3	1	4
Phosphorus (P)	948	989	951	948	1132	1255
Molybdenum (Mo)	2	<1	<1	<1	1	3
Calcium (Ca)	2381	2398	2328	2481	2915	3530
Magnesium (Mg)	13	19	17	15	16	14
Zinc (Zn)	1089	1116	1101	1157	1462	1534
Physical Tests						
Water (% by FTIR)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Soot (%)	0.8	3.2	2.8	2.5	1.2	1.8
Viscosity (cSt, 100°C)	12.4	14.0	13.5	12.5	19.2	18.4
PQ index	23	21	19	21	12	17
Oxidation (Abs)	6.2	18.4	18.3	18.1	11.8	15.3
Sulphation (Abs)	13.9	26.9	26.1	25.5	17.8	23.0
Fuel (%)	2	1	1	2	1	1
Dispersion	Pass	Pass	Pass	Pass	Pass	Pass
Total Base Number (by FTIR)	12.1	9.4	8.3	9.9	11.6	10.9

WCA
Chris Smalley
Aurukun



NORMAL

LEGEND

- SEVERE
- ABNORMAL
- CAUTION
- NORMAL

WEAR CHECK

Your Specialist in Oil, Fuel, Grease & Coolant Analysis

Diesel Engine



OIL AND EQUIPMENT CONDITION REPORT

UNIT NO.	GUN ENG4	DATE SAMPLED	20/06/08	COMPARTMENT NAME	Engine
UNIT MAKE		DATE RECEIVED	23/06/08	COMPARTMENT MAKE	Cummins
UNIT MODEL		DATE REPORTED	23/06/08	COMPARTMENT MODEL	QST30-G1
UNIT SERIAL NO.				COMPARTMENT SERIAL NO.	37216090
SYSTEM CAPACITY	135.0 Ltrs			MACHINE LOCATION	Gununa Power House

UIN 508D3

DIAGNOSIS

Current Sample :

All wear rates normal. Abrasive and other contaminant levels acceptable. Viscosity within specified operating range.

Action: As oil and filter(s) already changed, resample next service interval to further monitor.

Last Sample :

All wear rates normal. Abrasive and other contaminant levels acceptable. Viscosity within specified operating range.

Action: As oil and filter(s) already changed, resample next service interval to further monitor.

DATE SAMPLED	20/06/08	25/04/08	28/03/08	03/02/08	25/12/07	09/11/07
SAMPLE NO.	6535786	6535472	6536491	6534980	6400694	6004816
COMPONENT	Hrs 10678	10178	9677	8678	8173	7673
MACHINE	Hrs 10678	10178	9677	8678	8173	7673
OIL	Hrs 501	500	500	505	500	500
OIL MAKE	Shell	Caltex	Shell	Shell	Shell	Shell
OIL TYPE	Rimula Super	Delo 400	Rimula Super	Rimula Super	Rimula Super	Rimula Super
OIL GRADE	15W40	15W40	15W40	15W40	15W40	15W40
OIL ADDED	Ltrs 59.0	52.0	52.0	55.0	59.0	58.0
FILTER	Hrs 501	500	500	505	500	500
OIL CHANGED	Changed	Changed	Changed	Changed	Changed	Changed
Metals (ppm)						
Aluminium (Al)	<1	1	<1	1	1	1
Nickel (Ni)	<1	<1	<1	<1	<1	<1
Copper (Cu)	4	1	3	1	1	1
Chromium (Cr)	<1	<1	1	1	1	1
Iron (Fe)	4	4	3	5	5	5
Lead (Pb)	1	2	1	2	2	2
Tin (Sn)	<1	<1	<1	<1	<1	<1
Contaminants and Additives (ppm)						
Silicon (Si)	4	4	4	5	2	2
Boron (B)	65	72	40	<5	<5	<5
Sodium (Na)	6	6	5	2	3	3
Potassium (K)	2	2	1	1	3	3
Phosphorus (P)	1383	1497	1352	1175	1188	1123
Molybdenum (Mo)	229	267	122	<1	<1	<1
Calcium (Ca)	3354	3578	3101	2771	2686	2734
Magnesium (Mg)	21	14	16	16	18	20
Zinc (Zn)	1453	1617	1372	1338	1283	1312
Physical Tests						
Water (% by FTIR)	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Soot (%)	0.3	0.3	0.4	0.4	0.3	0.3
Viscosity (cSt, 100°C)	15.2	15.0	15.4	15.9	15.9	15.6
PQ Index	21	<10	17	25	12	12
Oxidation (Abs)	20.8	20.5	15.0	14.8	16.3	16.5
Sulphation (Abs)	23.9	24.8	19.8	19.4	20.5	20.3
Fuel (%)	1	1	1	1	1	1
Dispersancy	Pass	Pass	Pass	Pass	Pass	Pass
Total Base Number (by FTIR)	9.1	10.6	11.5	10.6	10.9	10.5

WCA
1000
1000
1000



NORMAL

LEGEND

- SEVERE
- ABNORMAL
- CAUTION
- NORMAL

WEAR CHECK

Your Specialist in Oil, Fuel, Grease & Coolant Analysis

Diesel Engine



OIL AND EQUIPMENT CONDITION REPORT

UNIT NO.	PAL ENG4	DATE SAMPLED	05/09/08	COMPARTMENT NAME	Engine
UNIT MAKE		DATE RECEIVED	15/09/08	COMPARTMENT MAKE	Cummins
UNIT MODEL		DATE REPORTED	15/09/08	COMPARTMENT MODEL	QST30-G2
UNIT SERIAL NO.				COMPARTMENT SERIAL NO.	37178918
SYSTEM CAPACITY	130.0 Ltrs			MACHINE LOCATION	Palm Island Power Station

UIN 4D407

DIAGNOSIS

Current Sample :
All wear rates normal. Abrasive and other contaminant levels acceptable. Viscosity within specified operating range.

Action: As oil and filter(s) already changed, resample next service interval to further monitor.

Last Sample :
All wear rates normal. Abrasive and other contaminant levels acceptable. Viscosity within specified operating range.

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	05/09/08	24/07/08	08/06/08	28/04/08	23/03/08	06/03/08
DATE SAMPLED	05/09/08	24/07/08	08/06/08	28/04/08	23/03/08	06/03/08
SAMPLE NO.	6443320	6443693	6443695	6443699	6283324	6443690
COMPONENT	Hrs 23925	23424	22918	22407	21894	21482
MACHINE	Hrs 23925	23424	22918	22407	21894	21482
OIL	Hrs 500	506	510	512	504	92
OIL MAKE	Caltex	Caltex	Caltex	Caltex	Caltex	Caltex
OIL TYPE	Delo 400	Delo 400	Delo 400	Delo 400	Caltex	Caltex
OIL GRADE	15W40	15W40	15W40	15W40	15W40	15W40
OIL ADDED	Ltrs			12.0		
FILTER	Hrs 500	506	510	512	504	92
OIL CHANGED	Changed	Changed	Changed	Changed	Changed	Not Changed
Metals (ppm)						
Aluminium (Al)	<1	<1	1	<1	<1	2
Nickel (Ni)	<1	<1	<1	<1	<1	<1
Copper (Cu)	2	2	2	3	3	4
Chromium (Cr)	<1	<1	<1	1	1	<1
Iron (Fe)	3	4	5	5	5	4
Lead (Pb)	3	4	6	7	6	4
Tin (Sn)	<1	<1	<1	1	<1	1
Contaminants and Additives (ppm)						
Silicon (Si)	4	4	5	4	4	3
Boron (B)	71	65	58	43	58	52
Sodium (Na)	6	5	6	5	6	8
Potassium (K)	2	4	2	2	2	34
Phosphorus (P)	1377	1383	1355	1134	1511	1188
Molybdenum (Mo)	257	258	248	193	233	192
Calcium (Ca)	3516	3532	3446	2867	3504	3140
Magnesium (Mg)	17	15	16	14	18	15
Zinc (Zn)	1567	1544	1490	1285	1525	1365
Physical Tests						
Water (% by FTIR)	<0.1	<0.1	<0.1	0.1	<0.1	0.5
Soot (%)	1.8	0.3	0.3	0.3	0.3	0.4
Viscosity (cSt, 100°C)	15.2	15.8	15.5	16.0	15.8	15.6
PQ Index	25	28	18	21	14	15
Oxidation (Abs)	12.4	11.8	18.0	17.9	13	20.8
Sulphation (Abs)	17.7	16.5	22.8	23.9	18.8	25.3
Fuel (%)	1	1	1	1	1	1
Dispersancy	Pass	Pass	Pass	Pass	Pass	Pass
Total Base Number (by FTIR)	11.4	11.3	8.2	8.2	11.2	8.07

REC 15/11/08
15/09/08
RAG:ALP



NORMAL

LEGEND

- SEVERE
- ABNORMAL
- CAUTION
- NORMAL

WEAR CHECK

Your Specialist in Oil, Fuel, Grease & Coolant Analysis

Diesel Engine



OIL AND EQUIPMENT CONDITION REPORT

UNIT NO. BUR ENG3
 UNIT MAKE
 UNIT MODEL
 UNIT SERIAL NO.
 SYSTEM CAPACITY 45.0 Ltrs

DATE SAMPLED 28/06/08
 DATE RECEIVED 07/07/08
 DATE REPORTED 07/07/08

COMPARTMENT NAME Engine
 COMPARTMENT MAKE Detroit
 COMPARTMENT MODEL Series 60 - 12L
 COMPARTMENT SERIAL NO. 06R0821453
 MACHINE LOCATION Burketown Power Station

UIN 789BD

DATE SAMPLED	28/06/08	03/12/07	13/11/07	18/10/07	28/09/07	08/07/07
SAMPLE NO.	6527112	6400564	6255420	6255421	6270625	6270627
COMPONENT	Hrs 6095	4050	3719	3350	3074	2310
MACHINE	Hrs 6095	4050	3719	3350	3074	2310
OIL	Hrs 350	350	350	350	350	350
OIL MAKE	Caltex	Shell	Shell	Shell	Shell	Shell
OIL TYPE	Delo 400	Rimula Super	Rimula Super	Rimula Super	Rimula Super	Rimula Super
OIL GRADE	15W40	15W40	15W40	15W40	15W40	15W40
OIL ADDED	Ltrs 5.0	8.0	8.0	3.0	3.0	3.0
FILTER	Hrs 350	350	350	350	350	350
OIL CHANGED	Changed	Changed	Changed	Changed	Changed	Changed
Metals (ppm)						
Aluminium (Al)	1	1	1	1	1	1
Nickel (Ni)	<1	1	<1	1	<1	<1
Copper (Cu)	1	2	2	3	3	3
Chromium (Cr)	<1	1	1	1	1	1
Iron (Fe)	4	5	5	5	4	4
Lead (Pb)	1	1	<1	1	<1	<1
Tin (Sn)	<1	<1	1	2	1	<1
Contaminants and Additives (ppm)						
Silicon (Si)	3	3	3	3	3	3
Boron (B)	27	<5	<5	<5	<5	<5
Sodium (Na)	9	7	7	8	8	5
Potassium (K)	2	3	2	2	3	<1
Phosphorus (P)	1175	1183	1073	1058	1068	1059
Molybdenum (Mo)	97	<1	<1	1	<1	<1
Calcium (Ca)	2891	2652	2553	2615	2523	2352
Magnesium (Mg)	17	13	13	13	15	16
Zinc (Zn)	1349	1271	1226	1102	1221	1184
Physical Tests						
Water (% by FTIR)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Soot (%)	1.8	1.8	1.8	1.8	1.8	<0.3
Viscosity (cSt, 100°C)	13.4	13.5	12.6	12.9	12.4	12.6
PQ Index	18	<10	19	18	15	20
Oxidation (Abs)	17.6	13.8	6.5	13.2	11.8	12.9
Sulphation (Abs)	21.1	18.4	11.4	18.5	17.2	17.0
Fuel (%)	1	1	2	1	2	2
Dispersancy	Pass	Pass	Pass	Pass	Pass	Pass
Total Base Number (by FTIR)	9.3	10.1	14.1	9.3	10.4	10.1

SEC
 10/06/08
 4/10/08
 1/10/08



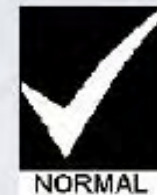
DIAGNOSIS

Current Sample :
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WEAR CHECK

Your Specialist in Oil, Fuel, Grease & Coolant Analysis

Diesel Engine



OIL AND EQUIPMENT CONDITION REPORT

UNIT NO.	LOC ENG2	DATE SAMPLED	18/08/08	12/07/08	16/06/08	11/05/08	20/03/08	30/01/08
UNIT MAKE		DATE RECEIVED	25/08/08	6276928	6276920	6276925	6276983	6276985
UNIT MODEL		DATE REPORTED	25/08/08	8989	8495	8488	7987	74819
UNIT SERIAL NO.				8989	8495	8488	7987	74819
SYSTEM CAPACITY	148.0			501	7	501	505	501
	Ltrs			Caltex	Caltex	Caltex	Caltex	Caltex
				Delo 400	Delo 400	Delo 400	Delo 400	Delo 400
				15W40	15W40	15W40	15W40	15W40
				45.0	45.0	45.0	40.0	40.0
				501	501	501	505	501
				Changed	Changed	Not Changed	Changed	Changed
DATE SAMPLED								
SAMPLE NO.								
COMPONENT	Hrs							
MACHINE	Hrs							
OIL	Hrs							
OIL MAKE								
OIL TYPE								
OIL GRADE								
OIL ADDED	Ltrs							
FILTER	Hrs							
OIL CHANGED								
Metals (ppm)								
Aluminium (Al)		<1	1	1	<1	<1	2	5
Nickel (Ni)		<1	<1	<1	<1	<1	<1	<1
Copper (Cu)		1	1	<1	1	1	1	1
Chromium (Cr)		<1	1	<1	<1	1	1	<1
Iron (Fe)		2	3	2	2	3	3	3
Lead (Pb)		<1	<1	<1	<1	1	1	1
Tin (Sn)		<1	<1	<1	<1	<1	<1	<1
Contaminants and Additives (ppm)								
Silicon (Si)		5	8	8	4	3	3	3
Boron (B)		97	92	102	98	78	65	65
Sodium (Na)		6	6	5	7	6	6	6
Potassium (K)		3	2	2	2	1	3	3
Phosphorus (P)		1259	1251	1283	1273	1309	1307	1307
Molybdenum (Mo)		244	245	233	231	237	203	203
Calcium (Ca)		3258	3293	3119	3235	3508	3267	3267
Magnesium (Mg)		18	15	14	16	16	18	18
Zinc (Zn)		1447	1416	1358	1423	1462	1487	1487
Physical Tests								
Water (% by FTIR)		<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1
Soot (%)		1.8	1.8	1.8	0.3	0.4	0.3	0.3
Viscosity (cSt, 100°C)		14.3	14.4	14.5	14.2	14.3	14.0	14.0
PQ Index		18	24	20	12	15	28	28
Oxidation (Abs)		19.0	17.5	16.6	14.7	18.5	18.5	18.5
Sulphation (Abs)		21.8	20.0	19.9	19.0	22.5	21.2	21.2
Fuel (%)		1	1	1	1	1	1	1
Dispersion		Pass	Pass	Pass	Pass	Pass	Pass	Pass
Total Base Number (by FTIR)		10.2	10.1	10.4	10.4	10.5	10.8	10.8

INC 12/2008
P10 W0808
Angela Lyle



UIN 63093

DIAGNOSIS

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