University of Southern Queensland
Faculty of Engineering & Surveying

Prediction of Feedlot Effluent Pond Odour Emission After Significant Inflow

A Dissertation submitted by

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Abstract

Feedlots in Australia have long been associated with odour, and as such, in the early 1990's research was carried out in order to better understand the processes driving the odour generation. Since that time, many practices have been identified as contributing to the odour problem, and feedlot management has changed to minimise the odour emissions. This has resulted in a distinct lack of odour emissions data relating to 'modern' feedlots.

Feedlot pad surfaces represent the largest odour emitting source, however, after a rainfall event, the odour emissions from the effluent ponds increase to a point where it may exceed that of the feedlot pad surface. Despite this, there has been little Australian research carried out to determine and predict the odour emissions from feedlot ponds after an inflow event.

This project set out to develop a model to predict the odour emission rate from the effluent ponds at a feedlot after a significant inflow. Odour samples were collected every few days for a period of time after an inflow at two commercial feedlots in Southern Queensland and Northern New South Wales, and assessed to determine the odour emission rate. The collected data displayed a similar pattern of odour emission to that measured in the early 1990's, reported by Casey *et al* (1997). At both feedlots, the odour emission rate from the primary holding pond rose quickly to a peak (454 and 578 ou/s.m^2) within 5 - 8 days, and then declined steadily back to 'normal' levels within 25 - 30 days.

A model was developed to reproduce the pattern of odour emissions from the primary holding pond at each feedlot. The model is a two-stage empirical algorithm, and is dependent on the inflow ratio, the 24 hour average ambient temperature experienced during the days of the rainfall event and the number of days since the first day of the rain event. A parameter named ‘Peak Day’ defines the two stages of the model, and is read from a table developed from the measured temperature data. It is known that the pond condition does impact the odour emission rate (Hobbs *et al*, 1999); however the current body of research is not conclusive, and not enough pond condition data was collected during the course of the project to permit this model to include pond condition parameters as input.

The model was tested with a number of hypothetical scenarios, and was also validated using the data collected by Casey *et al* (1997). The model was shown to be reasonably robust to moderate changes in parameter values, but failed to accurately reproduce the odour emission patterns measured in the earlier work. This was attributed to the different management practices of feedlots between the two data sets, and the simplistic nature of the model developed.

The limited number of odour emissions data sets and supporting data meant that a comprehensive model could not be developed.

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Limitations of Use

Prof G Baker
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Certification of Dissertation

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

NATHAN HEINRICH

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Signature

Date

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NATHAN HEINRICH

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Glossary

Anaerobic Pond	Effluent treatment ponds that degrade organic matter through anaerobic bacterial agents
Days Since Rain	Number of days since the start of the rain event in question
DPI & F	The Department of Primary Industries and Fisheries, Queensland
Feedlot A	One of the participating commercial feedlots in the project
Feedlot B	The other participating commercial feedlot in the project
FSA Consulting	Engaged by MLA to undertake research project into feedlot odour emissions, employer of the author
Inflow Ratio	The ratio of effluent inflow volume to initial pond volume
MEDLI	An effluent reuse model developed by the Queensland DPI & F
MLA	Meat and Livestock Australia, industry body funding the odour project undertaken by FSA Consulting
Odour Concentration	The measure of odour intensity, measured in Odour units (ou)
Odour Emission Rate (OER)	The rate of emission of odour from a surface, measured as odour units emitted per second square metre (ou/s.m^2)

Odour Sampling	The process of taking odorous air samples from a surface
Olfactometry	The assessment and quantification of odour concentration and emission rate
Peak Day	A parameter dependent on ambient temperature to define the day on which peak odour emission rate occurs
Primary Holding Pond	The pond which receives effluent from the sedimentation basin for initial treatment
Secondary Holding Pond	The treatment pond which receives effluent from the primary holding pond for final treatment before irrigation or re-use
Sedimentation Basin	A shallow pond that detains flowing effluent for a period of time to allow solids to settle out

Chapter 1

Introduction

This research project was part of a larger research project carried out by FSA Consulting. Meat and Livestock Australia commissioned FSA Consulting to undertake a research effort into feedlot odour, with the aim of developing industry-specific odour performance criteria for the development and assessment of feedlots across New South Wales and Queensland. Two commercial feedlots, one in southern Queensland and the other in the northern New South Wales, were involved as part of the research.

The feedlot pad surface is the major source of odour emissions in a feedlot. The larger project focussed on this, and a model to predict the odour emissions was developed. In addition, the feedlot effluent ponds can be a major source of odour from a feedlot, especially after rainfall when an inflow to the pond occurs.

The task of developing a model to predict the odour emissions from the effluent ponds after an inflow formed the basis of this research project, the results of which were included as part of the research project for Meat and Livestock Australia.

1.1 Background

Feedlots are a large source of odour, and as such some research has been carried out in the past in order to better understand and quantify the odour generation. However, the majority of this research was undertaken in the early 1990's and since that time, feedlot management practices have changed significantly, particularly in regard to odour management. In addition, the recent changes in technology, standards and regulatory guidelines presented a need to obtain more modern and reliable data.

1.1.1 Feedlot Hydrology

Feedlots in a catchment provide a source of nutrient contamination for any surface runoff. Hence, feedlots are required to capture any contaminated runoff, and divert clean runoff from entering the feedlot catchment area. The captured runoff is stored in effluent ponds for treatment and subsequent irrigation or re-use within the feedlot. A quick background of feedlot hydrology is provided.

After rainfall, once the moisture storage capacity of the feedlot surface, also known as the pad, has been met, then runoff will occur.

Modern feedlots maintain a shallow depth of manure on the feedlot pad. This means that rain events of as little as 10 - 15 mm may produce runoff.

Runoff containing dissolved manure is effluent, and is transported through the feedlots' drainage network and eventually terminates into the effluent treatment ponds. Effluent flowing from the drainage network is contained temporarily in a sedimentation basin. This is a large, shallow pond where solids have an opportunity to settle out of the effluent. Having such a basin reduces the amount of solid material making its way into the anaerobic effluent holding ponds. This consequently reduces the organic load on the holding ponds, making them more effective.

As the basin fills, the settled effluent passes through a small weir to the holding ponds, where it remains. The weir detains the effluent in the sedimentation basin for a time to settle out.

The effluent is treated anaerobically by bacteria in the holding ponds, which breakdown the organic matter and stabilise the nutrient load. After treatment, the effluent can then be utilised for irrigation of crops, or reused within the feedlot (watering of roads or wetting of compost, etc).

Stable, properly functioning effluent ponds do not produce a lot of odour. After a period of no inflow, the effluent holding ponds reach a state of bacterial equilibrium, and this is the point where the odour produced is minimal. The ponds take on a distinct pinkish colour, due to the bacteria present. However, after a rainfall event, a large amount of fresh effluent is introduced to the holding ponds, and this upsets the bacterial balance. The upsetting of the bacterial balance increases the odour generation from the ponds.

1.1.2 How Australian Feedlots Have Changed

Australian feedlots have changed their management practices significantly in light of research into odour emissions carried out in the early 1990's. High stocking densities, infrequent pen manure removal and pen maintenance and poor pen drainage were but a few practices that had a substantial impact on the odour emissions. The greater depths of manure (over 300 mm deep) on the pen surface led to higher organic and nutrient loads in the pen runoff, increasing the load on the feedlot effluent treatment system. The difference in management of feedlots is best represented by the photographs in Figures 1.1 and 1.2, taken after rainfall. It can be seen that the 'old' style feedlot has a lot of manure on the surface, and is poorly drained. The 'modern' feedlot has a small depth of manure, and is very well drained. The modern feedlot pad would therefore dry out much faster, and as the odour emissions are closely related to the moisture content of the manure, would produce less odour.

Modern feedlots have worked to remedy these practices that increase the odour generation, and as such any previous research into feedlot odour is less robust and reliable. This presented the need for further modern research.

1.2 Aim of the Research Project

The broad aim of this project was to develop and improve the knowledge of, and the factors influencing, the odour production from feedlot effluent ponds after a significant

Figure 1.1: 'Old' Style Feedlot after Rainfall

Figure 1.2: 'New' Style Feedlot after Rainfall

inflow. This culminated in the development of a predictive model to predict odour emissions under these conditions. This research was to be used by FSA Consulting in the formulation of guidelines to assess the environmental performance of new and existing feedlots.

1.2.1 Specific Objectives

The specific objectives of this research include:

Research the background information available relating to feedlot odour emissions in Australia (concentrating on, but not restricted to, feedlot effluent ponds), odour measurement and olfactometry and feedlot odour emissions models.

> This was required to identify any previous research and background the topic. Knowledge of the odour production processes, odorous air sampling and analysis was required to fully understand the capability of, and limitations of odour measurement and analysis (olfactometry). The backgrounding and identification of previous research began with specific feedlot effluent pond odour research; however research into the methods of sampling and olfactometry was also required. Relevant research was not only limited to feedlots; parallels were drawn from the extensive research into piggery effluent pond odour.

Assist in the collection of odour samples from two commercial feedlots, and collect data as appropriate.

> This was the practical part of the research, and provided the necessary data for analysis. The complex nature and prohibitive cost of the data collection does not allow personal involvement in the formulation and implementation of independent odour collection and analysis. Hence, involvement in the administration of, collection and analysis of odour samples was limited to assistance only. However my limited involvement was not detrimental to

the success of the research. As the data was collected professionally, we could safely assume a higher level of accuracy. Full involvement in this area of the project was also beyond the scope of the research and the subsequent timeline. The analysis of the data was where the majority of this projects' work was done.

Analyse field data and assess the major factors influencing the odour emission rate.

The analysis of the field data was necessary to determine any possible relationships between influencing factors and the measured odour emission rates from the effluent ponds. This discovery was essential for the model development.

Develop a model to predict the odour emission rate from the primary effluent pond after inflow.

This was the supreme objective of the research. The model needed to be developed, analysed and tested to relate the odour emissions from the effluent ponds to a number of easily measured parameters. The modelling was to be used in the formulation of feedlot assessment guidelines.

1.3 Dissertation Structure

This dissertation begins with a short introduction to the topic, with some essential background to feedlot hydrology. The aims of the research are detailed (Chapter 1), and an overview of the previous research into this area is provided (Chapter 2). The methodology behind the odour sampling and assessment and data collection is given in Chapter 3, the results are discussed in Chapter 4 and the development of the model is detailed in Chapter 5. The model is analysed and tested in Chapter 6, and the dissertation is concluded in Chapter 7. Appendices of supporting information and data are also included.

Chapter 2

Previous Research

2.1 Odour Sampling - Methods and Equipment

There are a number of methods of odour sampling that have been used in the past, each with particular advantages that suit different situations.

Feedlots have large areas of possible odour emissions, because of the pens and effluent ponds, and this presents a difficulty in sampling. Odour emissions from areal sources varies both spatially and temporally (Smith and Watts, 1994a). In fact, there is no direct way of measuring or sampling the odour emissions from extensive sources, and as such estimations need to be made through point measurements (using a wind tunnel or flux hood sampling system) or by taking downwind measurements and using back-calculation to estimate the emission rate (Smith and Kelly, 1995). In this project, as differentiation between various sources within the feedlot was required, the point source method was used to estimate the average emission rate across the effluent ponds. Methods of measurement include the flux hood and wind tunnel sampling systems. A description of these methods follows.

2.1.1 Flux Hood

The flux hood, shown in Figure 2.1 in use on an effluent pond, is an isolated chamber

Figure 2.1: Flux Hood in use on an effluent pond (taken from http://www.odour.unsw.edu.au/flux-hood-sampling.html)

placed over a representative site of the area being sampled. A controlled flow of odour free air (or nitrogen) is released into the chamber and allowed to mix with any emitted odours from the sample surface. This air is then released through the vents of the chamber. A sample is taken of this air as it is released from the chamber. The odour free air introduced into the chamber is known as the 'sweep gas', and is introduced at flow rates of between 2 and 10 litres per minute. Samples are taken at rates less than three-quarters of the sweep gas flow rate, to prevent ambient air being drawn into the chamber (UNSW, 2004).

The flux hood, in comparison to the wind tunnel, is slower to obtain a sample, and was not chosen for use in the sampling taken out in this project.

2.1.2 Wind Tunnel

A wind tunnel is somewhat similar to a flux hood in concept; however it does have some significant differences. Like the flux hood, the wind tunnel is a sealed enclosure over a site representative of the entire area being sampled. However, the wind tunnel involves much larger airflows through the chamber. A schematic of the University of New South Wales wind tunnel is shown in Figure 2.2.

The wind tunnel is placed over the site (solid or liquid surface). The float tubes are obviously required for use on effluent ponds. When the tunnel is used on a solid

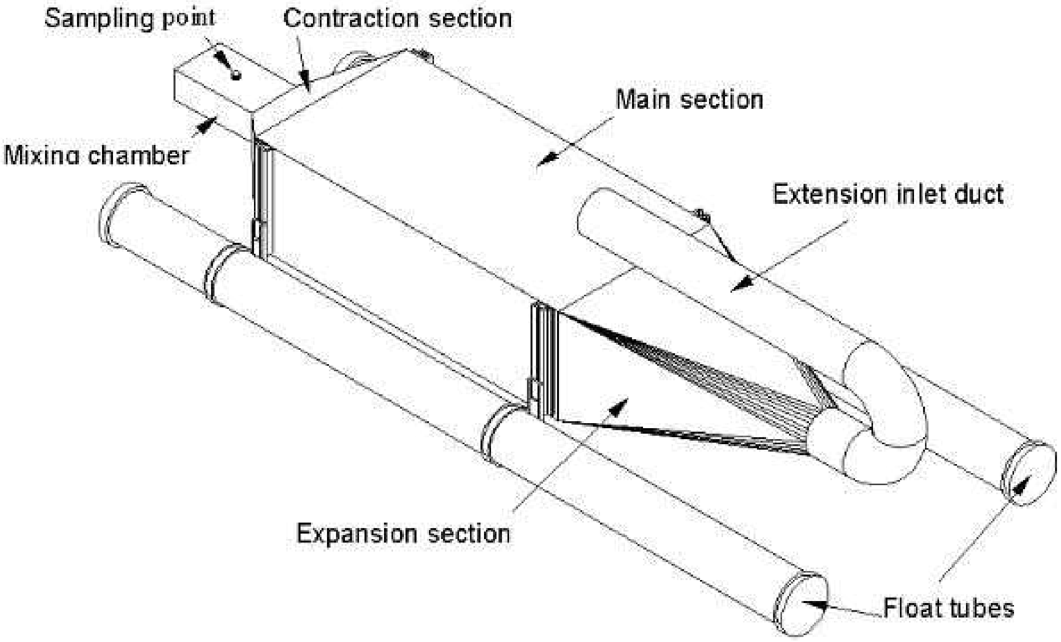

Figure 2.2: Schematic of the UNSW Wind Tunnel (taken from http://www.odour.unsw.edu.au/odour-sampling.html)

surface, a proper airtight seal can be created by packing around the bottom edges of the chamber with moist sand. On liquid surfaces, an airtight seal can be achieved by slightly submerging the bottom edges. Odour-free air is pumped through the chamber via the inlet duct, and mixes with the odours emitted from the sampling surface, and exits via the exhaust duct. As the odorous air exits the wind tunnel, a sample is taken. The odour emission rate can then be determined knowing the surface area sampled and the wind velocity through the wind tunnel. Smith and Watts (1994a) recommend that the wind velocity be set with regard to the final use of the measurements. For instance, if the sampling is aiming to replicate the ambient conditions, then the wind speed needs to match the ambient wind speed for the particular site. If the sampling is for comparative purposes, then a selected wind speed should be used and maintained for all samples (i.e. 1 m/s).

The wind tunnel was used for sampling in this project. The wind tunnel has now all but superseded the flux hood for point source odour sampling, and is considered the best method of sampling areal odour emitting sources (UNSW, 2004; Smith and Watts, 1994).

2.2 Olfactometry

Olfactometry is, in essence, the use of the human nose to determine and quantify odours. The human nose has been, and still is, the only satisfactory method of odour measurement, even though recent efforts have been made into developing an electronic nose for odour measurement.

2.2.1 Types of Olfactometers

In the past, there have been many different types of olfactometers used. They are described here briefly as a background.

Scentometer

The scentometer is a handheld, portable olfactometer that is used in the field. It consists of a small box with nostril sniffing ports at one end, with a series of orifices along the bottom. There are two ports that filter ambient air (through a carbon filter), and the rest allow odorous ambient air to enter. The operator closes all ports, and places their nostrils over the sniffing ports. Once the filtered ports are opened, the ports introducing odorous air are opened in turn (smallest to largest), gradually lowering the dilution of the odorous air, until the operator can just detect an odour. The port where the odour is detected is recorded, and used to determine the odour concentration. This method is used by some regulatory authorities in the USA; however operator fatigue is a considerable limitation (Watts, 1999)

Static Olfactometer

A static olfactometer presents odorous air in a sealed container to a panellist. The oldest form of dilution is the syringe dilution method. A sample of odorous air is drawn into the syringe, and made up to volume with odour-free air. The mixture is then expelled into a panellist's nose for measurement. This method differs from the dynamic method of olfactometry as there is no flowing air. The odour can also be introduced to the panellist through odorous cotton swatches. The swatches are exposed to the odour, and the odorous particles adsorb onto the cotton. The swatches are then presented to the panellist for analysis.

Butanol Olfactometer

Here the ambient, or odorous air is quantified through comparison with a reference odour, butanol. One example of a butanol olfactometer is the Tecnodor™ (Enviro-Access 2004). This is a portable unit, and it is used on-site. A panellist is allowed to breathe ultra-pure air for one minute, to calibrate their nostrils and prevent habituation to the ambient and reference odours. After this has occurred, the panellist sniffs the reference odour (butanol) and compares the ambient air (odorous) to this odour. The relative intensities are entered into the olfactometry unit via a tactile screen. This is repeated for a range of butanol dilutions, and the ambient odour intensity is given in terms of 1-butanol concentrations.

Dynamic Olfactometry

There are two basic types of dynamic olfactometry; yes / no and forced choice.

Yes / No olfactometry uses one sniffing port for each panellist, and the panellist is asked whether an odour exists in the diluted odorous air presented (yes or no). As the dilutions are continually changed, the level of odour concentration can be determined. Usually, each successive dilution is chosen at random to maintain accuracy.

Forced choice dynamic olfactometry places panellists with three sniffing ports. Clean, odour free air is presented in two of the ports, with diluted odorous air in the third. The panellists are asked to choose which port contains the odorous air, and give a measure of certainty of their answer (certainty, inkling or guess). The port from which the odorous air is presented is completely random. The title ‘Forced-choice olfactometry’ if given as the panellists are forced to make a choice. It is called dynamic olfactometry as the odour dilution can be constantly varied through a series of pipes and flowmeters.

The type of olfactometer used in this project is a forced-choice, dynamic olfactometer, owned and operated by the Department of Primary Industries and Fisheries, Queensland. It has been constructed to conform to the Australian / New Zealand Standard

- Stationary Source Emissions - Determination of odour concentration by dynamic olfactometry (AS/NZS 4323.3) (QDPI & F, 2004).

2.3 Existing Legislation and Guidelines

The overall purpose of the project being carried out by FSA Consulting, sponsored by Meat and Livestock Australia, is to develop odour impact criteria for use in assessing the performance of new and existing feedlots. Existing odour legislation can be generic and conservative, and industry specific criteria are required for feedlotters.

The existing legislation, taken from the Environmental Protection Act 1994, states that persons "*must not carry out any activity that causes, or is likely to cause, environmental harm unless the person takes all reasonable and practicable measures to prevent or minimise the harm (the* ***general environmental duty****)*".

The Department of Primary Industries and Fisheries has been delegated the responsibility of administration of cattle feedlotting. This includes assessing new and expanding developments, issuing environmental authorities, monitoring operational performance and investigating complaints (QDPI, 2000).

Guidelines for the establishment and operation of Queensland cattle feedlots are available (QDPI, 2000), and they complement the National Guidelines for Beef Cattle Feedlots in Australia (ARMCANZ, 1997). These guidelines are not mandatory for feedlotters in Australia; however they are based on industry best practice, and as such will provide outcomes that are acceptable to regulatory authorities.

In particular reference to odour from effluent ponds, the guidelines state that the ponds should be designed such that odour emissions after an inflow should stabilise relatively quickly. The recommendations for achieving this are to maintain at all times a level of effluent in the pond to allow the bacterial population to survive, ready to commence breakdown of the next inflow; and to maintain regular irrigation with the effluent to limit evaporation losses and therefore the salinity of the effluent (to ensure the survival of the bacteria). However the guidelines do not go into any detail with regard to satisfactoriness of pond odour emission rates, or acceptable post-inflow, return-to-normal (odour emission rate) timelines.

2.4 Mechanisms of Odour from Anaerobic Effluent Ponds

The mechanisms of odour generation from feedlot effluent ponds is not fully understood, but research has been undertaken into this area. Hobbs *et al* (1999) stated that while the bio-decay of organic compounds is performed by a multitude of microbial populations, and the actual mechanisms may not be well understood, the behaviour of these bacterial populations can be ascertained through the changes in concentration of the substrate (energy source) and their by-products.

Research undertaken by Hobbs *et al* (1997, 1999) suggested that the majority of the odour from anaerobic ponds is due to volatile fatty acids present in the effluent. Volatile fatty acids are created when volatile solids are digested, and the volatile fatty acids are converted to a gas, and escape to the atmosphere. The degradation of the volatile fatty acids that produce methane gas is known as methanogenesis. Under the high loading rates sometimes encountered in piggery ponds, methanogenesis can be inhibited by high concentrations of hydrogen sulphide, ammonia or volatile fatty acids, which increases the likelihood of odour emissions.

2.5 Previous Research into Effluent Pond Odour in Australia

The amount of research into feedlot effluent pond odour in Australia is limited, however there has been some research undertaken with respect to effluent ponds in piggeries, from which some parallels can be drawn. However it was reported in Huegle *et al* (2001) that odour from cattle effluent was consistently less than that from piggery effluent, and this is duly noted.

2.5.1 Piggeries

The work undertaken by Galvin et al (2002) studied the effect of the volatile solids loading rate and season on odour emissions from piggery effluent ponds in South East Queensland. Six similar piggery ponds were chosen and odour samples were taken from each during winter and summer using a wind tunnel. A grid of sampling points was set up over the pond to gain an average value for the odour emissions.

Odour emissions were found to increase from summer to winter, and a strong relationship between volatile solids loading rate and odour emissions was observed. Anecdotal evidence of higher rates of odour emissions from more heavily loaded ponds was supported by their results.

The differences in odour emissions for each loading rate of volatile solids were found to be the same for both seasons. It was concluded that the difference in temperature caused the difference in odour emissions between the two seasons; however, as the ponds were part of commercial piggery operations, the active volume of the effluent pond would have reduced between sampling seasons as more solid material built up in the ponds. This may have affected the treatment efficiency of the ponds themselves (less liquid volume in which to accommodate the bacterial population).

2.5.2 Feedlots

The only direct Australian research into feedlot effluent pond odour emissions was carried out in 1993 / 1994, reporting the odour emission rates over time after an inflow at three feedlots on the Darling Downs (Casey *et al*, 1997). However the scope of the research did not extend to development of a predictive model.

The inflow occurred after an extended period of zero runoff, and hence inflow into the pond. After rainfalls of 70 mm at two of the feedlots, and 47 mm at the other, inflow into the pond occurred, and odour measurements were taken in the period following. The patterns of odour emissions and the corresponding rainfall from the three feedlots under examination can be seen in Figures 2.3 to 2.5. The relationship between odour

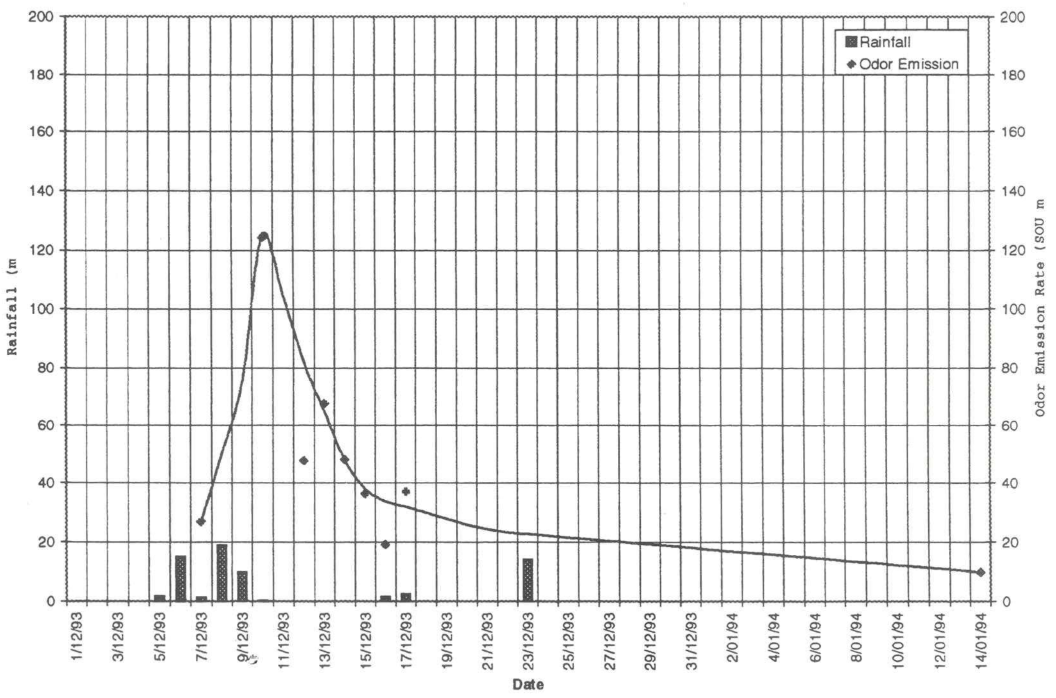

Figure 2.3: Feedlot 1 – Odour Emission and Rainfall

emissions, pH and electrical conductivity from the pond at Feedlot B is shown in Figure 2.6.

Casey *et al* (1997) found that the odour emission rate rose to a peak 6-8 days after the inflow, and then slowly declined to pre-inflow ('normal') levels at all feedlots. The peak odour emission rates were 124, 488 and 524 standard odour unit m/s, a range of 12 to 67 times the normal odour emission rates of the ponds. Up to 40 days elapsed before the odour emission rate returned to near baseline levels. It was also found that the peak odour emission rate was related to the ratio of initial pond volume to inflow volume, which alters the dilution ratio. In all cases, the feedlots had irrigated the majority of the effluent, after an extended dry period, leaving only a small depth of effluent in the ponds. This worked to increase the inflow to existing pond effluent ratio, lowering the dilution effect on the inflowing effluent.

The pond chemical analysis shown in Figure 2.6 shows a dramatic drop in pH soon after the inflow event, with a similar drop in electrical conductivity (indicating the salt levels in the pond). It was posed that the sudden slug loading of the pond unbalanced the anaerobic digestion process, and the fact that the existing bacterial population was

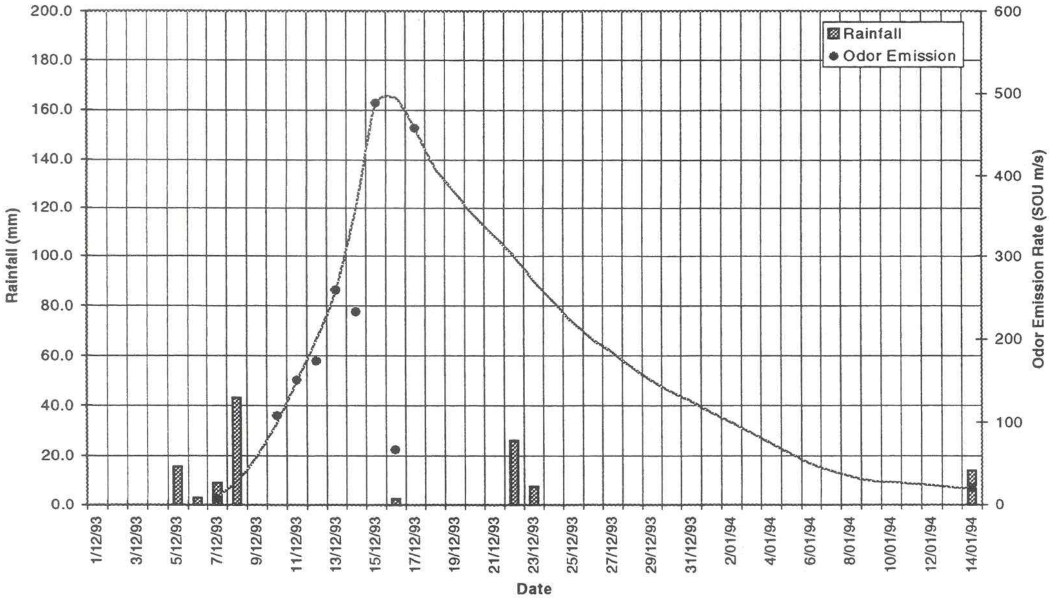

Figure 2.4: Feedlot 2 – Odour Emission and Rainfall

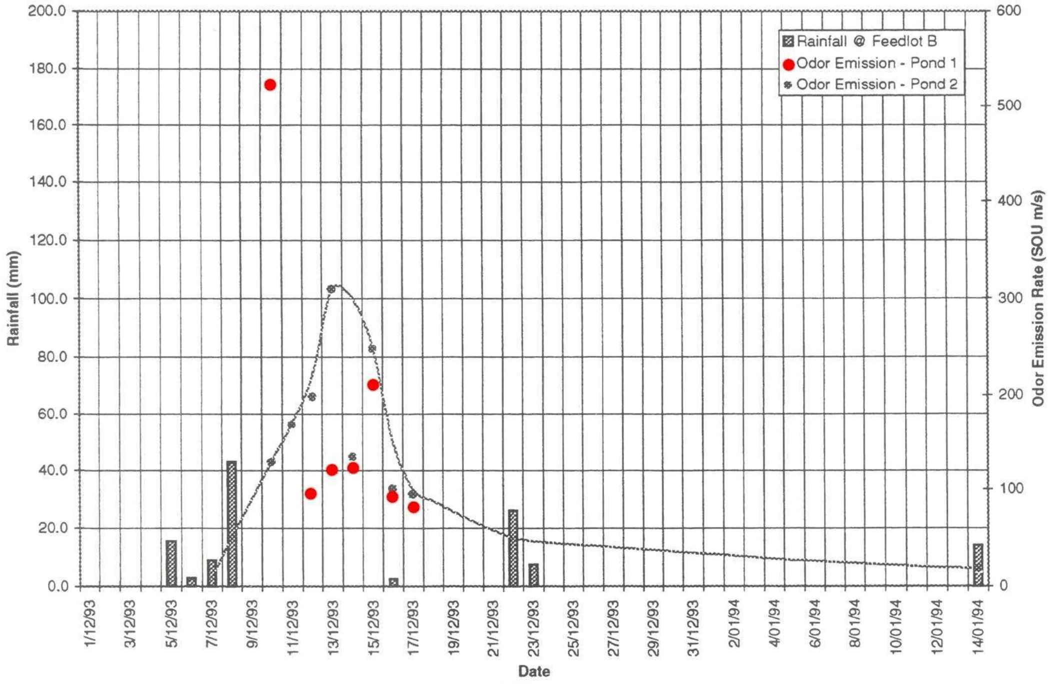

Figure 2.5: Feedlot 3 – Odour Emission and Rainfall

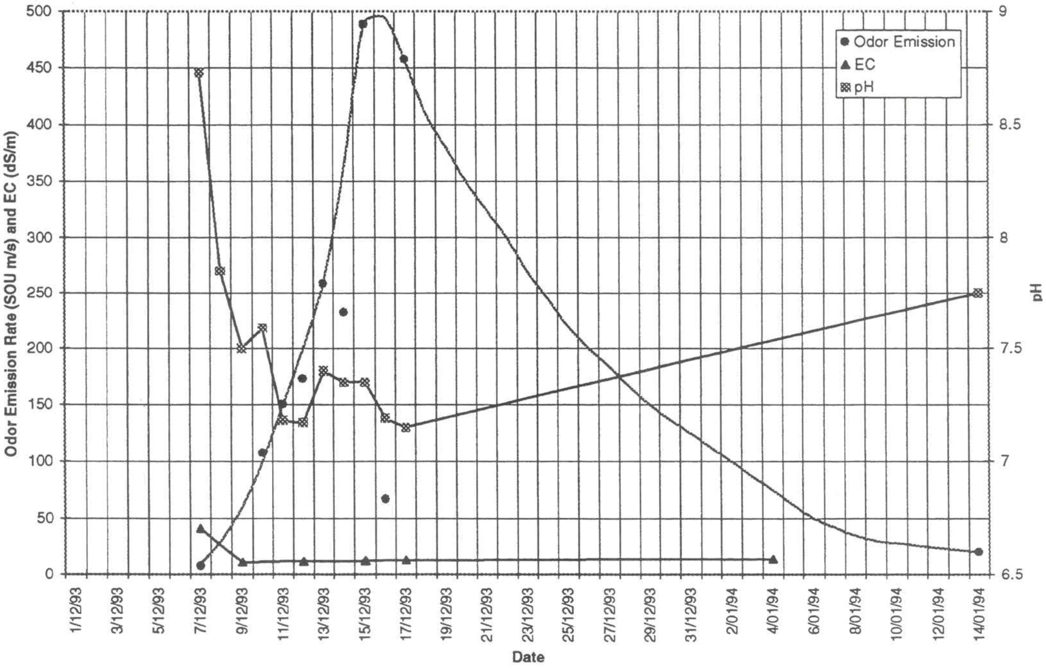

Figure 2.6: Feedlot 2 – Odour Emission, Electrical Conductivity and pH

unable to cope with the large amount of degradable organic matter introduced, led to this sudden lowering of the pH. It was also noted that the salt levels were very high prior to the inflow event, and this may have inhibited bacterial activity somewhat, leading to the increased levels of odour emissions soon after the inflow (as there were only a small population of bacteria available to begin the breakdown).

2.6 Previous Research into Feedlot Odour Modelling

Some research into feedlot odour modelling has been carried out in Australia, however it has mostly focussed on the feedlot pad. Lunney and Smith (1995) developed an odour emissions model for feedlot pads based on odour sampling carried out during the early 1990's. The model takes as input the stocking rate of the feedlot pens, moisture content of the pad surface, pad temperature, wind speed and days since rain factor (as the model can handle the increase in pad surface odour emissions after rainfall). The model performed reasonably well, with a correlation of 0.64 between the measured and modelled odour emission rates, for over 700 measurements.

2.7 Previous Research into Effluent Pond Odour Modelling

The amount of research into the modelling of odour production from anaerobic ponds is quite limited, or non-existent in Australia. Specific research into modelling of odours from anaerobic ponds has been carried out overseas; however this is also quite limited.

Picot et al (2003) conducted research into the emission of hydrogen sulphide from anaerobic ponds. The experiments were conducted on full scale anaerobic ponds used for the initial treatment of urban wastewater in the south of France. A model was developed to predict the hydrogen sulphide emissions from the water characteristics of temperature, pH and sulphides concentration, however the full document, detailing the model, could not be accessed.

Some research has also been undertaken by the National Centre for Engineering in Agriculture (NCEA) with regard to piggery pond odour, and the effects of loading rate on odour emissions (2002). This research aimed to develop a model to describe the relationship between pond condition and odour emission rate.

Chapter 3

Project Methodology

3.1 Introduction

As the practical work of this project was been carried out under the guidance of, and as part of a greater research project undertaken by FSA Consulting, the methodology of odour sampling and measurement had been formulated in the best interest of the greater research project. Personal involvement in the formulation and modification of the methods used was limited; however assistance was given in the collection of odour samples and other data. A detailed description of the methods of odour sampling and assessment follows.

The experience and expertise of the Queensland Department of Primary Industries and Fisheries (DPI & F) odour sampling and olfactometry department (part of the Intensive Livestock Systems Unit) was called upon to undertake the field work involved. The Department has many years of experience in the collection of odour samples from feedlot sites, and have the necessary equipment and technology required. Standards appropriate to odour measurement are followed where possible, and industry best practice is followed where no relevant standards exist.

The odour project undertaken by FSA Consulting, titled "Development of Odour Performance Criteria for the Australian Feedlot Industry" was sponsored by Meat and

Livestock Australia. There were two co-operating feedlots involved with this study, as described below.

3.2 Feedlots Involved in the Research

Feedlot A

Feedlot A is an 18,000 head feedlot located in southern Queensland. This feedlot is located on the Darling Downs at a latitude 27°13' S and 151°43' E, about 16 kilometres north east of Dalby at an elevation of 350 metres AHD. The annual rainfall and evaporation at Dalby are 670 mm and 2007 mm respectively. The site experiences a cool to cold winter and warm to hot and humid summers (Nicholas *et al*, 2004).

Feedlot B

Feedlot B currently is a 24,000 head beef cattle feedlot. The feedlot is located on the New England Tablelands, in northern New South Wales at a latitude 29°30' S and longitude 151°45' E. The feedlot is about 28 kilometres north of Glen Innes. It is located near the confluence of the Severn River and Beardy Waters at an elevation of about 900 metres AHD.

The annual rainfall and evaporation at the site are 771 mm and 1650 mm respectively. The evaporation rate is significantly greater than that at Glen Innes (1355 mm) as the property is on the western fall of the Great Dividing Range. The site experiences a cool to cold winter and relatively mild summers (Nicholas *et al*, 2004).

3.3 Odour Sampling

The focus of this odour sampling was to collect odour data which would give an indication of how the effluent ponds at a feedlot respond to a large inflow of fresh effluent, for a period of time after the inflow. Therefore, staff at the DPI & F and at FSA Consulting (author included) had to be ready to begin odour sampling as soon as possible

Table 3.1: Feedlot A – Program of Odour Sampling

Date	Rainfall (mm)	Odour Sampling	Days Since Rain
3 December 2003	0.2		
4 December 2003	2.6		
5 December 2003	73.6		
6 December 2003	37.2		
7 December 2003	11.2		
8 December 2003	–	1st Sample	3
10 December 2003	–	2nd Sample	5
12 December 2003	–	3rd Sample	7
13 December 2003	3.2		
15 December 2003	–	4th Sample	10
16 December 2003	0.8		
17 December 2003	–	5th Sample	12
19 December 2003	–	6th Sample	14
22 December 2003	–	7th Sample	17
23 December 2003	1		
8 January 2004	9.2	8th Sample	34

after an inflow.

A rainfall event occurred from the 4th to the 7th of December, 2003 at Feedlot A. A total of 124.8 mm of rain fell during this period. A rainfall event of 107.4 mm fell at Feedlot B during the period from the 1st to the 3rd of October 2003. These rainfall events were considered great enough to cause a significant inflow to the ponds, and as such an effluent pond sampling program was drawn up to follow these inflows. The sampling program at both feedlots began within one day of the end of the rain event. The programs of odour sampling at both feedlots can be seen in Tables 3.1 and 3.2.

A wind tunnel was employed to take the odour samples from the surface of the effluent ponds and sedimentation basins. The following figures show the equipment in use on the surface of the secondary holding pond at Feedlot A. Figure 3.1 shows the equipment being floated out on the effluent surface after the ambient air and sample air lines had been connected. The wind tunnel was then lowered onto the surface by way of a remote and electric motor and cable setup (Figures 3.2 and 3.3), and an airtight seal was created between the tunnel and the liquid surface ready for sampling to begin (Figure 3.4). (When the wind tunnel is used on a hard surface, such as a feedlot pad surface, an airtight seal cannot be created. In such cases, moist sand is used to around the edge of the exposed surface to prevent air escaping out the base of the tunnel. This

Table 3.2: Feedlot B – Program of Odour Sampling

Date	Rainfall (mm)	Odour Sampling	Days Since Rain
1 October 2003	95.0		
2 October 2003	10.2		
3 October 2003	2.2	1st Sample	2
5 October 2003	3		
6 October 2003	11.4		
7 October 2003	–	2nd Sample	6
9 October 2003	–		8
12 October 2003	–	3rd Sample	11
14 October 2003	–	4th Sample	13
16 October 2003	–	5th Sample	15
17 October 2003	–	6th Sample	
19 October 2003	15.4		
23 October 2003	0.2		22
24 October 2003	–	7th Sample	
28 October 2003	1		
30 October 2003	9.2	8th Sample	29

is obviously not required in pond odour sampling.)

The wind tunnel was supplied with filtered ambient air (filtered through a charcoal filter) through the flexible ducting as shown in Figures 3.1 to 3.4. The air then entered the wind tunnel (at a target throat wind speed of 4 m/s) and passed over the exposed liquid surface. As it did so, it picked up odours emitted from the surface, and this odorous air passed out through the exhaust of the wind tunnel. At this point, a sample of this air was drawn, through the small white Teflon tubing placed inside the exhaust vent of the wind tunnel. The sample was taken from the centre of the exhaust ducting. The air sample was drawn into the drums shown in Figure 3.5, and was then transported to the olfactometer for analysis. All parts of the sampling equipment that were exposed to odorous air were constructed from Grade 316 stainless steel or polytetrafluoroethylene (PTFE).

The odorous sample air was contained within new plastic Melinex™ (Polyethylene Terephthalate) bags inside the sample drums. Initially the bags were empty, and were pre-conditioned by filling with odorous air and then evacuated prior to taking a sample, as per the standard. This allowed any 'bonding' of odour particles (to the inside of the bag) to occur before the sample is introduced into the bag. This aimed to increase the accuracy of results, as no odour particles were lost from the sample to bonding.

Figure 3.1: Launching the Wind Tunnel onto the Pond Surface

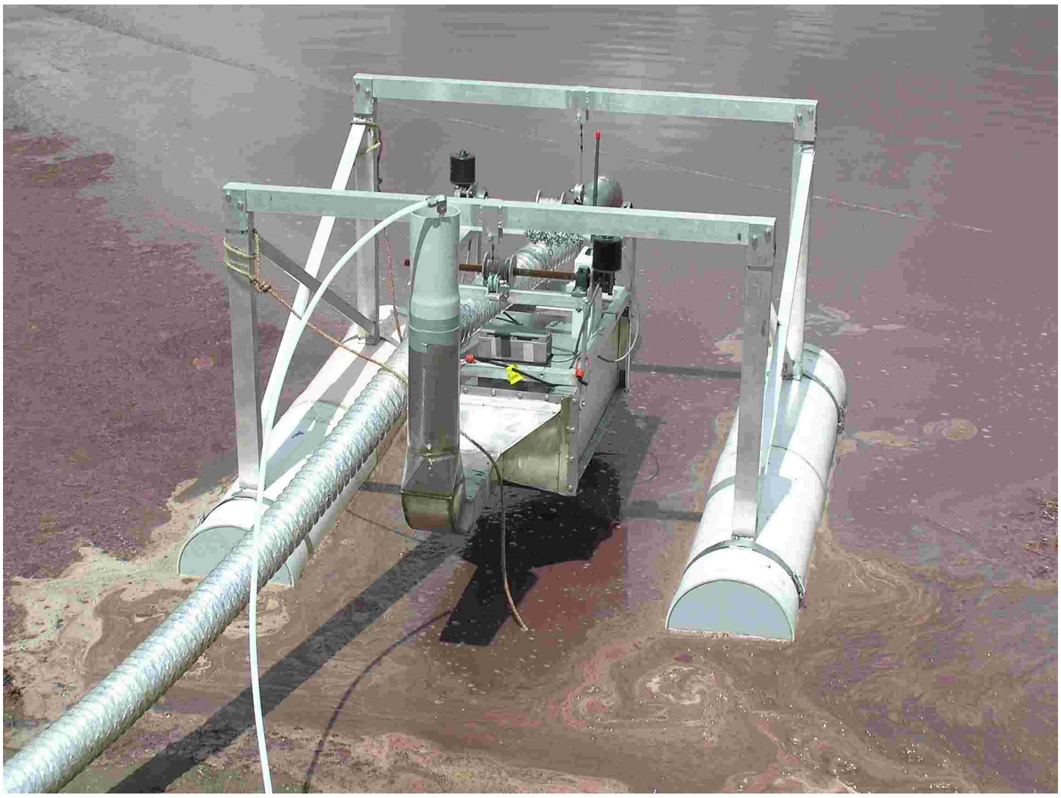

Figure 3.2: Wind Tunnel in Lifted Position

Figure 3.3: Wind Tunnel, Ready to be lowered into Sampling Position

Figure 3.4: Wind Tunnel in Sampling Position

Figure 3.5: Odorous Air Sample Collection Drums

The drums were airtight, and air was pumped from the drums to draw the odorous air sample into the bags (in a lung arrangement). This ensured minimal contact of the sample air with the equipment. It took around 6 minutes to fill the sample bag within the drum.

3.4 Additional Measurements taken at time of Sampling

Additional measurements taken at the time of sample collection include the ambient temperature and humidity, and the wind speed at the throat of the wind tunnel. This was done with a Thermosystems Incorporated (TSI) Model 8355 hot wire anemometer. By taking this measurement, and knowing the physical dimensions of the wind tunnel, the wind velocity at the base of the tunnel (the odour emitting surface) could be determined. For the wind tunnel used by the DPI and F, a wind speed of 4 m/s equates to a wind speed of 0.37 m/s at the surface (a factor of 0.093). The wind speed at the emitting surface is required when correlating wind tunnel odour measurements

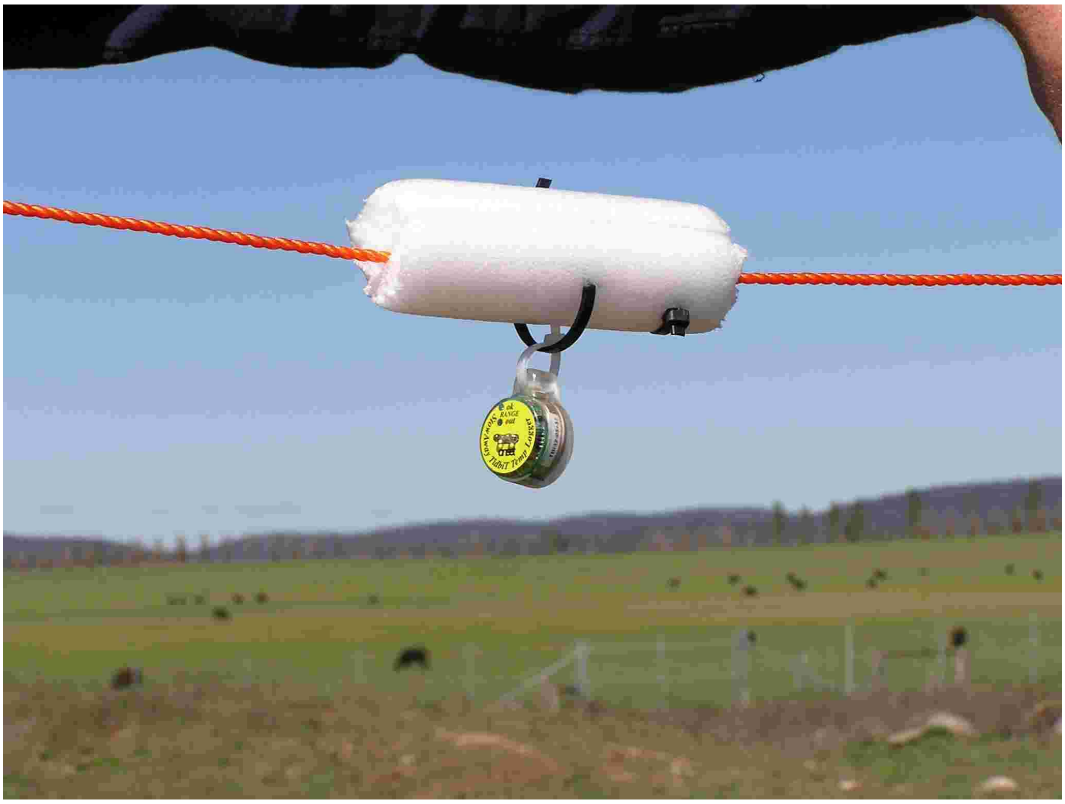

Figure 3.6: Pond Effluent Temperature Sensor / Logger

to climatic wind speed data.

Soon after the inflow event occurred, data loggers measuring pond temperature were floated on the surface of the primary holding pond at each feedlot. The loggers took pond temperature measurements every ten minutes, approximately 5 cm below the pond surface. The photographs in Figures 3.6 and 3.7 show the data logger itself, and its operating position on the surface of the primary holding pond at Feedlot B.

Both feedlots have automatic weather stations (AWS) installed, that were used extensively throughout this project. Data collected included air temperature, humidity, wind speed and direction, soil / manure temperature, rainfall, incoming / outgoing solar radiation and potential evaporation (calculated).

The time and exact location of sampling and (subjective) weather conditions are noted also, for reference.

Other data, required to formulate the pond odour emissions model, that were not

Figure 3.7: Pond Effluent Temperature Sensor / Logger In Position

directly measured (such as initial pond volumes and inflow volumes) were derived, as detailed in Section 3.6.1.

3.5 Odour Assessment

3.5.1 Sample Stability

The odour samples, stored within the Melinex™ sample bags (in the sample drums) were taken to the DPI & F's olfactometer for analysis. This was generally done within 24 hours of collection. The Standard recommends that samples be analysed within 30 hours of collection (Standards Australia and Standards New Zealand, 2001). The project undertaken for Meat and Livestock Australia, of which this work is part, has undertaken some work into sample stability (Nicholas, 2004), and concluded that the deterioration of odour samples over the time frames encountered is acceptable for the purposes of this project. Figure 3.8 shows the variation in odour concentration from

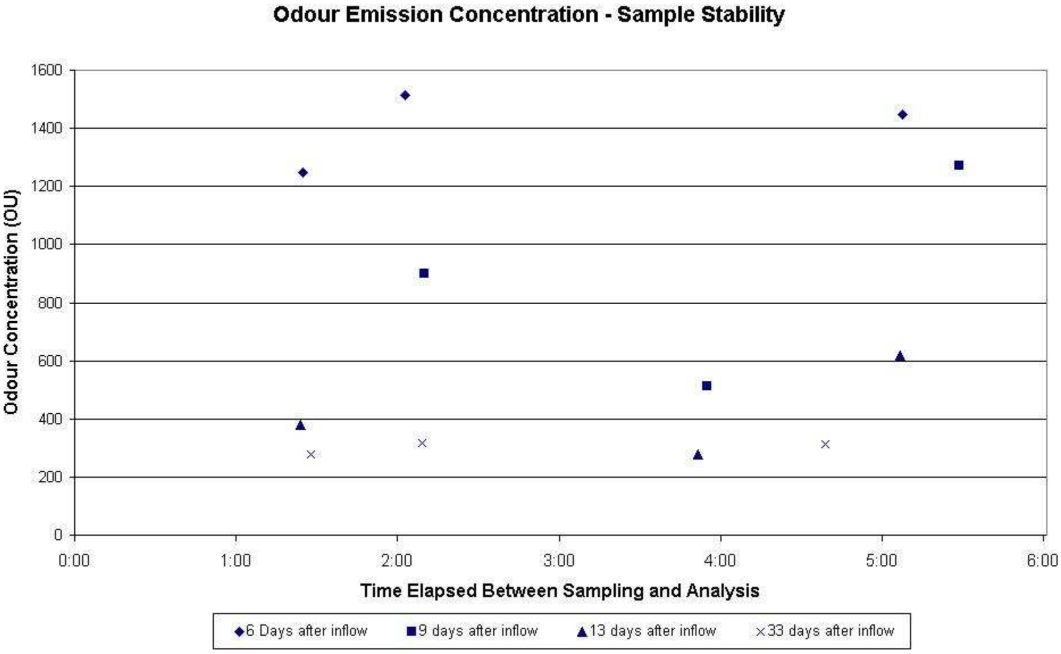

Figure 3.8: Variation in Odour Concentration with Elapsed Time to Analysis

samples taken in duplicate / triplicate (at the same time and location) with differing elapsed times to analysis. The data in Figure 3.8 is from Feedlot A only, and it can be seen that all samples were analysed within 6 hours of sample collection. An equivalent analysis was not possible from Feedlot B, as all identical samples were analysed with similar elapsed times after collection. All samples from Feedlot B, excepting the first day of sampling, were analysed at between 21–22 hours after collection. The first day of samples were analysed approximately 6 hours after collection.

3.5.2 Olfactometry

The Department has a state of the art forced-choice dynamic olfactometer, operated in accordance with the Australian / New Zealand Standard - Stationary Source Emissions - Determination of Odour Concentration by Dynamic Olfactometry (AS/NZS 4323.3).

The following description of the olfactometry process and calculation is taken from Hudson et al (2004) - *The Effect of Loading Rate and Spatial Variability on Pond Odour Emission.*

The Olfactometer consists of a panel of eight people (assessors), used to evaluate the ‘air’ being presented at three sniffing ports. Each panellist was first screened with the reference gas (*n*-butanol) to ensure their detection thresholds for the reference gas were between 20 and 80 parts per billion (ppb). This was in accordance with the Standard. Two of the ports were supplied with clean, odour free air, and the third was supplied with (diluted) odorous air. The panellists then had to select which port contained the odorous air, and give an indication of confidence in their choice (certainty, inkling or guess).

The process was repeated, doubling the strength of the odour sample presented each time until each panellist had responded with certainty and correctly for two consecutive presentations. Each panellist’s individual threshold estimate (Z_{ITE}) was then determined by calculating the geometric mean of the dilution at which the panellist did not respond with certainty and correctly and the first of the two dilutions where the panellist did respond with certainty and correctly. This entire process is defined as a round, and three rounds were completed for each sample, provided enough sample was available.

At the end of the three rounds, the results of the first round were discarded in accordance with the Standard. The results from rounds two and three were then geometrically averaged ($\overline{Z}_{ITE}$). The ratio between Z_{ITE} and $\overline{Z}_{ITE}$ is defined as ΔZ. The calculation of ΔZ is presented in Equations 3.1 and 3.2.

$$If(Z_{ITE}) >= (\overline{Z}_{ITE})\; then\; \Delta Z = \frac{(Z_{ITE})}{(\overline{Z}_{ITE})} \tag{3.1}$$

$$If(Z_{ITE}) <= (\overline{Z}_{ITE})\; then\; \Delta Z = \frac{(\overline{Z}_{ITE})}{(Z_{ITE})} \tag{3.2}$$

If ΔZ is greater than ± 5 then all Z_{ITE}s of the panel member with the largest ΔZ are excluded from the data set. The screening procedure is then repeated, after recalculation of $\overline{Z}_{ITE}$ for that measurement. If a panel member again did not comply, the panel member with the largest ΔZ was omitted. This was repeated until all the panel members in the dataset had an acceptable ΔZ value. The last value of $\overline{Z}_{ITE}$ is then defined as the odour concentration and expressed as odour units per cubic metre (ou/m^3).

To calculate the odour emission rate (OER), Equation 3.3 is used.

$$OER = CV_t\frac{A_t}{A_s} \tag{3.3}$$

where C is the odour concentration in the bag; V_t is the wind speed inside the tunnel; A_t is the cross-sectional area of the tunnel; and A_s is the surface area covered by the tunnel. OER is measured in units of odour units per second square metre (ou/s.m^2)

This equation assumes that; All background odour in the air introduced to the wind tunnel is removed by the carbon filter, and there is complete mixing between the emissions and airflow in the tunnel.

The calculated OER was then scaled to a standard tunnel wind speed of 1 m/s according to Smith and Watts (1994), using Equation 3.4.

$$\frac{E_v}{E_1} = V_t{}^{0.63} \tag{3.4}$$

The exponent of 0.63 was derived as a factor for wind tunnels from research conducted on solid surfaces at feedlots. This exponent does not apply to liquid surfaces such as anaerobic ponds. However, Pollock (1997) recommended the use of an exponent of 0.5 for liquid surfaces (based on the work of Bliss et al, 1995). This value was adopted for use in all calculations of odour emission rate in this poject.

3.6 Methods of Data Analysis

The analysis of the collected data was a significant component of this project. Most of the required data was ready at hand, however, some data required was not directly measured and needed to be derived from other data.

3.6.1 Derived Data Collation

In order to better understand, and subsequently model, the odour emissions from the effluent ponds after a significant inflow, some data was required that was not measured. This included the volume of effluent inflowed to the pond system, and the initial volume of effluent in the ponds. This was not measured for a number of reasons. Firstly, the amount of effluent in the ponds (initially and following the inflow event) is difficult to measure and assess. Secondly, the co-operating feedlots were already committing a lot of resources and time toward the project, and it was considered unnecessary to burden them with additional daily data collection and record keeping. As the ponds at both feedlots have no system of flow measurement in place, it was also impossible to work out actual inflow volumes in real time.

To obtain the inflow volumes, considered vital in formulating the emissions model, the MEDLI software was employed. MEDLI (**M**odel for **E**ffluent **D**isposal through **L**and **I**rrigation) is a program that was jointly developed by the CRC for Waste Management and Pollution Control, the Queensland Department of Natural Resources and the Department of Primary Industries and Fisheries (v2.0, 2003), to model the generation and disposal of effluent from piggeries, sewage treatment plants, feedlots, dairies, etc. MEDLI includes a feedlot module, which, after input of various feedlot specific parameters and a site specific climate file, will return, among a host of other modelled parameters, values of inflow to the effluent pond system. As the model is focussed on the primary holding pond (see Chapter 5), the software was run with parameters to model the inflow to this pond only.

To calculate the initial pond volumes, photographs taken during the sampling period were analysed. Many photographs were taken each day that sampling took place. Photographs of the ponds, depth gauges (if present) and permanent fixtures in the pond were taken. Analysing these defined the depth variation in the ponds over the sampling period. Coupled with an aerial photo (Feedlot A) and a scaled, contoured site plan (Feedlot B) the volume of each primary holding pond could be calculated, to an estimated accuracy of ±0.5 ML. The task for Feedlot A was made considerably easier, as the photographic evidence revealed that the primary holding pond was dry

Figure 3.9: Feedlot A – AutoCad-manipulated Aerial Photograph

prior to the inflow. However, this did pose a problem with the modelling, as detailed in Chapter 5.

Feedlot A Inflow Volume Calculation

The MEDLI feedlot module was run to determine the inflow volume to the primary holding pond. MEDLI has many input parameters which can be adjusted to suit a particular feedlot. As many of these input parameters are required for the effluent irrigation modelling, they were ignored (i.e. left as default values), as they had no effect on the amount of effluent inflow to the pond system. The most important factors in determining the inflow volume were the areas of the feedlot (pen, hard and soft area). Pen area is obviously the area of the feedlot of which is taken up by cattle pens. Hard area is the area that is relatively impervious (roads, drains, etc) and soft area is grassed or cultivated area within the feedlot catchment. These areas were estimated for Feedlot A using an aerial photograph in AutoCad. The areas were outlined on the photograph and measured. The AutoCad drawing is included as Figure 3.9.

The sensitivity of the model to the area estimates was tested, as shown in Table 3.5. Only the hard and soft areas were tested for sensitivity as the pen areas can be estimated

Table 3.3: Feedlot A - Final MEDLI Parameters for Inflow Estimation

Parameter	Units	Value
Cattle Number	head	18,000
	SCU	19,114
Occupancy	%	80
Cattle Entry Weight	kg	350
Cattle Exit Weight	kg	650
Feeding Period	days	120
Pad Interface Depth	mm	20
Pad Manure Depth	mm	20
Average Pen Cleaning Interval	days	84
Number of Pens		95
Pen Stocking Density	m^2/SCU	14.8
Total Pen Area	ha	28.261
Feedlot Hard Area	ha	10.46
Feedlot Soft Area	ha	1.0
Total Catchment Area	ha	39.721

reasonably accurately from the aerial photograph.

The inflow volume to the pond system was most sensitive (5%) to the estimate of hard and soft areas, as shown in Table 3.5. (Only the soft area was changed, and the hard area reduced to maintain correct catchment area). However, no improvement to the accuracy of the estimation of these areas could be made, and hence this small sensitivity was accepted.

The other factors required (that would impact on the estimation of inflow) were either supplied by the management of Feedlot A or measured throughout the course of this project, and were considered reliable. These factors were also adjusted to test sensitivity, as shown in Table 3.5.

The final parameters accepted for the MEDLI run, which returned the value of inflow into the effluent pond system for Feedlot A, are listed in Table 3.3. Again the emphasis is made that there are many input parameters needed to run MEDLI, however the parameters listed are those which directly affect the amount of runoff, and consequently inflow into the effluent pond system.

MEDLI was run for the full period of available climate data (47 years), to allow the system to come to equilibrium.

Table 3.4: Feedlot A - MEDLI Values of Effluent Inflow from Rainfall

Date	Rainfall (from MEDLI, mm)	Inflow (m^3)
5 December 2003	21	3,942
6 December 2003	81	24,345
7 December 2003	22	5,265
Total	124	33,552

Table 3.5: Feedlot A - Sensitivity Analysis of MEDLI Parameters

Input Parameter	Old Value	New Value	% Change	New Inflow	Error (%)
Soft Area	1.00	3.00	66.6	31,815	-5.20
Cattle Exit Weight	650	600	8.33	33,717	0.50
Overall Pad Thickness	40	20	100	34,098	1.75
Pen Cleaning Interval	84	56	33.3	33,765	0.63

The MEDLI predicted inflow volumes for each day of the rain event, and the actual rainfall which produced them, are listed in Table 3.4.

It is noted that not all parameters were tested for sensitivity. Some parameters are contingent on others, such as the hard / soft areas and cattle weights / feeding period, and cannot be adjusted separately.

As can be seen, the sensitivity of the final inflow volume to all these factors was less than ±5%. This is acceptable due to the limited accuracy of initial effluent pond volume estimations.

Feedlot A - Primary Holding Pond Initial Volume Estimation

Photographic evidence taken prior to the time of inflow has clearly indicated that the primary holding pond at Feedlot A was *completely dry at the time of inflow.* A photograph of the pond condition at this time is provided in Figure 3.10.

Feedlot A - Inflow Retained by Sedimentation Basins

The sedimentation basin retains a certain amount of effluent after a runoff event. In time, this effluent either passes through the weir into the primary holding pond or evaporates. For the modelling of the primary effluent pond, this volume of effluent can be considered to be removed, as it does not enter the primary pond immediately.

Figure 3.10: Feedlot A - Primary Holding Pond Primary to Inflow

Figure 3.11: Feedlot A - Main Sedimentation Basin Prior to Inflow

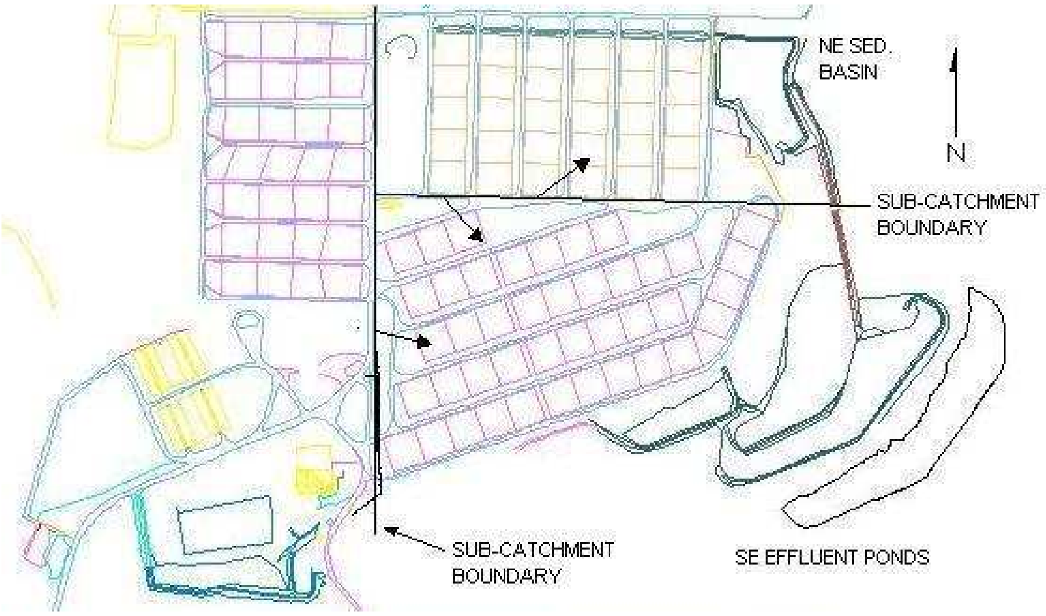

Figure 3.12: Feedlot B – AutoCad Design Drawing

The two sedimentation basins have a total area of 3.01 ha, and were (almost) dry at the time of inflow. Figure 3.11 shows the main sedimentation basin prior to the inflow. The depth of effluent retained by the weirs in both basins is about 150 - 200 mm. As 100 mm of effluent over 1 ha is 1 ML, the amount of effluent retained was 6.02 ML. This volume was removed from the inflow volume to the primary holding pond.

Hence the total volume of inflow to the first holding pond after the rain event was 33.552 - 6.02 = **27.53 ML**.

Feedlot B

Again the MEDLI feedlot module was employed to determine the inflow volumes into the effluent pond system at Feedlot B. Feedlot B is located on the crest of a hill, and as such the feedlot drains into three separate effluent systems. The effluent system under consideration was the main one (known as the South-Eastern Holding Ponds), which accepted runoff from over half of the feedlot. The primary holding pond of this system accepts effluent overflowing from two separate sedimentation basins (NE and SE), as can be seen in the AutoCad design drawing in Figure 3.12.

The two sedimentation basins, which overflow into the pond under consideration, accept runoff from the entire eastern side of the feedlot. Figure 3.12 shows where the drainage lines split the feedlot in half. The relative pen, hard and soft areas could be found relatively easily from Figure 3.12, using AutoCad software. The *total* capacity of the feedlot was known, however the number of cattle either side of this drainage line was not. Hence some interpolation of cattle numbers was required to determine this, using the stocking density and known pen area. This helped to determine some of the input parameters for MEDLI.

A total of 72 pens exist within the SE Effluent Ponds Catchment. 36 pens in the north-east quadrant of the feedlot drain to the NE sedimentation basin, before overflowing to the primary holding pond of the south-east pond system. The balance of the pen area drains to the SE sedimentation basin.

The 72 pens have a total area of 238,000 m^2 (measured from the AutoCad plan). This calculates to 3305 m^2/pen, which agrees well with data supplied from the feedlot management itself (3300 m^2 quoted). At an average stocking rate of 13.6 m^2/head, this is 243 head per pen (on average). Hence there is 243 x 72 = 17496 head in the catchment, which at 95% occupancy, and with a JapOx SCU conversion (QDPI, 2000) of 1.147, gives a total number of SCU's in the catchment (at any particular time) of 19069. From the AutoCad drawing, the number of pens is 72, with a stocking rate of 13.6 m^2/head (or 11.86 m^2/SCU), hard area of 14.827 ha and a soft area of 5.129 ha. The pen area, as stated previously, is 23.8 ha. All the relevant input parameters required for the MEDLI run are listed in Table 3.6.

The MEDLI predicted inflow volumes for each day of the rain event, and the actual rainfall which produced them, are listed in Table 3.7.

As the exact amount of soft area was not certain, the sensitivity of the area parameters was checked. In the most extreme, where the proportion of soft and hard area was changed from approx 25:75 to 35:65, the changes to the inflow amounts changed by 5% or less. The pen area was held constant, as its value was estimated accurately from the design drawing. The other parameters were not tested for sensitivity as it was proven for Feedlot A that the effect of any error was minimal.

Feedlot B - Primary Holding Pond Initial Volume Estimation

Table 3.6: Feedlot B - Final MEDLI Parameters for Inflow Estimation

Parameter	Units	Value
Cattle Number	head	17,496
	SCU	20,068
Occupancy	%	95
Cattle Entry Weight	kg	420
Cattle Exit Weight	kg	720
Feeding Period	days	300
Pad Interface Depth	mm	20
Pad Manure Depth	mm	20
Average Pen Cleaning Interval	days	90
Number of Pens		72
Pen Stocking Density	m^2/SCU	11.9
Total Pen Area	ha	23.800
Feedlot Hard Area	ha	14.827
Feedlot Soft Area	ha	5.129
Total Catchment Area	ha	43.756

Table 3.7: Feedlot B - MEDLI Values of Effluent Inflow from Rainfall

Date	Rainfall (from MEDLI, mm)	Inflow (m^3)
1 October 2003	67	21,987
2 October 2003	38	12,519
Total	105	34,506

The volume of effluent in the primary holding pond at Feedlot B was estimated using a combination of photographic evidence and the design drawing in Figure 3.12. From the photograph in Figure 3.13, taken before the inflow event, the level of the pond can be seen relative to the mesh cage. The maximum capacity of this pond (36 ML) was quoted from the feedlot management (Tudor, P., 2004 *pers. comm.*) to occur at 650 mm above the mesh cage. It can be seen that the level of effluent is approximately 300 - 350 mm below the top of this structure. Hence the level is about 950 - 1000 mm below maximum. The area at Top Water Level (TWL) of this pond is 3.05 ha. As 100 mm depth over 1 ha = 1 ML, there is approximately (950 / 100) x 3.05 = 29 ML of effluent 'missing' from the pond. As the maximum capacity is 36 ML, this implies that there is about **7.0 ML** of effluent present in the pond.

Needless to say, there have been some gross assumptions made in this estimate. This assumes that the pond has vertical sides and a flat bottom. In reality this is not the case, but close examination of the contour lines in Figure 3.12 (not shown for clarity) shows that these assumptions are acceptable. The level of accuracy required for the

Figure 3.13: Feedlot B - Primary Holding Pond Prior to Inflow

model development has already been limited by the estimates of inflow volume, however a measure of the level of accuracy of this estimate cannot be made. In the absence of a better method, the estimate will be accepted. The impact of this estimate is assessed in Chapter 5.

Feedlot A - Inflow Retained by Sedimentation Basins

The sedimentation basins at Feedlot B also retain a certain amount of effluent, which cannot be considered in the modelling of the primary holding pond. The photographic evidence of the north-east sedimentation basin shows that the basin was nearly full at the time of inflow (see Figure 3.14) and as such would not have retained any fresh effluent.

The south-east sedimentation basin was not full, and therefore retained some effluent before overflowing to the primary holding pond. Figure 3.15 shows the level prior to the inflow event. (It needs to be stated that even though the weirs at both feedlots are semi-permeable (wooden boards), the effluent is indeed removed from the inflow to

Figure 3.14: Feedlot B - North-East Sedimentation Basin Prior to Inflow

the primary holding pond, as the effluent takes a number of days to move through the weir.)

The sedimentation basin covers an area of 0.86 ha. The level had to rise 300 mm to overflow, and therefore the amount of effluent retained was (300 / 100) x 0.86 ha, which is approximately 2.58 ML. This volume is therefore removed from the total inflow volume calculated.

Hence the total volume of inflow to the first holding pond is 34.506 - 2.58 = **31.93 ML**.

Figure 3.15: Feedlot B - South-East Sedimentation Basin Prior to Inflow

Chapter 4

Results

4.1 Odour Emission Rate Results

The odour concentration and emission rate data was calculated by the Department of Primary Industries and Fisheries as part of their olfactometry service, and the relevant data was delivered to FSA Consulting for analysis via e-mail. All complete odour emission rate data sets / working spreadsheets have been included in full in Appendix B.

The odour emission rate data measured from both feedlots is best displayed in graphical form to better understand the pattern of odour emission; however the average odour emission data for each of the ponds at both feedlots is included.

4.1.1 Feedlot A

The odour emission rate over the sampling period (34 days after the rainfall event) at Feedlot A for the three effluent treatment areas (sedimentation basin, primary and secondary holding ponds) is shown in Figure 4.1. Note that the samples were taken in duplicate or triplicate, and as such the average odour emission rate of these samples was used to define the pattern.

The odour emission data from Feedlot A is included in Table 4.1. From Figure 4.1, it

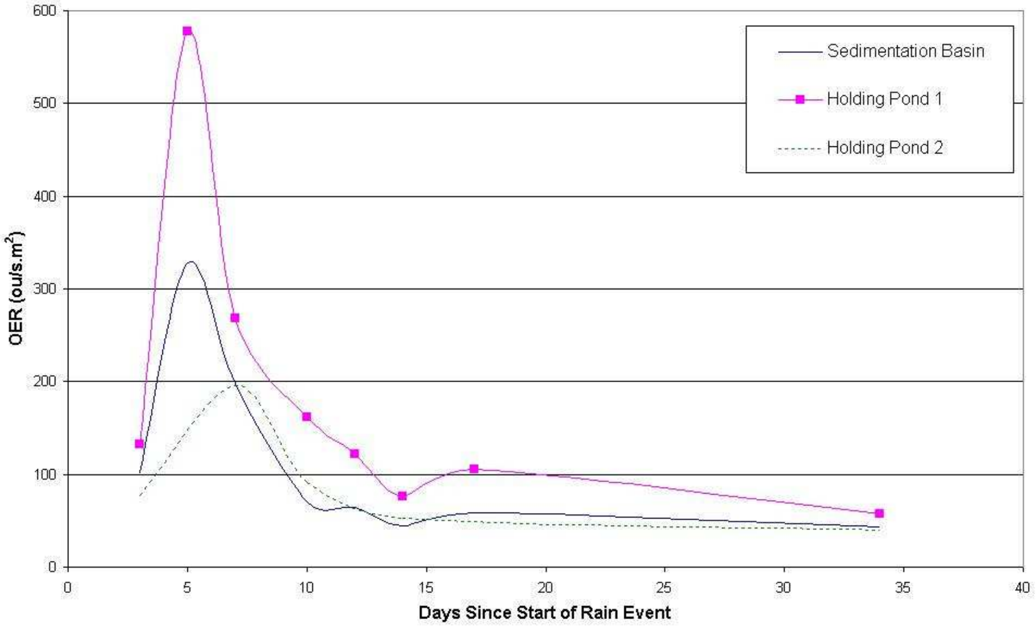

Figure 4.1: Feedlot A - Odour Emission Rates from All Effluent Ponds

Table 4.1: Feedlot A - Odour Sampling Results (All Ponds)

Sampling Date	Pond	Avg. Odour Emission Rate (ou/s.m^2)
8 Dec 2003	Sedimentation Basin	102
	Primary Holding Pond	132
	Secondary Holding Pond	77
10 Dec 2003	Sedimentation Basin	328
	Primary Holding Pond	578
	Secondary Holding Pond	–
12 Dec 2003	Sedimentation Basin	198
	Primary Holding Pond	269
	Secondary Holding Pond	196
15 Dec 2003	Sedimentation Basin	70
	Primary Holding Pond	161
	Secondary Holding Pond	91
17 Dec 2003	Sedimentation Basin	64
	Primary Holding Pond	122
	Secondary Holding Pond	–
19 Dec 2003	Sedimentation Basin	44
	Primary Holding Pond	76
	Secondary Holding Pond	53
22 Dec 2003	Sedimentation Basin	59
	Primary Holding Pond	105
	Secondary Holding Pond	–
8 Jan 2004	Sedimentation Basin	43
	Primary Holding Pond	57
	Secondary Holding Pond	40

can be seen that the primary holding pond peaked close to 600 ou/s.m^2, the secondary holding pond peaked just below 200 ou/s.m^2 and the sedimentation basin peaked above 300 ou/s.m^2. This pattern of emission is similar to that reported by Casey *et al* (1997).

Focussing on the primary holding pond (the pond which will be modelled) we see a sharp rise to a peak (578 ou/s.m^2) after 5 days. Within two days the odour emission rate had dropped to less than half this peak. After this the odour emission rate tended to plateau out, and slowly decreased over the remainder of the sampling period. The pattern also shows a dip in the odour emissions at the 14 day (after the rain event) mark. This cannot be logically explained, and is attributed to the inherent variability in olfactometry.

It is noted that both the sedimentation basin and the secondary holding pond both displayed a similar pattern of odour emission. This is not always the case, as the characteristics of both ponds can be heavily influenced by management. The movement of effluent from the sedimentation basin is weir-controlled, and the movement of effluent into the secondary holding pond is controlled by pumping. After a rainfall event of this magnitude, pumping into the secondary holding pond usually occurs quite quickly, as the primary holding pond level needs to be reduced in case of further rain. It is clear that the level of odour emissions from the secondary holding pond will alter with the amount of 'untreated' effluent being introduced to it through pumping.

4.1.2 Feedlot B

The odour emission rate over the sampling period (29 days after the rainfall event) at Feedlot B for the three effluent treatment areas (sedimentation basin, primary and secondary holding ponds) is shown in Figure 4.2. Note that again the samples were taken in duplicate or triplicate, and as such the average odour emission rate of these samples was used to define the pattern.

The odour emission data is included in Table 4.2. As shown in Figure 4.2, the sedimentation basin showed a peak emission rate of just over 300 ou/s.m^2. The primary and secondary holding ponds' odour emissions peaked around the 450-480 ou/s.m^2

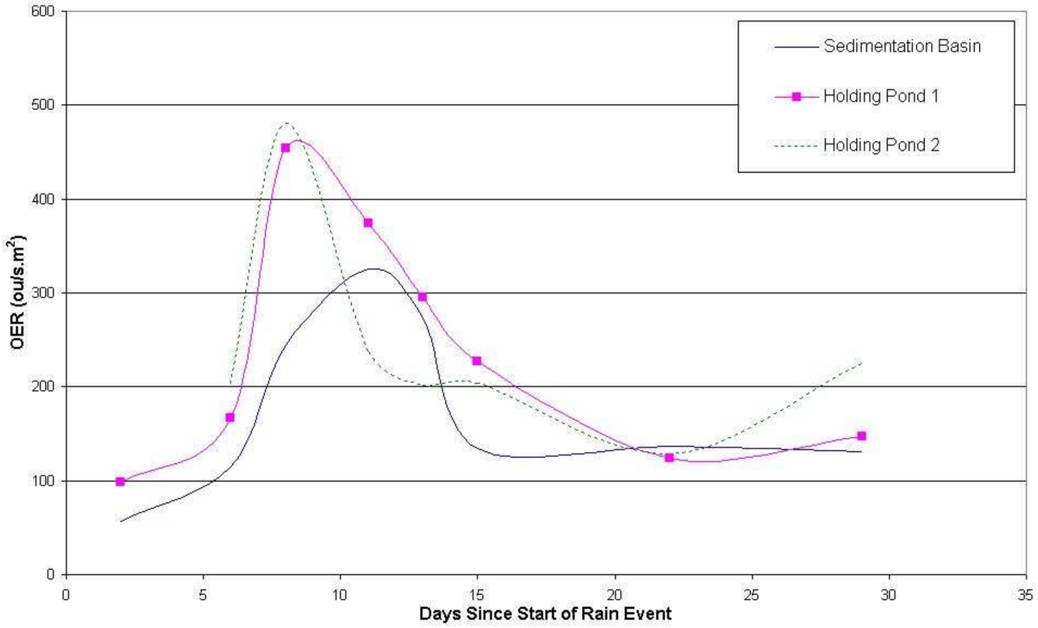

Figure 4.2: Feedlot B - Odour Emission Rates from All Effluent Ponds

Table 4.2: Feedlot B - Odour Sampling Results (All Ponds)

Sampling Date	Pond	Avg. Odour Emission Rate (ou/s.m^2)
3 Oct 2003	Sedimentation Basin	56
	Primary Holding Pond	99
	Secondary Holding Pond	–
7 Oct 2003	Sedimentation Basin	115
	Primary Holding Pond	167
	Secondary Holding Pond	204
9 Oct 2003	Sedimentation Basin	244
	Primary Holding Pond	454
	Secondary Holding Pond	481
12 Oct 2003	Sedimentation Basin	325
	Primary Holding Pond	374
	Secondary Holding Pond	238
14 Oct 2003	Sedimentation Basin	273
	Primary Holding Pond	295
	Secondary Holding Pond	201
16 Oct 2003	Sedimentation Basin	134
	Primary Holding Pond	227
	Secondary Holding Pond	204
23 Oct 2003	Sedimentation Basin	137
	Primary Holding Pond	124
	Secondary Holding Pond	129
30 Oct 2003	Sedimentation Basin	131
	Primary Holding Pond	148
	Secondary Holding Pond	225

mark. This pattern of emission is also similar to that reported by Casey *et al* (1997), with emissions peaking 8 days after inflow, followed by a relatively uniform and slow reduction in emission rates over the next 25-30 days.

Again focussing on the primary holding pond, the odour emission rate rose to a peak (454 ou/s.m^2) after 8 days, with a much broader peak displayed than at Feedlot A. The odour emission decreased steadily until the the final day of sampling, where the emission rate was seen to increase slightly. This may be explained through a further small inflow to the pond system on the 19th of October (18 days after the rain event, see Table 3.2 in Chapter 3). The small rainfall event on the 6th of October may have also contributed to the broader peak of the graph (i.e. elevated odour emission rate over a longer period of time) shown at Feedlot B.

As mentioned earlier in this chapter, the patterns of odour emission from the sedimentation basin and secondary holding ponds may vary significantly from the pattern from the primary holding pond due to management decisions. This is shown in Figure 4.2, where the pattern of odour emissions for the sedimentation basin is quite irregular, in comparison to the pattern for the primary holding pond. It is noted here that the management of the sedimentation basin at Feedlot B is quite different to that at Feedlot A. The sedimentation basin at Feedlot B is weir-controlled, and a 200-300 mm depth of effluent is kept in the basin at all times. Whilst the weir at Feedlot A is also controlled by a weir, the sedimentation basin is allowed to dry out completely following a runoff event.

The pattern of odour emission for the secondary holding pond is fairly similar to the primary holding pond. While effluent was still running off the feedlot catchment into the holding ponds after the rain event, management had decided to allow some effluent to flow into the secondary holding pond. This meant that at the same time that the primary holding pond was filling with fresh effluent, the secondary holding pond was also receiving ‘untreated’ effluent, with a similar effect on odour emissions. Unfortunately neither feedlot kept records on the amounts of effluent pumped between the two holding ponds, or the days on which pumping occurred. It can also be seen in Figure 4.2 that the odour emissions from the secondary holding pond increased markedly towards the end of the sampling period. One would expect that this is due to a further

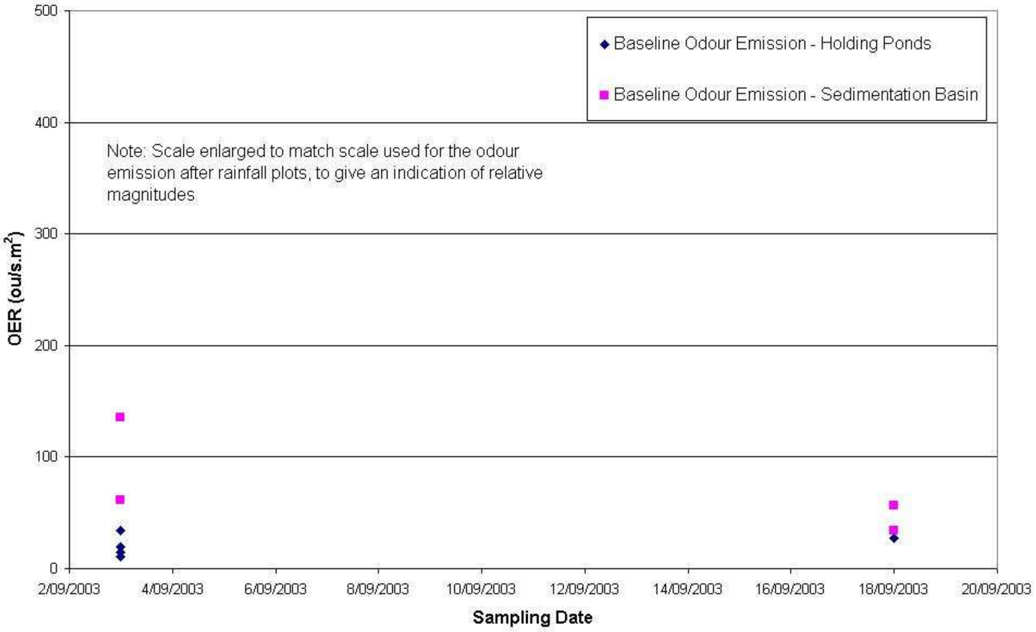

Figure 4.3: Feedlot B - Baseline Odour Emission Rates from All Effluent Ponds

pumping event into the secondary pond.

The 'baseline' odour emission rates from undisturbed ponds at Feedlot B are shown in Figure 4.3. These odour samples were taken from ponds which had not experienced an inflow for many months, and as such the odour emission rates would be expected to be slightly lower than 'normal', as the ponds would have had ample time to come to equilibrium. At most times of the year, 'normal' odour emission rates would include some effect from the last inflow event, as it can take some time for ponds to come to equilibrium.

The ponds at Feedlot A were dry before the inflow events described in these results, and therefore there is no equivalent estimate of 'baseline' odour emission rates at Feedlot A. However, some measurements were taken from the secondary holding pond at Feedlot A prior to the inflow, with odour emission rates close to 5 ou/s.m^2. This value of odour emission rate has been accepted as the baseline odour emission rate for the primary holding pond at Feedlot A.

The last day of the inflow sampling odour emission rates (for the primary holding pond at Feedlot A) were assumed to be the 'baseline' rates for the purposes of the larger project for Meat and Livestock Australia, however these odour emission rates would still display some of the effects of the inflow event.

4.1.3 Discussion of Odour Emission Rate Results

There are some important differences in the two patterns of odour emissions (from the respective primary holding ponds). The first is the delay in the times to peak between the two feedlots. Feedlot A rose quickly to peak on the 5th day, where Feedlot B peaked on the 8th day after the rain event. This could be due to a number of factors, but it is postulated that the difference in climate between the feedlots is responsible. Feedlot B is situated in a cool climate, and the sampling was carried out in the spring whereas Feedlot A is in a hot climate, and the sampling was carried out at the beginning of summer. The average ambient temperature difference between the two feedlots was a full 10° warmer at Feedlot A, during their respective sampling periods.

Feedlot B also displays a much broader peak of odour emissions, with rates remaining elevated for a longer period of time than at Feedlot A. This is also thought to be due to the different climates in which the two feedlots are situated. In the same way that the odour emissions took longer to rise to a peak, the odour emissions took longer to decline after the peak.

4.2 Other Measured Data

4.2.1 Pond Surface Temperature

As mentioned previously in Chapter 3, the surface temperature of the primary holding ponds at both feedlots was logged every ten minutes. The change in pond surface temperature at both feedlots over the sampling period is shown in Figures 4.4 and 4.5.

The odour emission pattern from Feedlot B (in Figure 4.5) does look slightly different to that depicted in Figure 4.2, as the odour samples were collected separately, from the same pond, at slightly different times. Hence all samples could be shown in comparison

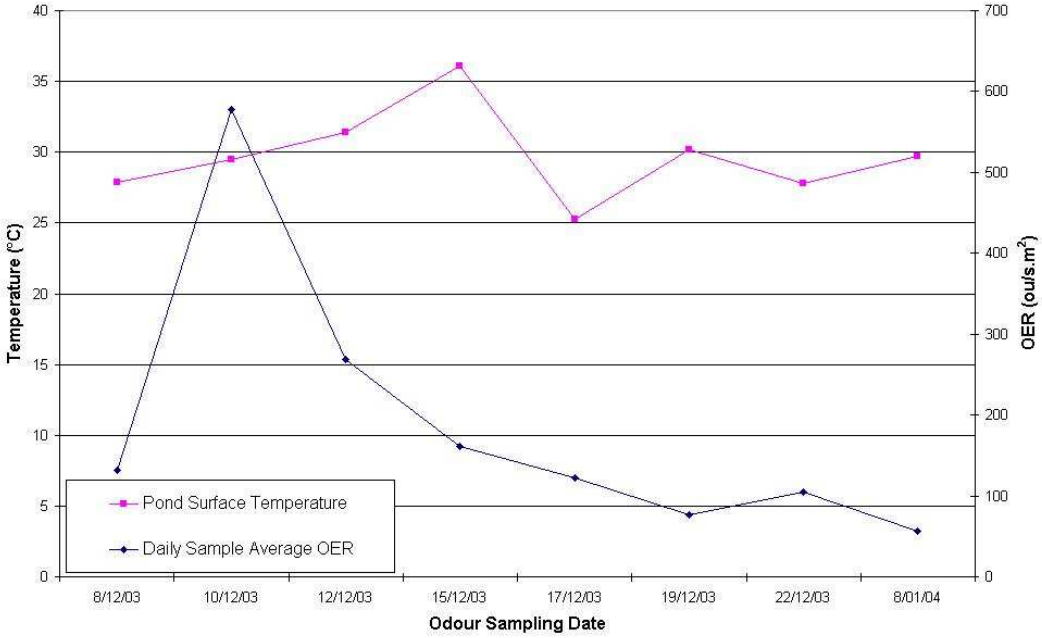

Figure 4.4: Feedlot A - Variation of Pond Surface Temperature At Times of Sampling

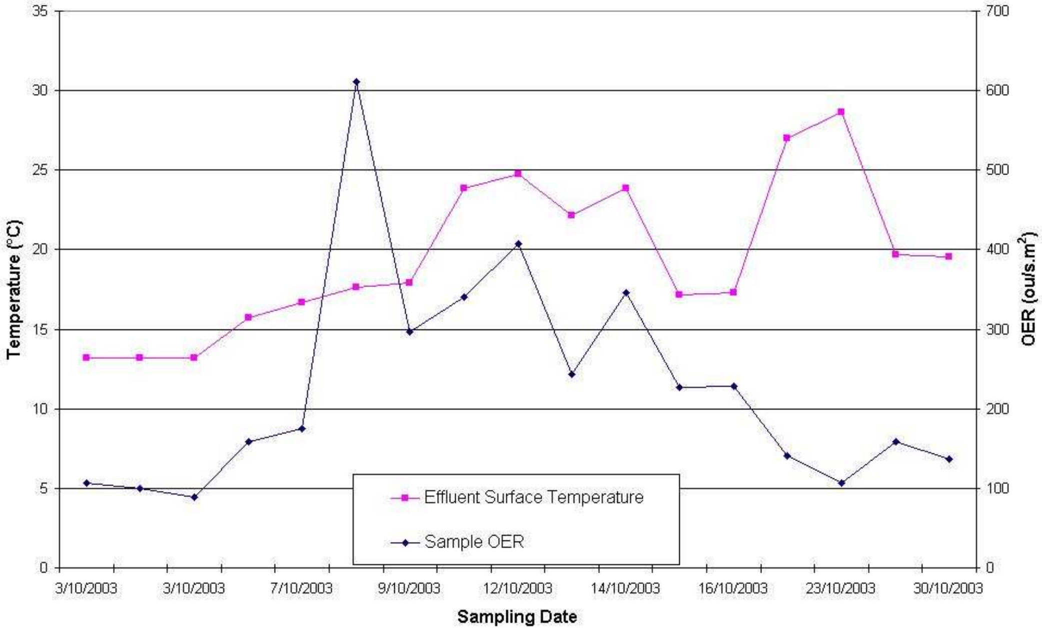

Figure 4.5: Feedlot B - Variation of Pond Surface Temperature At Times of Sampling

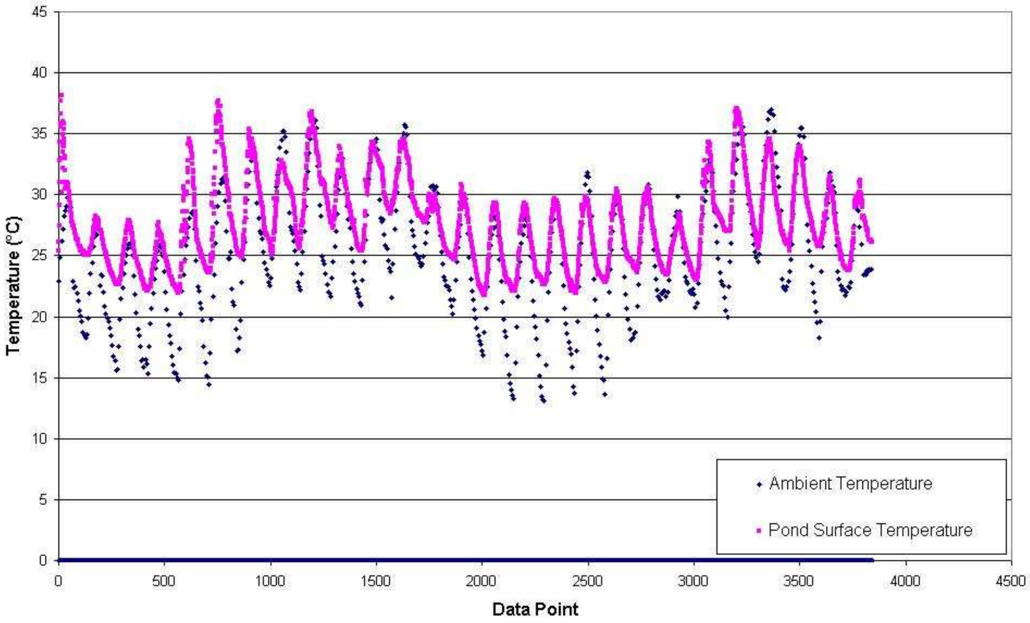

Figure 4.6: Feedlot A - Comparison of Pond Surface and Ambient Temperature

to the relative pond surface temperature. In Figure 4.4, the samples were taken in duplicate / triplicate (at the same time), so this plot shows the *average* odour emission rate.

It is also noted that the pond temperature loggers were not installed into the ponds until the 15th of December (2003) at Feedlot A, and the 9th of October (2003) at Feedlot B. Hence to complete the comparison plot with the odour emission data, the temperatures up to the date of installation were assumed from ambient temperatures (as the pond surface temperature follows the ambient temperature quite closely). A comparison of the pond and ambient temperatures is given in Figure 4.6, for the sampling period at Feedlot A.

It is clear that the pond surface temperature follows the daytime higher temperatures quite closely. However the ponds remain much warmer during the night, with a large difference between the measured temperatures. This has little bearing on the assumed pond surface temperatures (to complete the data set for the comparison in Figure 4.4) as all the *measured* pond temperatures were above 25°. At this range of temperatures, there is little difference between the pond surface and ambient. Similar results were found at Feedlot B.

4.2.2 Discussion – Pond Surface Temperature Results

It is reasonably clear that there is no direct relationship between the pond surface temperature and the odour emission rate. The pond surface temperature at both feedlots remained reasonably steady over the days and times of each odour sampling session. It was unfortunate that the temperature of the pond liquor could not be measured at greater depths, or a range of depths, as this would have given a better indication of any temperature changes in time.

Having said this, it is likely that small changes in temperature would alter the bacterial activity significantly (and the corresponding odour production) and as such, a sensitive thermometer would be required to pick up these slight changes.

As the temperature of each pond measured was taken at the effluent surface (at a depth of 4-5 cm), it could be safely assumed that as the pond temperature follows the ambient temperature quite closely (during the day), any relationship formed between the odour emission rate and the ambient temperature would implicitly include the pond surface temperature.

4.2.3 Effluent Analyses

A set of effluent samples were collected from the primary holding pond at Feedlot B, spanning the sampling dates from the 3rd of October 2003 to the 16th of October 2003. Unfortunately, only one effluent sample could be collected from Feedlot A, which was also taken from the primary holding pond, on the first day of sampling (the 8th of December, 2003). An analysis of the effluent sample analysis results was carried out. Many parameters are analysed; however a few of the more important parameters (i.e. parameters that have been shown to vary after a rainfall event (Casey, *et al*, 1997)) have been plotted and are shown here, in Figures 4.7 to 4.10. A copy of the analysis results sheet, returned from the Toowoomba City Council's Water Testing Laboratory, is attached as Appendix C.

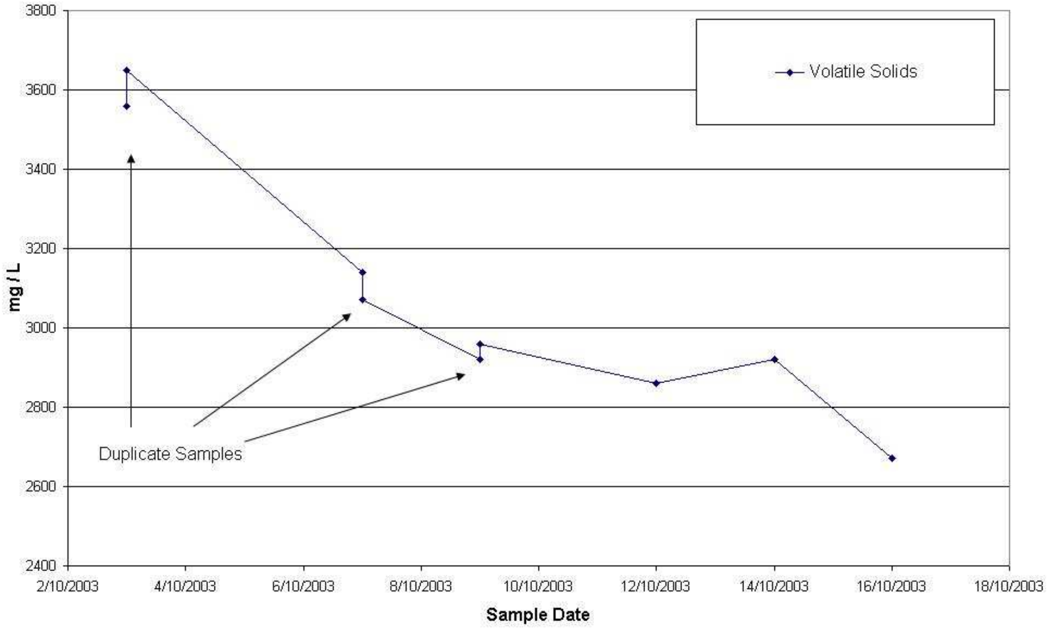

Figure 4.7: Feedlot B Effluent Analysis - Volatile Solids Variation Over Sampling Period

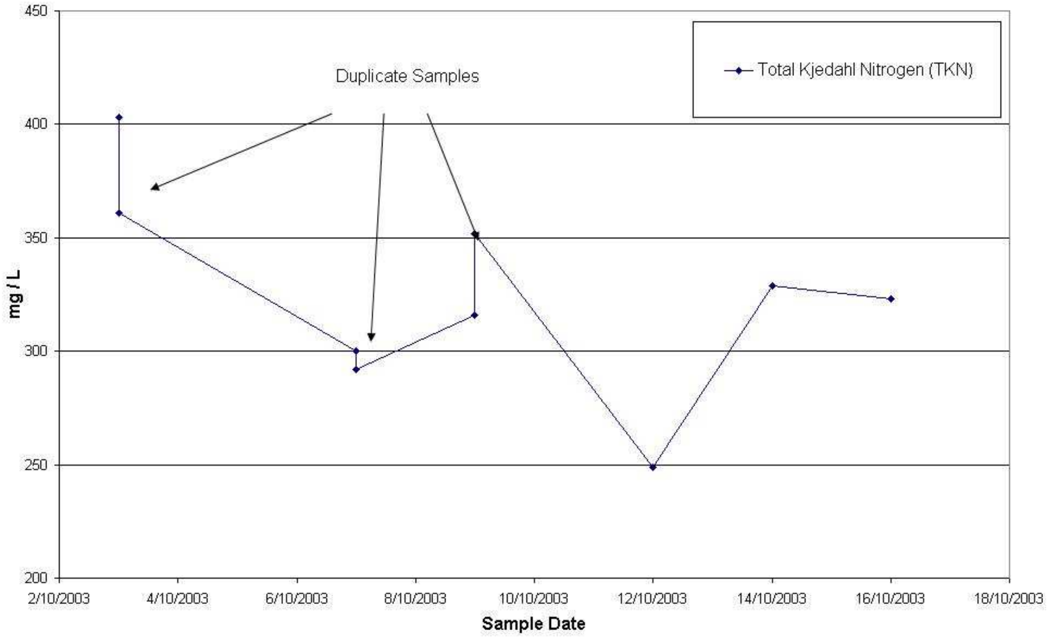

Figure 4.8: Feedlot B Effluent Analysis - Total Kjedahl Nitrogen Variation Over Sampling Period

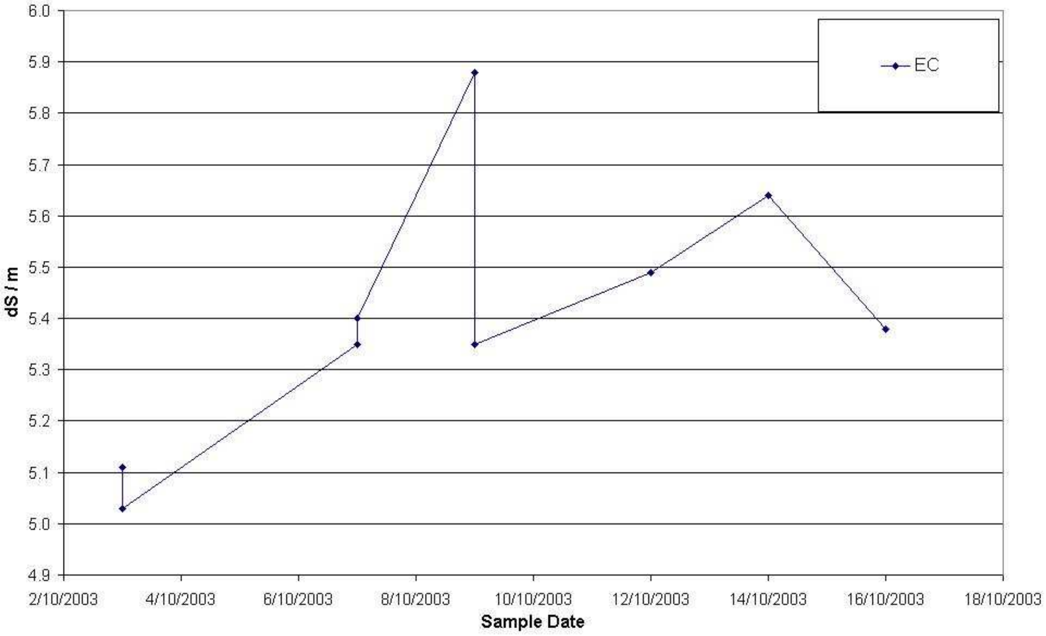

Figure 4.9: Feedlot B Effluent Analysis - Electronic Conductivity Variation Over Sampling Period

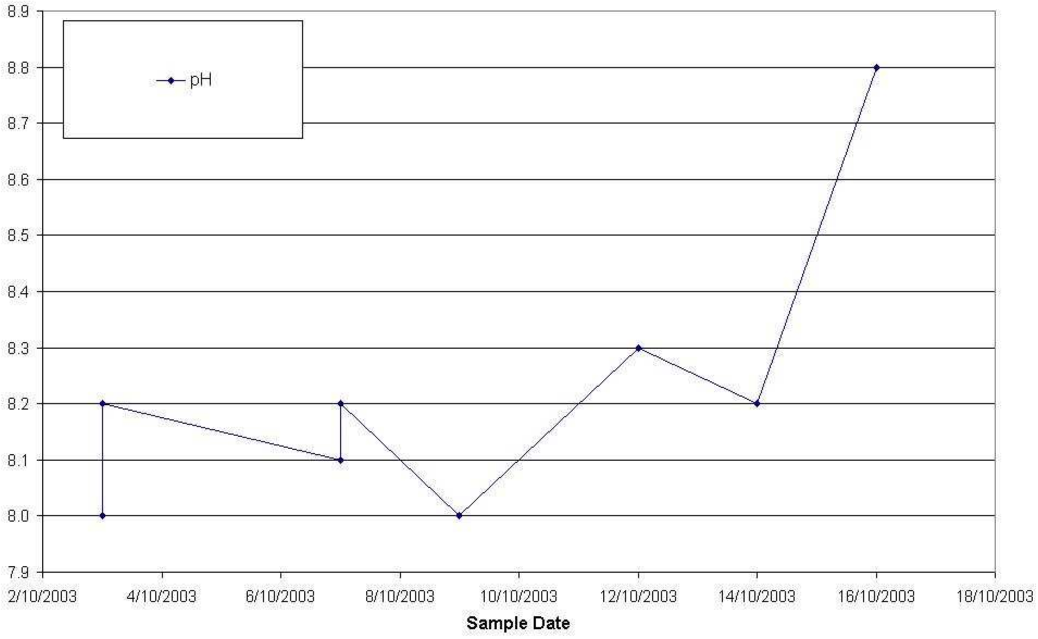

Figure 4.10: Feedlot B Effluent Analysis - pH Variation Over Sampling Period

4.2.4 Discussion – Effluent Analysis Results

The effluent analyses carried out on the samples from Feedlot B have been useful, however they have not shown any conclusive evidence as to a relationship with the odour emission rate. The only relationship that may exist is with the electronic conductivity (EC), as shown in Figure 4.9, with this changing in a similar manner to the odour emission rate. However, this is not seen to be significant as there does not seem to be any logical reason why the EC could reduce in value (as shown in Figure 4.9). The EC is essentially a measure of salt content, and as salt does not evaporate, without a dilution of low EC liquid (either effluent or water), it does not seem feasible that the EC could be lowered through bacterial activity alone. However, Casey *et al* (1997) reported pond chemistry results from their studies of effluent ponds after inflow. They reported a substantial decrease in EC soon after an inflow in one of the ponds measured, followed by a gradual increase.

The pH was inconclusive as to any relationship with the odour emission rate, with the levels remaining stable, however the graph in Figure 4.10 does show a spike in value with the last effluent sample. The pH levels reported by Casey *et al* (1997) showed a different pattern, with the pH dropping substantially soon after the inflow, and then a slow return to previous levels. A more thorough review of this report is included in Chapter 2.

The Volatile solids content and the Kjedahl Nitrogen content reduced steadily over the period of effluent samples. This is to be expected as the bacterial population steadily consume and degrade these substances, producing odour in the process.

The available data does suggest that pond chemistry parameters *can* indicate upset conditions within feedlot holding ponds following inflow events. Sudden substantial changes in electrical conductivity and / or pond pH are likely to provide the most reliable *indicators* of elevated pond odour emission rates.

However, the *magnitude* and *length* of elevated odour emissions is likely to vary with climate, pond design, pond management, and the time elapsed since the previous inflow event. Consequently, an extensive data set would be required to enable changes in pond odour emission rate after inflow events to be predicted from pond chemistry data. Also, the fact that the samples were only taken from one feedlot makes it difficult to draw meaningful conclusions for use in this project.

Chapter 5

Model Development

5.1 Initial Analyses

The model development took place after an analysis of the key parameters affecting the odour emissions, the limiting factors and the potential data sources was undertaken. These issues are addressed in the following sections.

5.1.1 Key Parameters Influencing Odour Emissions

There are a number of key parameters that influence the odour emissions from a feedlot effluent pond after an inflow event. The most obvious influencing parameter is the relative volume of fresh inflow to the volume of effluent already present in the pond. The effluent initially present in the pond provides the necessary residual bacterial population to begin the decomposition of any fresh effluent introduced. As the volume of fresh effluent increases, the ratio of fresh effluent to existing effluent increases, and consequently the odour emissions would be seen to increase also (as the bacterial population present in the pond becomes less and less adequate in breaking down the fresh organic matter). This parameter was also investigated as part of the MRC project (Casey *et al*, 1997).

The number of days since the rain event is also a key parameter. The pattern of odour

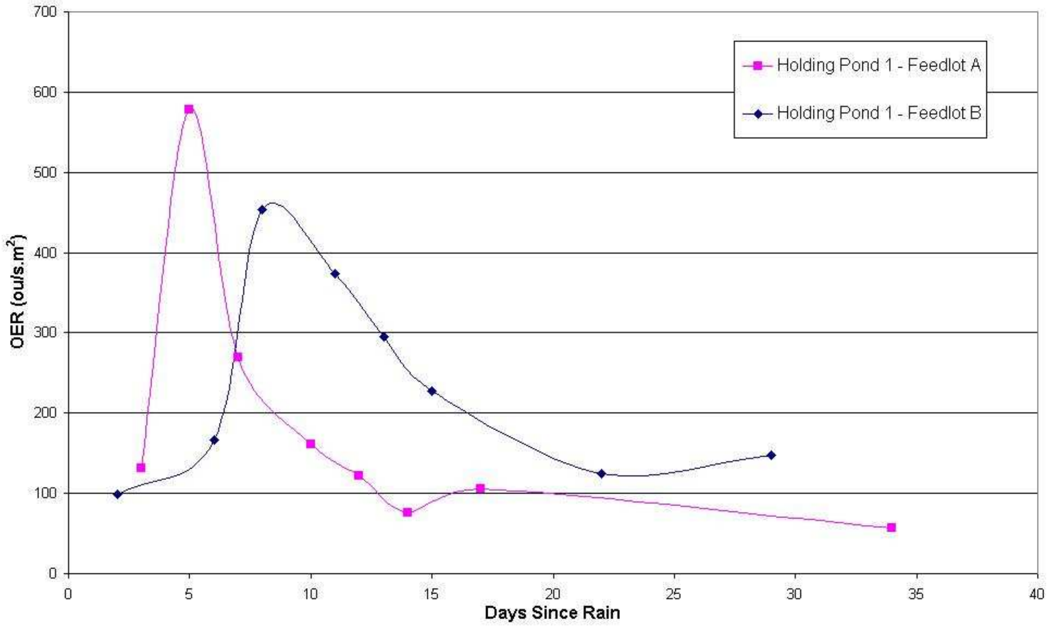

Figure 5.1: Comparison of Odour Emission Rate Patterns from the Primary Holding Pond at Both Feedlots

emissions has been displayed, and the rise and fall of odour emissions occurs over a time period of around 30-40 days.

The data has also shown that the ambient temperature also influences the odour emissions after an inflow event. The warmer climate at Feedlot A displayed a higher peak odour emission rate and a faster rise to that peak than that at Feedlot B, where the average ambient temperature at the time of sampling was some 10 degrees cooler. This can be seen in Figure 5.1, which shows the odour emissions pattern from the primary holding pond at both feedlots.

The effect of the pond surface temperature was investigated and discussed in Chapter 4. The temperature data did not display any relationship to the odour emission rate, in any of the ponds where loggers were installed. However, the pond surface temperature is implicit in the ambient temperature (*see* Section 4.2.2 in Chapter 4), and as such any effect it may have is accounted for in that parameter.

The available data also suggests that pond chemistry parameters typically indicate upset conditions within feedlot holding ponds following inflow events. This was discussed in detail in Chapter 4. As discussed, an extensive dataset would be required to enable changes in pond odour emission rate after inflow events to be predicted from pond chemistry data. As we do not have an extensive dataset (two feedlots only), and as there is a distinct lack of background research into this area of feedlots, it is difficult to use pond chemistry in the formulation of any model.

5.1.2 Practical Limitations to Model Development

The practical limitations on any odour emissions model developed for feedlot effluent ponds are significant. Some of the limitations described were beyond the control and scope of this project.

The time and monetary investment in the odour sampling and assessment after a single runoff event at one feedlot is considerable, but to develop a robust model numerous datasets are required (maybe 10+?). The fact that odour samples need to be taken for up to 40 days since the rainfall event further increases the cost of the research. Coupled with this, effluent samples would need to be drawn and analysed. The cost of this research, with extensive odour and effluent analysis costs, is beyond the reach of most organisations and industry bodies.

Feedlots vary widely in design and management and this limits the applicability of odour models. Every feedlot is different, with different layouts, slopes and pond designs. Every facet of a feedlot's operation will impact on the effluent generated (pond design, chemistry, bacterial mechanism in the pond, etc) and therefore will affect the odour emissions. This is a big limitation on accurate odour modelling from effluent ponds.

The differing climates in which feedlots in Australia are located also present another level of uncertainty. The climate, in particular the temperature, affects the level of bacterial activity in the pond. According to K.D Casey (2004, *pers. comm.*), lower winter temperatures alter the balance of the bacterial population. Temperatures below 15°C will produce partial breakdown and increased levels of intermediate volatile organic acids. pH will be lowered by the level of increased acidity. Many volatile organic acids are highly odorous, and an increase in production may lead to increased odour emission rates. Galvin *et al* (2002) reported seasonal variation in piggery ponds with winter odour emission rates approximately double summer emission rates. The impact of low temperatures on microbial populations was proposed as the primary cause of these increased winter odour emissions.

This is obviously a point of discussion, and the seasonal change in odour emissions is a confounding factor in the development of an odour emissions model.

The spatial and temporal variability of a feedlot effluent pond is also a point of discussion. There has been little research into the variability of odour emissions across feedlot ponds in space and time. However, research has been carried out investigating this variability in piggery ponds, (Hudson *et al*, 2004) and some spatial and temporal variability of odour emissions from piggery effluent ponds was reported. It was also reported that the spatial variability appeared random across the ponds measured.

No attempts were made in this project to accommodate the spatial and / or temporal variability that may be present in feedlot effluent ponds, due mainly to the limited knowledge that exists regarding this issue. However, if this variability is significant, then this will compromise the model developed.

5.1.3 Data Sources for the Model

Initial Pond and Inflow Volumes

The initial pond volumes were estimated in this project using a combination of photographic evidence (taken during the sampling period), the feedlot design data and the management practices employed. This process is described in detail in Chapter 3.

There are potentially three methods available to calculate the inflow volume to an effluent pond: real-time flow measurement, rainfall-runoff modelling following the event or change in pond depth. In this project, the modelling was chosen as there were no flow measurement devices installed at either feedlot, and it was difficult to assess the inflow accurately through depth analyses, as photographs taken were the only indicator of the change in pond depth, and these were indicative at best.

The runoff modelling was performed with MEDLI software, and parameters unique to the feedlot were input, along with climate data that encompassed the rainfall event in question. MEDLI outputs copious amounts of data, one of which is inflow to the effluent pond system. These numbers can be used with the estimates of initial pond level to determine the ratio of fresh to existing effluent in the pond.

Climate Data

Most modern feedlots today also have an automatic weather station installed on-site for use in their management. This provides a ready source of climate data, including (among others) temperature, humidity, rainfall and solar radiation. This also allows the number of days since rain that has elapsed to be found. Both feedlots involved in this project had automatic weather stations installed.

Pond and Effluent Data

The pond surface temperature data was collected in this project using temporary loggers floated out onto the pond. These particular loggers are not reusable and are expensive, and as is clear from the results (Chapter 4), the impact on the odour emissions from the ponds was limited.

The physical chemistry of the pond effluent displays the effects of an inflow, with changes in pH and electrical conductivity being the most obvious. However, to take regular effluent samples before and after rainfall events and have them analysed is also expensive, and the research is still not conclusive as to its direct effect on the odour emissions. As a result, the effluent analyses made during this project were not used to formulate the model.

5.2 Model Development and Structure

5.2.1 Introduction

Upon assessing all of the limitations (see Section 5.1.2) it was obvious that a comprehensive model would not result from the data available and the previous research regarding feedlot effluent ponds. However, a model was written, albeit simple, and dependent only on a small number of parameters. The limited data available meant that a model for the primary holding pond was developed only. The sedimentation basins at both feedlots are managed quite differently (as discussed in Section 4.1.2, Chapter 4) and hence are difficult to model. The secondary holding ponds are also influenced by management (through pumping), and as data relating to pumping volumes, etc was not available, a model was not able to be developed. In essence, the primary holding pond is least affected by management. The results of this project have shown that the primary holding pond produces the highest odour emission rates (following an inflow), and as such the model would return conservative values of odour emissions (higher than in reality) if applied to the other ponds / sedimentation basins.

The development of the model was carried out primarily using Microsoft Excel™ spreadsheet software. The Mathworks™ mathematical software MATLAB™ was initially employed, however the advantages of real-time modification of various algorithms and the corresponding graphical representations in Microsoft Excel™ enabled much faster development (MATLAB™ is essentially command line software). The wider availability of Excel™ was also a benefit as the work was carried out over a number of different workstations.

5.2.2 Initial Approach

The initial approach to the model development was to calculate or determine an equation, or set of equations that would describe the pattern of odour emissions displayed in Chapter 4. This was done through a process of trial and error and consultation with persons more experienced with mathematics. Initially an equation of the form

$$Mxe^{(-kx)} \tag{5.1}$$

was found to describe the general pattern of odour emissions, with a fast rise to peak, and a slower decay to baseline odour levels. A vast number of different values were input to this general equation to try and fit the equation to the measured data, and it soon became clear that whilst this equation could successfully reproduce the tail end of the odour emissions pattern, it failed to reproduce the rising limb adequately. It was then proposed that the pattern of emissions was made up of two stages, as the pattern of odour emissions seems to display two separate processes, those being the fast rise to peak of odour emissions (within the first 5-8 days); and the slower decline in odour emission rate in the 20-30 days that follow.

Hence a different equation was found to fit the rising limb of the odour emissions pattern. From the assumption that the odour generation from ponds is a two-stage process, the refinement of the model could begin.

5.2.3 Model Algorithm

As Equation 5.1 was able to describe the tail end of the odour emission rate pattern, it was retained as the second stage of the model. However Equation 5.1 was still able to accurately reproduce the curve without the x multiplying factor, and as such this was dropped from the second stage equation. The rising limb of the odour emissions pattern was then analysed to see what equation would best describe it.

As the rise to peak is quite swift, an exponential or power relationship was suspected to best describe the rising limb. It was found that a simple power relationship worked best, of the form shown in Equation 5.2.

$$Kx^{y} \tag{5.2}$$

Quite obviously, there needs to be a point where the model algorithm will peak, and change from the rising limb equation (of the form in Equation 5.2) to the tailing limb equation (of the form in Equation 5.1). This was simply set as an input parameter into the model. As the model developed, this input was linked to a real, measured parameter.

5.2.4 Inclusion of Measured Parameters

The conceptual model developed in Sections 5.2.2 and 5.2.3 was structured as a two-stage algorithm. The model parameters were then modified to accept real parameter values.

The parameters chosen were the inflow to existing volume ratio, the ambient temperature at the time of sampling and the number of days since the rain / runoff event. These parameters were chosen as the model's input as they were the most obvious influencing parameters on the odour emissions, and they were easy to define and collect data for (*see* Section 5.1.3). It was difficult to include any other (more specific) parameters for reasons listed in Sections 5.1.1 and 5.1.2. The model is essentially empirical to enable a good fit to the available data. The limited amount of data available did not expose any meaningful relationships from which the modelling could draw from, and ensured that an empirical model was the only feasible method of model development.

Through a process of trial and error, the parameters were fitted to the general two-stage model developed until the best fit to the measured data was found.

The inflow to existing effluent ratio and the number of days since rain were seen as the most important factors influencing the odour emissions. Hence they were used as the dominant factors in the model. The ambient temperature was seen as the factor that influenced how soon after the rain event the peak occurred, and as such was employed to define the day of the peak odour emissions.

5.2.5 Final Model

Microsoft Excel™ was used to refine the model, and the model in its complete form is shown below.

If $x < Peak\ Day$

Then $y = 45 \times (1.25)^x + b$

Else $y = M \times e^{(-kx)} + b$

where $x =$ Days Since Rain Event,

$y =$ Odour Emission Rate ($ou/s.m^2$),

$b =$ Baseline Odour Emission Rate ($ou/s.m^2$),

$M = 170 \times (Inflow\ Ratio)$; and

$k = \frac{Inflow\ Ratio}{52.5}$.

The parameter Peak Day is read from Table 5.1.

The second stage of the model will produce high values of odour emissions with low values of x, the number of days since rain. The decisional algorithm allows only the number of days *less* than the peak day to be modelled by the first stage, and as such, if the peak day occurs earlier, the second stage of the model forces the peak odour emissions up. The peak odour emission rate is produced from the second stage of the model.

Explanation of Model Parameters

The *Days Since Rain Event* parameter is measured from the *first* day of the rain event.

The *Baseline Odour Emission Rate* parameter was necessary as the model will tail off (given enough time) to a zero value of odour emission rate. This parameter is essentially a transform, so that the odour emission rate returns to 'normal', pre-inflow values of pond odour emissions. These values were measured, as set out in Section 4.1.2 in Chapter 4.

The *Inflow Ratio* is the amount of fresh effluent inflowing to the pond as compared to the amount of effluent already present in the pond. For example a 3 ML inflow into a pond with 1.5 ML of effluent already present would have an inflow ratio of 2 (3 ML / 1.5 ML). The initial and inflow effluent volumes were found as detailed in Chapter 3.

Table 5.1: Lookup Table for Peak Day Determination

Temperature Range (°C)	Peak Day
5 to 10	9.5
10 to 15	8.0
15 to 20	6.5
20 to 25	5.0
25 to 30	3.5
30 to 35	2.0

The *Peak Day* is defined by the ambient temperature, and is read from a table developed from the measured data. This table is reproduced in Table 5.1. It is noted that the ambient temperatures required are the daily (24-hour) average ambient temperatures experienced during the days of the actual rainfall / runoff period.

Chapter 6

Model Analysis

6.1 Introduction

The model developed in Chapter 5 was applied to the measured data, and the performance of the model is reported in this chapter.

The model developed needed to be analysed and tested to determine its robustness, limits and applicability to other feedlots under similar circumstances. The fact that the model was developed on a very limited amount of data meant that significant errors could exist.

A sensitivity analysis was therefore required, and this was carried out as part of Section 6.3 – *Hypothetic Testing of the Model.*

Somewhat fortunately, portions of the data collected as part of the Meat Research Corporation (MRC) project on feedlot effluent ponds, carried out during 1993 / 1994, and finally reported in Casey *et al*, (1997) were available for use in this project, through FSA Consulting. This enabled some validation of the developed model with real, measured feedlot effluent pond data.

6.2 Model Application

The model was obviously developed around the measured data. The following Sections (6.2.1 and 6.2.2) report the performance of the model in comparison to the measured data.

It is again noted that the model was developed on data acquired from the primary holding pond at both feedlots, and as such the model is only applied to this pond.

6.2.1 Feedlot A

The input values to the model, for Feedlot A, are shown in Table 6.1. The model analysis data spreadsheet is included in Appendix B.

The inflow volume was determined using MEDLI, and the initial pond volumes were estimated from photographs taken during the sampling period and the physical dimensions of the ponds, as detailed in Chapter 3. The ambient temperature data was recorded using an automatic weather station installed on-site, which returns daily (24 hour) average ambient temperature. The average ambient temperature used in the model is an average of the daily average ambient temperatures recorded for the days of the rainfall event. The Peak Day is read from Table 5.1 in Chapter 5, dependent on the daily average ambient temperature, and is referent to the *first* day of the rain event. The baseline odour emission rate is the average odour emission rate found during odour sampling prior to the inflow event, as part of the greater feedlot odour project undertaken by FSA Consulting.

The data used as input for the model, especially the estimates of inflow and initial volume, were only able to be quantified to an accuracy of ±0.5 ML. This was not expected to impact the accuracy of the model in light of the limitations experienced throughout the course of this project, and the simplicity of the chosen input parameters. The same applies for the data used in the modelling for Feedlot B, as the data was attained in the exact same fashion.

Table 6.1: Feedlot A – Input Values for Pond Odour Model

Parameter	Units	Value
Initial Pond Volume	ML	0
Inflow Volume	ML	33.5
Inflow Ratio		12.0*
Average Ambient Temperature	°C	20.4
Peak Day	Days Since Rain	5
Baseline Odour Emission Rate	ou/s.m^2	5

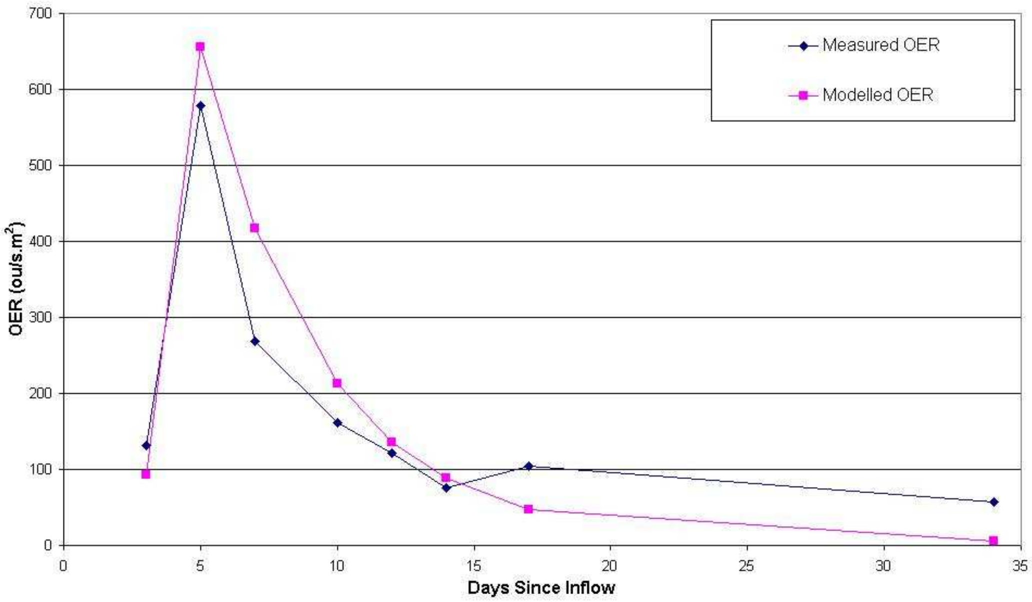

Figure 6.1: Feedlot A, Primary Holding Pond – Measured vs Modelled Odour Emission Rate

As the primary holding pond at Feedlot A was initially empty, the ratio of existing pond volume to inflow volume should theoretically be infinite (any real number divided by zero equals infinity). This is impossible to include in any model. As a result, the ratio of existing to inflow volume was capped at the value of 12, and is marked in Table 6.1 by an asterisk (*). This value was chosen as it is arguably the highest ratio that would be seen in reality at most feedlots (after an inflow event).

A graphical representation of the performance of the model (i.e. its goodness of fit to the measured data) for Feedlot A can be seen in Figure 6.1. The actual data is reproduced in Table 6.2.

Table 6.2: Feedlot A, Primary Holding Pond – Measured vs Modelled Odour Emission Rate Data

Date	No. Days After Inflow	Measured OER ($ou/s.m^2$)	Modelled OER ($ou/s.m^2$)
8 Dec 2003	3	132	93
10 Dec 2003	5	578	656
12 Dec 2003	7	269	417
15 Dec 2003	10	161	212
17 Dec 2003	12	122	136
19 Dec 2003	14	76	88
22 Dec 2003	17	105	47
8 Jan 2004	34	57	6

Table 6.3: Feedlot B – Input Values for Pond Odour Model

Parameter	Units	Value
Initial Pond Volume	ML	7
Inflow Volume	ML	31.9
Inflow Ratio		4.6
Average Ambient Temperature	°C	11.4
Peak Day	Days Since Rain	8
Baseline Odour Emission Rate	$ou/s.m^2$	23

6.2.2 Feedlot B

The input values to the model, for Feedlot B, are shown in Table 6.3.

The input parameter values were determined in the exact same way as for Feedlot A (described in Section 6.2.1). The model analysis data spreadsheet is included in Appendix B.

The primary holding pond at Feedlot B did contain some effluent prior to the inflow event. As a result, an actual ratio of existing to inflow effluent was able to be generated.

A graphical representation of the performance of the model (i.e. its goodness of fit to the measured data) can be seen in Figure 6.2. The actual data is reproduced in Table 6.4.

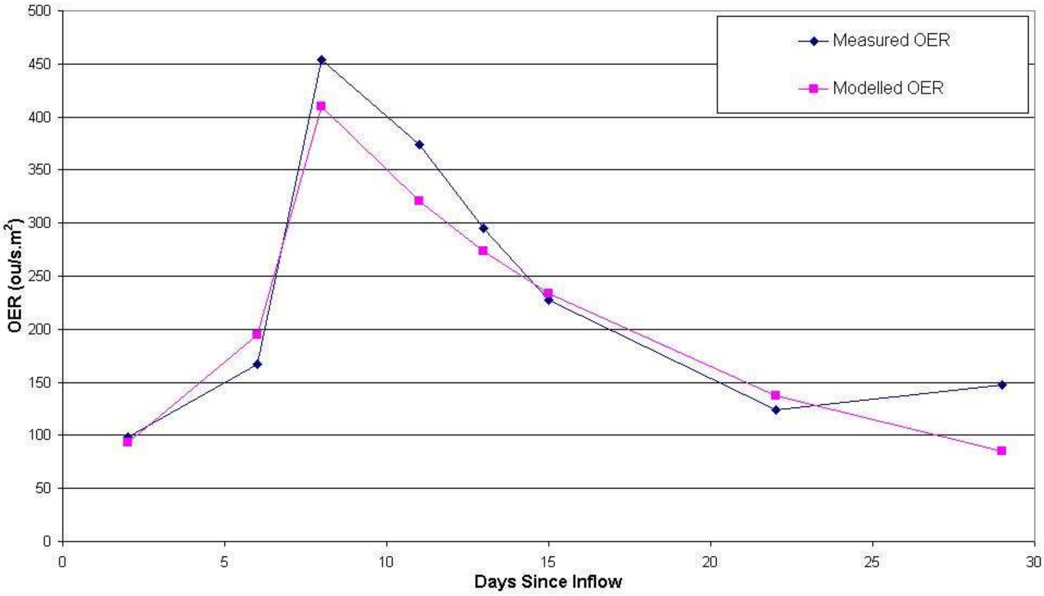

Figure 6.2: Feedlot B, Primary Holding Pond – Measured vs Modelled Odour Emission Rate

Table 6.4: Feedlot B, Primary Holding Pond – Measured vs Modelled Odour Emission Rate Data

Date	No. Days After Inflow	Measured OER (ou/s.m^2)	Modelled OER (ou/s.m^2)
3 Oct 2003	2	99	93
7 Oct 2003	6	167	195
9 Oct 2003	8	454	410
12 Oct 2003	11	374	321
14 Oct 2003	13	295	274
16 Oct 2003	15	227	234
23 Oct 2003	22	124	138
30 Oct 2004	29	148	85

6.2.3 Discussion – Model Accuracy

The model over predicts the peak odour emissions for Feedlot A, and struggles to reproduce the rapid decline in odour emissions following the peak. It is seen that there is a slight increase in the actual odour emissions again after 17 days, however this is not explained as there was no further inflow event in the sampling period. The model would better fit this tail curve if this slight increase was not present.

At Feedlot B, the model slightly under predicts the peak odour emissions, and under predicts the odour emissions for the first part of the tail curve. After this point the model performs well, however there is again an increase in the odour emissions that serves to decrease the goodness of fit of the model.

It was difficult to develop a model that would accurately reproduce both of these particular patterns, as they are quite different.

At Feedlot A, the rise and fall of odour emissions is much faster (with a higher peak odour emission rate) than that at Feedlot B, where the odour emissions remained elevated for a much longer period of time. This posed a problem, as the model had to be compromised somewhat to fit both measured patterns of odour emissions.

The actual goodness of fit for both feedlots is quantified in Table 6.5. The table lists the measured values of odour emission rate, the modelled values and the sum of squares error (SSE). The squares error is the difference between the actual and modelled values of odour emission rate, squared. The differences are squared in order to maintain positive values, which when summed, gives a better indication of the *total* error. The actual error is also stated, given as a percentage of the modelled odour emission rate. The actual error helps to keep the magnitude of the squares error in perspective.

As can be seen in Table 6.5, there is a reasonable spread of actual error magnitudes. However, there are many errors above 15%, which indicates that the model does not fit all that well to the measured data. The largest error is 89.7% of the measured value, which is very excessive. If we consider that the contribution to the SSE of this value is only 6.8%, it is easy to see why the squares error needs justification with the actual

Table 6.5: Error Analysis - Both Feedlots

	Meas. OER (ou/s.m^2)	Mod. OER (ou/s.m^2)	Squares Error	SSE Contribution to Total SSE (%)	Actual Error (% of Mod. OER)
Feedlot					
A	98.50	93.31	26.9	0.3	5.3
	166.75	194.66	779.0	7.7	-16.7
	454.15	409.94	1954.7	19.4	9.7
	373.90	321.18	2779.6	27.6	14.1
	294.95	273.63	454.5	4.5	7.2
	227.30	233.66	40.5	0.4	-2.8
	123.90	137.69	190.3	1.9	-11.1
	147.60	85.44	3863.4	38.3	42.1
		Total	*10088*	*100.0*	
Feedlot					
B	98.50	93.31	1521.7	4.0	29.6
	166.75	194.66	6001.5	15.6	13.4
	454.15	409.94	21909.6	57.0	55.1
	373.90	321.18	2615.0	6.8	31.7
	294.95	273.63	217.5	0.6	12.1
	227.30	233.66	145.3	0.4	15.8
	123.90	137.69	3377.0	8.8	55.4
	147.60	85.44	2620.4	6.8	89.7
		Total	*38408*	*100.0*	

error.

Looking at the sum of squares error in isolation, we can see that there are some contributions higher than 20%. Hence if it were possible to reduce the error of these values, then the total SSE would be reduced considerably. However, to improve the overall fit of the model, the actual error of each of the individual values would also need to be reduced.

The model generally is a reasonable, but not excellent fit to the measured data. The differences in the measured odour emissions patterns between the two feedlots are too significant to achieve a better fit.

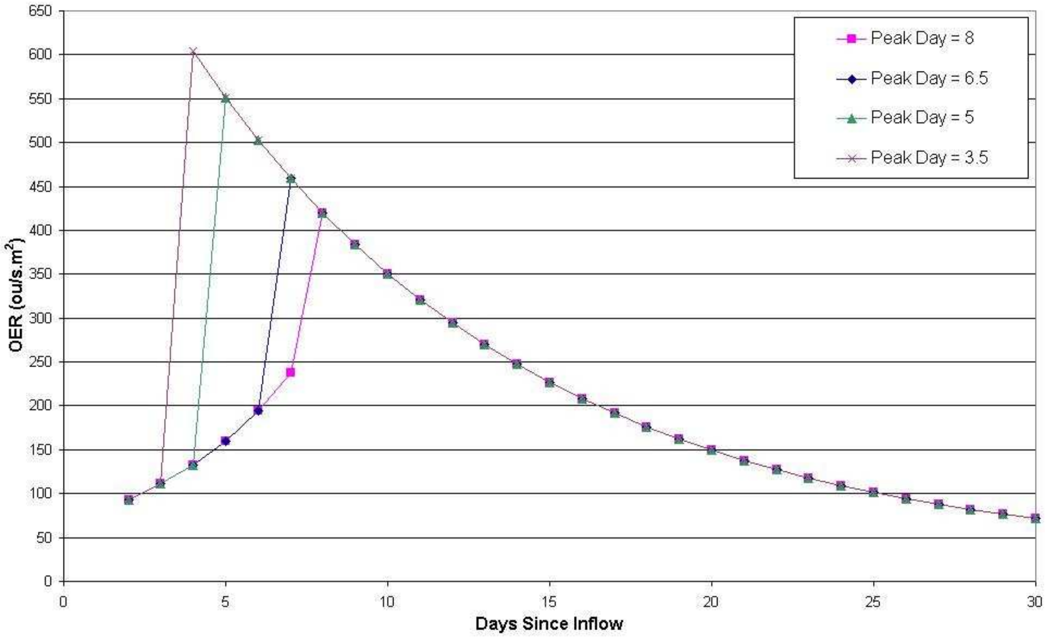

Figure 6.3: Effect of Modifying the Peak Day Whilst Holding the Inflow Ratio Constant at 5:1

6.3 Hypothetic Testing of the Model

The model was subjected to variations in parameters to assess its robustness, and to determine the limits under which the model would return sensible values of odour emission rate. As the model is relatively simple, this process was relatively easy, with few parameters needing analysis.

The parameters that were analysed were the inflow ratio and the days to peak odour emission rate. In Figure 6.3, the peak day is changed while the inflow ratio is held constant at an intermediate value of 5:1.

Figures 6.4 and 6.5 show the effects of changing the inflow ratio whilst holding the peak day constant at 5 and 8, respectively. The peak day values of 5 and 8 days were those encountered during the project, and it is expected that the number of days to peak for most inflow events would fall within, or very close to, this range.

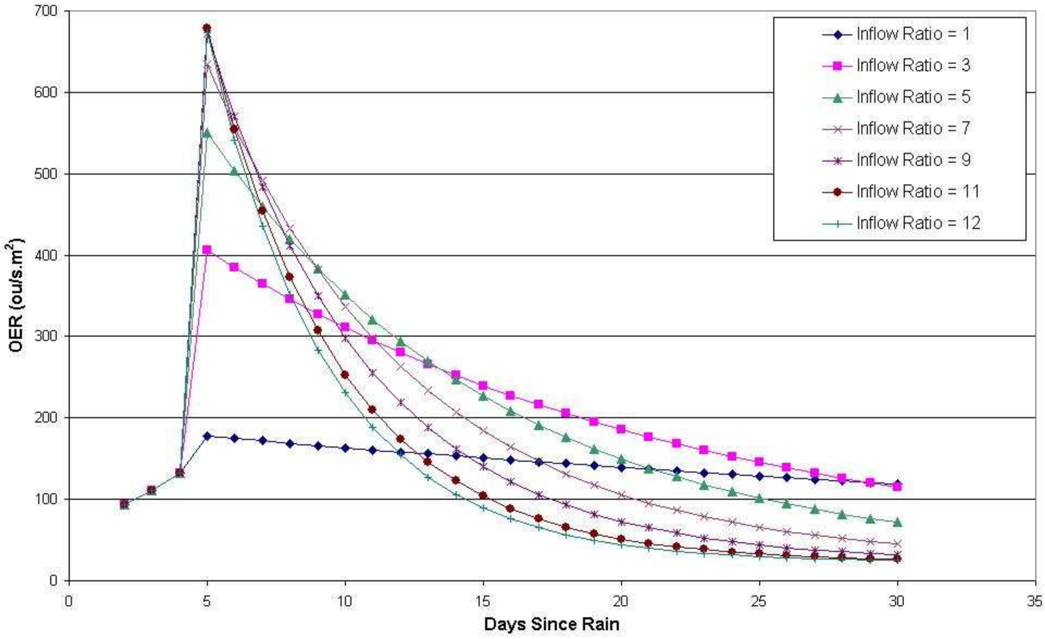

Figure 6.4: Effect of Modifying the Inflow Ratio Whilst Holding the Peak Day Constant at (Day) 5

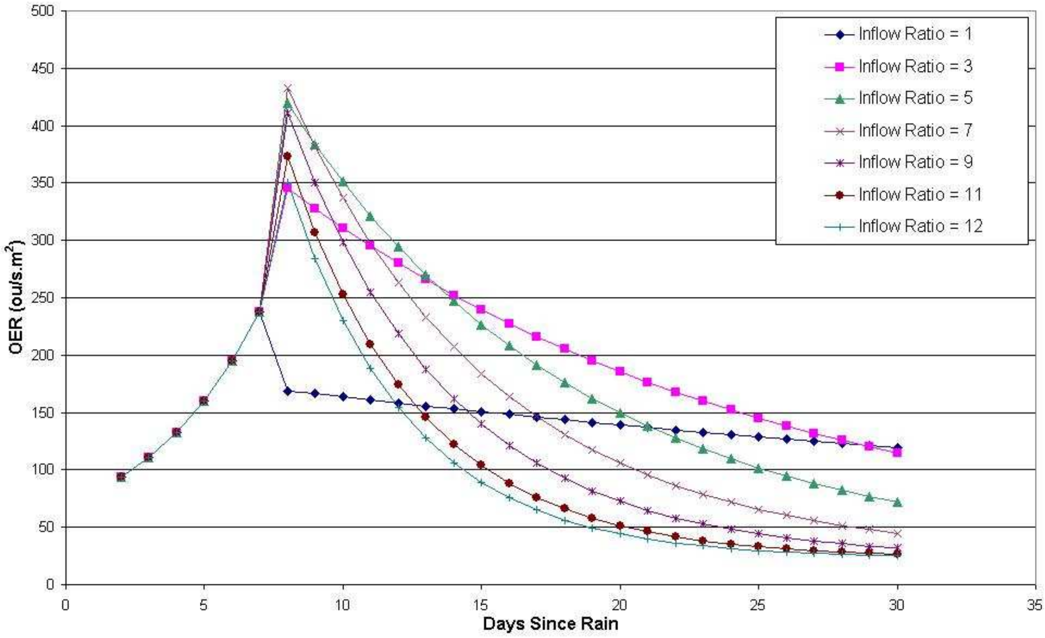

Figure 6.5: Effect of Modifying the Inflow Ratio Whilst Holding the Peak Day Constant at (Day) 8

6.3.1 Discussion – Model Robustness and Limits

Inflow Ratio

The model was shown to be fairly robust, with uniform patterns of odour emissions for most inflow ratios. However, the lower values of inflow ratio (i.e. ratios of 1:1 and 3:1) showed trends that were not consistent with the measured data. These values of inflow ratio had lower peak odour emission rates, which was expected, however the tail curve was considerably flat, with higher than expected odour emission rates towards the end of the trial period. In fact the odour emission rate at the end of the period for these values of inflow ratio were *higher* than the emission rates for the higher inflow ratios. It was expected that the lower inflow ratio curves would return to the baseline odour emission rates faster than the higher inflow ratio curves.

All attempts to rectify this anomaly failed. The reason that the model behaves in this manner is because the lower inflow ratio at Feedlot B displayed a broader odour emission rate curve, and the model was written to accommodate this. Hence even lower values of inflow ratio exacerbate this. Perhaps the odour emission rate curve from Feedlot B was partially unique in the fact that it maintains a higher level of odour emission rate for a longer time, and this has adversely impacted the development of the model. However, this cannot be substantiated, and the model could only be written according to the data available.

It is proposed that these lower inflow ratios cannot be justified as 'significant' inflows, hence the model does not return intuitive results. Obviously this was not supported through the measured data, and is merely a supposition.

Peak Day

Modifying the peak day served to shift the time to peak, and the resulting peak odour emission rate. Decreasing the peak day parameter, and consequently shortening the time elapsed to the peak emission rate increases the peak of the curve, resulting in a much steeper rising limb. The recession (tail) curves all displayed the same curvature as the inflow ratio was held constant (the inflow ratio is the only input parameter for the recession curve). This is consistent with the measured data, with Feedlot A's higher peak odour emission rate coinciding with a faster rise to that peak, as compared to Feedlot B's slower rise to a lower peak emission rate.

Reducing the peak day parameter outside the range experienced in this project (between 5 and 8 days) delivers intuitive results, however it is difficult to support this with no data available. It is obvious that reducing the peak day to a very short interval (i.e. 2 days) results in a very steep rising limb, and a perhaps inconceivable peak odour emission rate (near 750 ou/s.m^2).

The model was written to return steadily decreasing peak odour emission rates with longer times to peak, however this does not occur with times to peak of over 10 days. A peak day of greater than 10 returns a higher peak odour emission rate as compared to shorter time intervals to peak, and the trend continues with higher values of peak day. Hence the model will only return intuitive results when used within the range of 3 - 9 days to peak.

6.4 Model Validation Using Previous Research Data

An attempt to validate the model was made using the data collected by Casey *et al* (1997). In that project, initial and inflow volumes were collected, along with temperature and rainfall data, in addition to the odour emissions data collected. This enabled the model developed in this project to be applied to these datasets. However, it must be remembered that the data collected during the early 1990s for the MRC project was taken from old style feedlots. Today's modern feedlots operate much differently to older style feedlots (see Chapter 1), especially with regard to odour generation, and while it is known that the patterns of odour emissions are similar between the two, the determining parameters may have changed.

The input data used in the modelling of the feedlot ponds from the MRC project is shown in Table 6.6. It is noted that the baseline odour emission rate data was not available from this earlier work; and as such it was assumed (as an average of the measurements from all primary and secondary ponds) from the work done in this

Table 6.6: MRC Input Data used in Validation of the Odour Emissions Model

Parameter	Units	Value			
		Feedlot 1	Feedlot 2	Feedlot 3 (Pond 1)	Feedlot 3b (Pond 2)
Inflow Ratio	dim.	1.44	1.92	2.11	2.11
Avg Ambient Temp	°C	20.9	21.8	21.8	21.8
Peak Day	Days	5	5	5	5
Baseline OER	ou/s.m^2	5	5	5	5

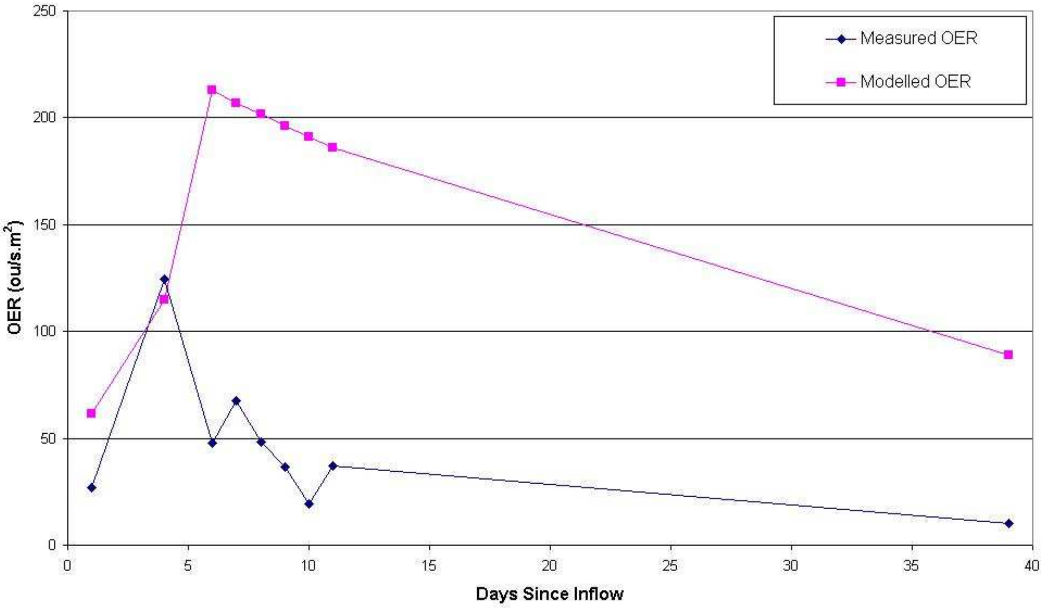

Figure 6.6: Feedlot 1, MRC Project – Measured vs Modelled Odour Emission Rate

project.

The fit of the model to the measured data at all feedlots is shown in Figures 6.6 to 6.9.

6.4.1 Discussion – Validity of the Model

It can be clearly seen that the model fails to reproduce the measured data from the MRC project to any sort of accuracy. This could be attributed to the fact that the data was collected from feedlots differing widely in their management (‘old’ versus ‘new’ style feedlots) and the fact that the model is quite simple and fails to adequately address what is happening in reality.

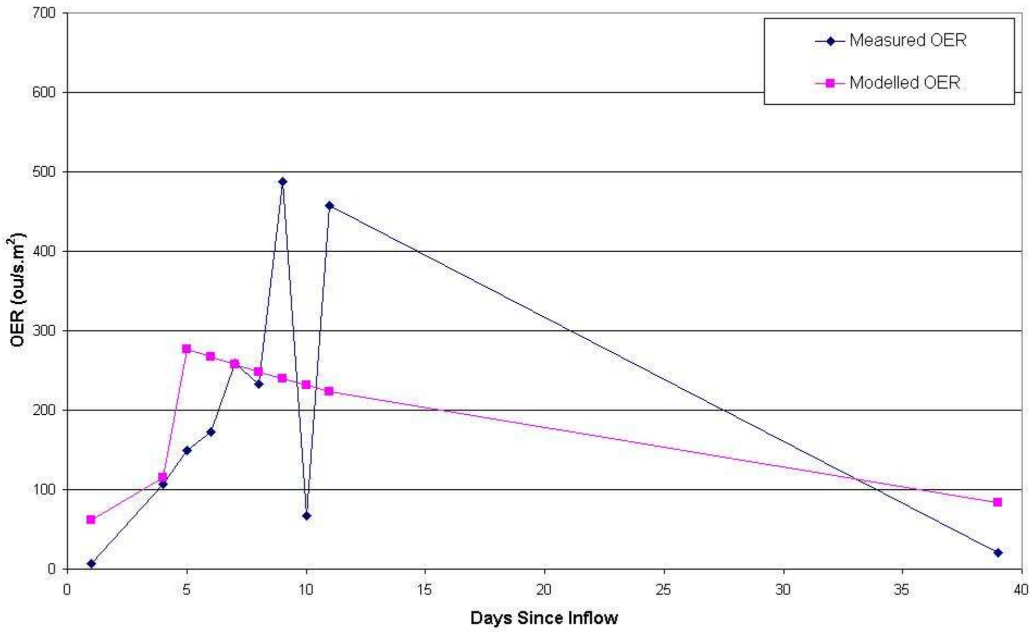

Figure 6.7: Feedlot 2, MRC Project – Measured vs Modelled Odour Emission Rate

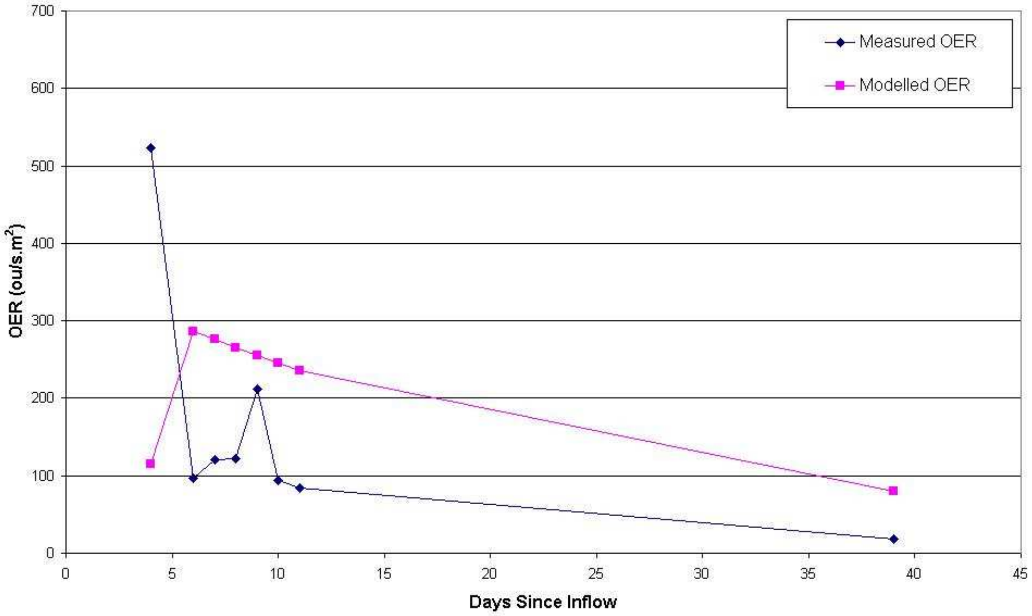

Figure 6.8: Feedlot 3 (Pond 1), MRC Project – Measured vs Modelled Odour Emission Rate

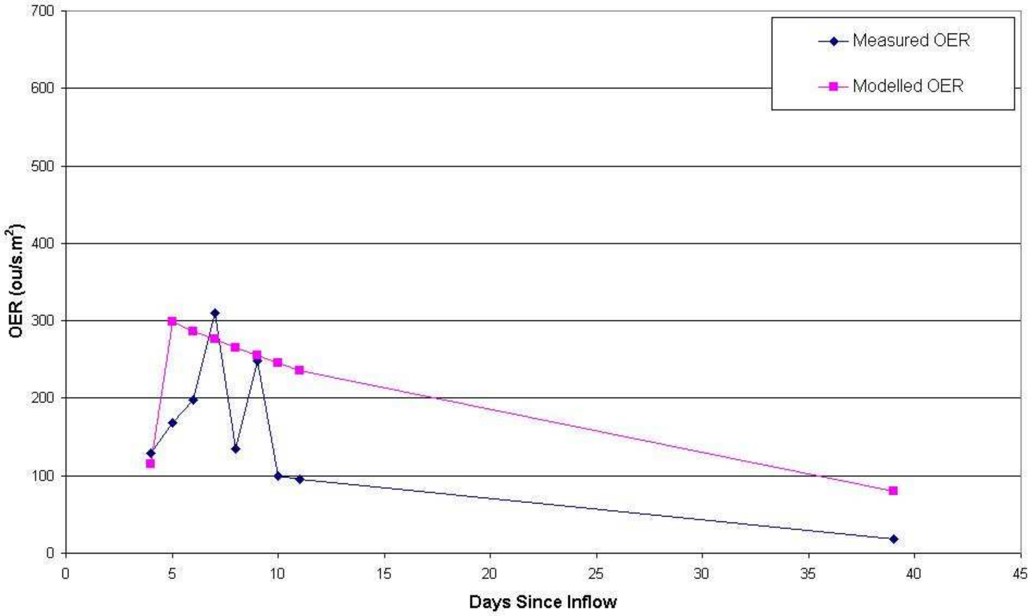

Figure 6.9: Feedlot 3 (Pond 2), MRC Project – Measured vs Modelled Odour Emission Rate

The data from the MRC project was collected from a cruder (relative to today's technology) olfactometer, and was done according to a different standard (or operating procedure). This would introduce further variability into the odour emissions data, therefore reducing its accuracy. The data from the work carried out during the early 1990's shows similar patterns of odour emission rate, however the patterns are somewhat more 'erratic' in comparison to the patterns measured in this project. The similarities and differences between the patterns of emission rate between the two data sets can be better appreciated by considering Figures 6.10 and 6.11. A discussion and comparison of the current project and the MRC project effluent analysis data is also included as Appendix D, however whilst there were differences found, the impact on the model is limited due to a lack of supporting data. The differences in the data do show the change in feedlot pad management that has occurred in the past decade, as detailed in Chapter 1. (The actual odour emissions data is included in Appendix B).

The limited applicability of this model to other data sets was to be expected with reference to the many particular limitations of the modelling process, and the limited data available with which to construct the model.

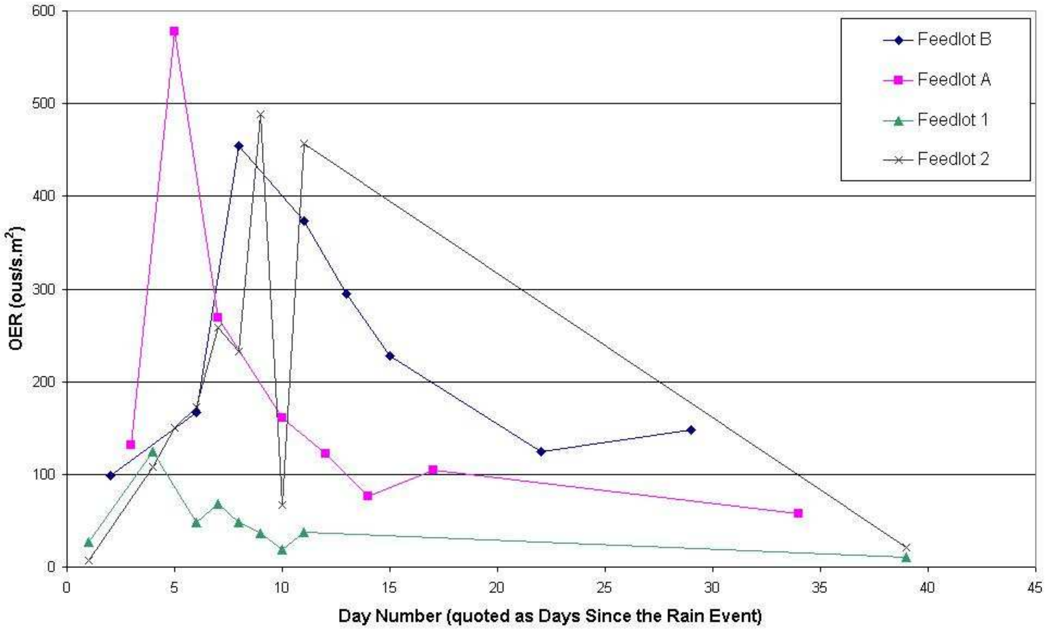

Figure 6.10: Comparison of Odour Emission Rate Patterns - Feedlots A and B, and 1 and 2

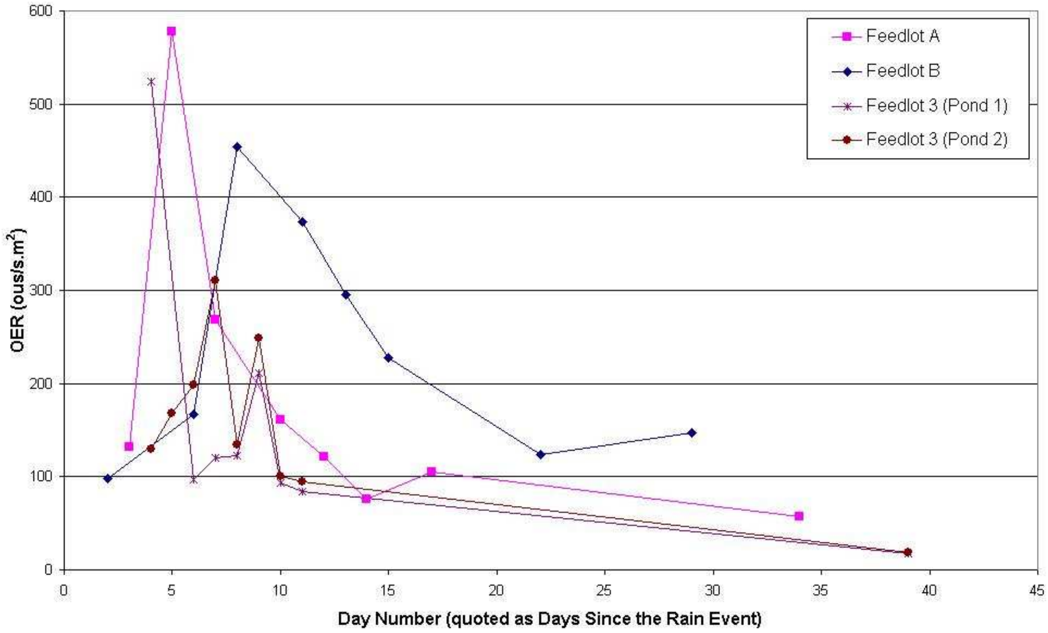

Figure 6.11: Comparison of Odour Emission Rate Patterns - Feedlots A and B, and 3 (Pond 1) and 3 (Pond 2)

6.5 Conclusion

The model developed has been shown to fit to the measured data, to a limited degree of accuracy, as shown through the error analysis. The model does reproduce the odour emission rates curves from both feedlots well, and the model is robust enough to withstand substantial changes in its parameter values, however it is apparent that there is a minimum level of inflow ratio that will produce a meaningful pattern of odour emission rate. The data measured in this project has also suggested that there is an upper limit; the conditions prior to the inflow event at Feedlot A should, in theory, produce the highest rates of odour emissions (no existing effluent in the pond, hence limited bacterial population present).

The model fails to reproduce the measured data from the MRC project, however this was expected considering the significant differences in management that have occurred in the decade since.

The model performs as well as could be expected given the limitations imposed throughout throughout the project, and the extremely limited data available.

Chapter 7

Conclusions and Further Research

It is clear that a model to predict the odour emissions from feedlot ponds would be advantageous to better reproduce the changing odour emissions from feedlots. Whilst undisturbed feedlot effluent ponds are a minor source of odour at a feedlot, after an inflow the odour emission rates can rise above that of the feedlot pad surface. Despite this, no research had previously been carried out into developing a model to reproduce the variability of odour emissions from ponds. This project set out to develop such a model, however the limited number of data sets and supporting data meant that a comprehensive model could not be developed.

Whilst accurate odour emissions data was collected, and the sequence of odour samples taken was adequate, the amount of supporting data collected was limited, or unable to be used in the modelling. This became more apparent as the analysis of the data continued, and the factors influencing the odour emissions became clear. In particular, real time measures of the change in pond volume would have been advantageous, as the model relied on the accuracy of this data (which was estimated at ± 0.5 ML). This accuracy was accepted for use in this project. The estimates of inflow volume were made using MEDLI, and these volumes were expected to be at least as reliable as the estimates of initial pond volume.

The effluent data collected was not able to be used in the modelling. This was due to the fact that a complete set of effluent samples were taken from Feedlot B only, and no direct comparison could be made with Feedlot A. In addition to this, previous research into feedlot effluent pond chemistry is limited, and inconclusive as to the connection between pond condition and the odour emissions.

The measured data showed differences in the patterns of odour emissions. The cooler Feedlot B displayed a broader pattern of odour emissions, with the warmer Feedlot A showing a sharp peak, and a faster return to lower values of odour emissions. The difference in climate between the two feedlots was considered responsible for the different odour emissions patterns.

An empirical model that fitted the measured odour emission rate pattern from both feedlots was developed, taking as input the inflow ratio, the number of days since rain and the ambient temperature. The model performed reasonably well, with a good fit to the measured data. However, the model was compromised somewhat so that the two very different patterns of odour emissions could be reproduced. Hence some significant errors between some individual measured and modelled data points existed, and this error was not able to be improved.

The model was applied to the data measured in the MRC project. The model failed to accurately reproduce the pattern of odour emissions recorded, however this was expected. The change in feedlot management over the period of time since the MRC research has been substantial, and the factors influencing the odour emissions may have changed significantly. The limited applicability was also attributed to the simplicity of the model.

7.1 Success of the Project

The project was successful in the fact that a model to predict the odour emission rate from effluent ponds after an inflow was developed. However, the fact remains that the model is essentially empirical, and is far from comprehensive in regard to input parameters. This was no fault of the project itself; every effort was made with the data available. However, for a comprehensive model to be developed, more data would be required, in terms of independent data sets, supporting pond chemistry data and more accurate (real-time) measures of pond volumes, inflows and outflows. A research effort of the magnitude required to achieve this is far beyond the scope of a final year research project, and may even challenge the resources of an industry body.

7.2 Further Research into this Area

Future, further research to model the odour emissions from primary holding ponds would obviously need to overcome the practical limitations experienced in this project (as discussed in Chapter 5) and cover the ideas to improve the model as presented in Section 7.1. A committed research effort of this nature would have to include the modelling of the sedimentation basin and secondary holding pond, to complete the picture of odour emissions from feedlot effluent treatment (pond) systems.

Research, perhaps not separately, would also need to be conducted to better determine the driving processes of odour emissions from feedlot ponds under these conditions. It is considered that not enough is known about feedlot pond chemistry, and such information would be invaluable in modelling the odour emissions. Such pond information may also lead to new developments in feedlot effluent pond management, from a odour minimisation perspective.

This research would be an inevitable step in further understanding feedlot pond odour emissions as the industry strives to improve its overall odour performance.

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⟨`http://www.odour.unsw.edu.au/flux-hood-sampling.html`⟩

Appendix A

Project Specification

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG 4111 / 4112 Research Project

PROJECT SPECIFICATION

FOR:	**Nathan Andrew HEINRICH**
TOPIC:	PREDICTION OF FEEDLOT EFFLUENT POND ODOUR EMISSION AFTER SIGNIFICANT INFLOW
SUPERVISORS:	Dr. Rod Smith Dr. Peter Watts, FSA Consulting
ENROLMENT:	ENG 4111 – S1, D, 2004 ENG 4112 – S2, D, 2004
PROJECT AIM:	This project aims to investigate the variation in odour emissions from feedlot effluent ponds following significant inflow, defining the major factors that influence the odour emissions and attempts to develop a model to predict odour emission rate.
SPONSORSHIP:	FSA Consulting
PROGRAMME:	**Issue B, 12 October 2004**

OBJECTIVES:

1. Research the background information available relating to feedlot odour emissions in Australia (concentrating on, but not restricted to, feedlot effluent ponds), odour measurement and olfactometry and feedlot odour emissions models.
2. Assist in the collection of odour samples from two commercial feedlots, and collect data as appropriate.
3. Analyse field data and assess the major factors influencing the odour emission rate.

4. Develop a model to predict the odour emission rate from the primary effluent pond after inflow.

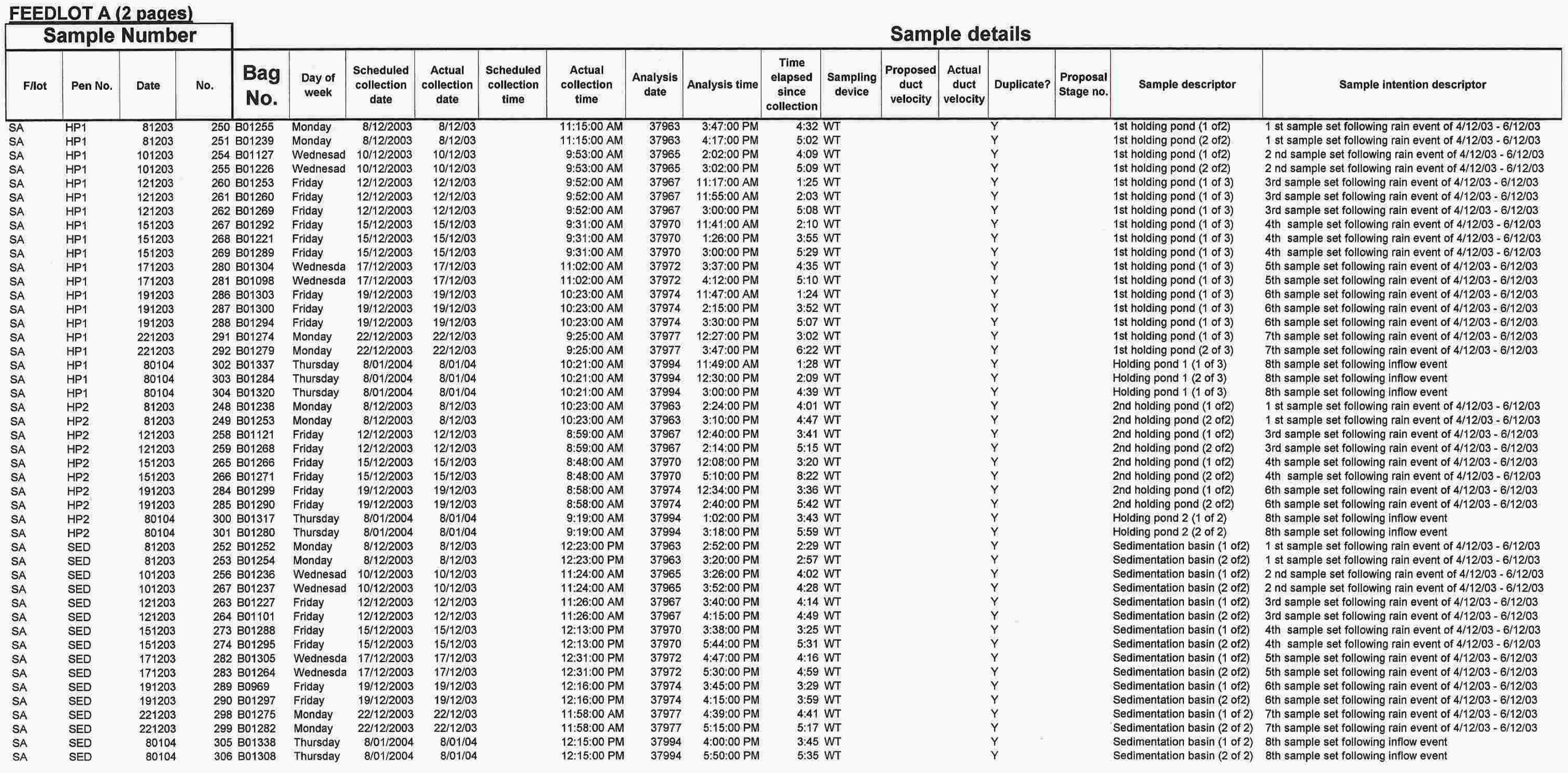
AGREED:

________________(Student) ________________, ________________(Supervisors)

____/____/____ ____/____/____ ____/____/____

Appendix B

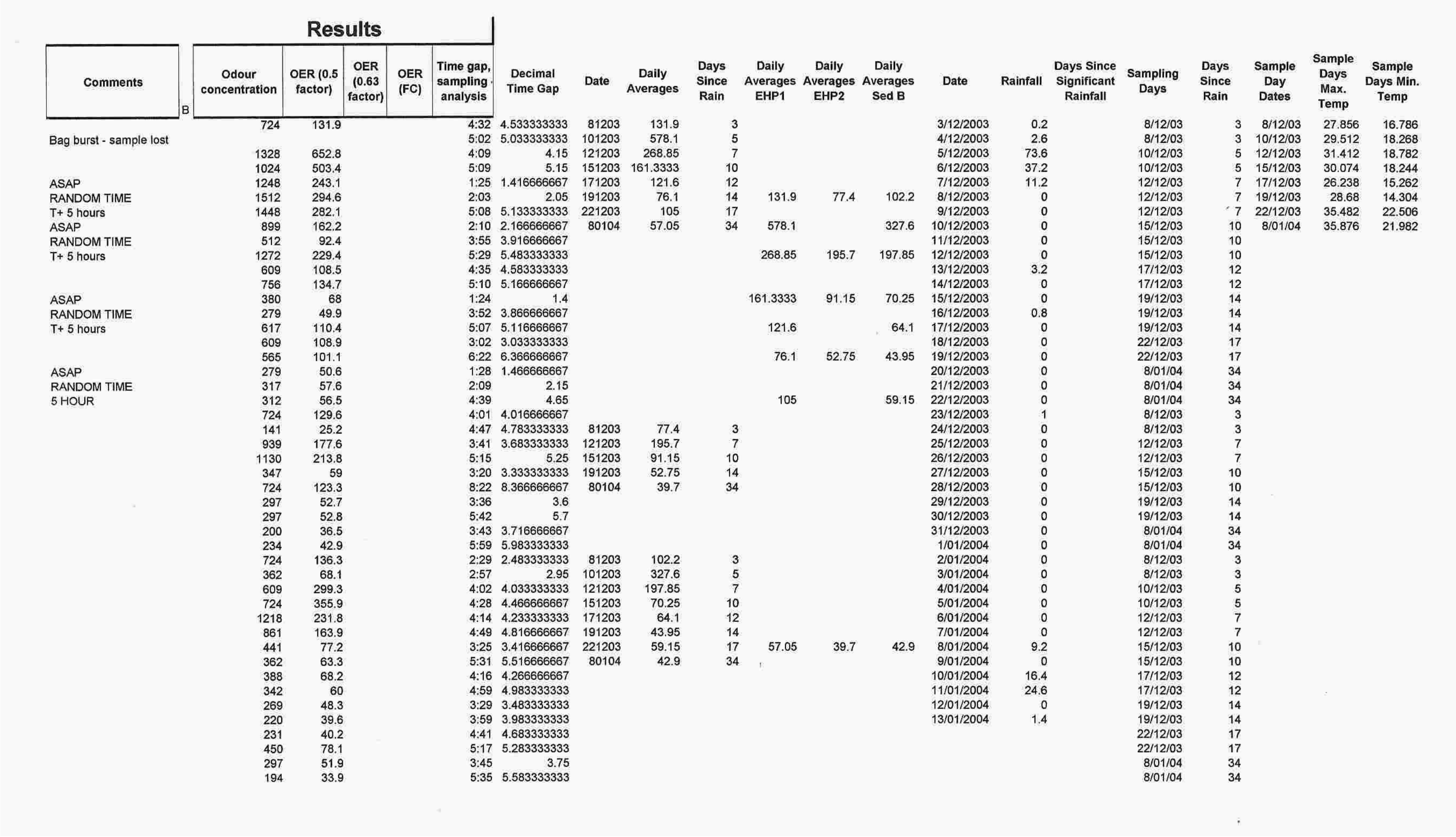
Odour Emissions Data Analysis Spreadsheets



FEEDLOT A (2 pages)

Sample Number				Sample details															
F/lot	Pen No.	Date	No.	Bag No.	Day of week	Scheduled collection date	Actual collection date	Scheduled collection time	Actual collection time	Analysis date	Analysis time	Time elapsed since collection	Sampling device	Proposed duct velocity	Actual duct velocity	Duplicate?	Proposal Stage no.	Sample descriptor	Sample intention descriptor
SA	HP1	81203	250	B01255	Monday	8/12/2003	8/12/03		11:15:00 AM	37963	3:47:00 PM	4:32	WT			Y		1st holding pond (1 of2)	1 st sample set following rain event of 4/12/03 - 6/12/03
SA	HP1	81203	251	B01239	Monday	8/12/2003	8/12/03		11:15:00 AM	37963	4:17:00 PM	5:02	WT			Y		1st holding pond (2 of2)	1 st sample set following rain event of 4/12/03 - 6/12/03
SA	HP1	101203	254	B01127	Wednesad	10/12/2003	10/12/03		9:53:00 AM	37965	2:02:00 PM	4:09	WT			Y		1st holding pond (1 of2)	2 nd sample set following rain event of 4/12/03 - 6/12/03
SA	HP1	101203	255	B01226	Wednesad	10/12/2003	10/12/03		9:53:00 AM	37965	3:02:00 PM	5:09	WT			Y		1st holding pond (2 of2)	2 nd sample set following rain event of 4/12/03 - 6/12/03
SA	HP1	121203	260	B01253	Friday	12/12/2003	12/12/03		9:52:00 AM	37967	11:17:00 AM	1:25	WT			Y		1st holding pond (1 of 3)	3rd sample set following rain event of 4/12/03 - 6/12/03
SA	HP1	121203	261	B01260	Friday	12/12/2003	12/12/03		9:52:00 AM	37967	11:55:00 AM	2:03	WT			Y		1st holding pond (1 of 3)	3rd sample set following rain event of 4/12/03 - 6/12/03
SA	HP1	121203	262	B01269	Friday	12/12/2003	12/12/03		9:52:00 AM	37967	3:00:00 PM	5:08	WT			Y		1st holding pond (1 of 3)	3rd sample set following rain event of 4/12/03 - 6/12/03
SA	HP1	151203	267	B01292	Friday	15/12/2003	15/12/03		9:31:00 AM	37970	11:41:00 AM	2:10	WT			Y		1st holding pond (1 of 3)	4th sample set following rain event of 4/12/03 - 6/12/03
SA	HP1	151203	268	B01221	Friday	15/12/2003	15/12/03		9:31:00 AM	37970	1:26:00 PM	3:55	WT			Y		1st holding pond (1 of 3)	4th sample set following rain event of 4/12/03 - 6/12/03
SA	HP1	151203	269	B01289	Friday	15/12/2003	15/12/03		9:31:00 AM	37970	3:00:00 PM	5:29	WT			Y		1st holding pond (1 of 3)	4th sample set following rain event of 4/12/03 - 6/12/03
SA	HP1	171203	280	B01304	Wednesda	17/12/2003	17/12/03		11:02:00 AM	37972	3:37:00 PM	4:35	WT			Y		1st holding pond (1 of 3)	5th sample set following rain event of 4/12/03 - 6/12/03
SA	HP1	171203	281	B01098	Wednesda	17/12/2003	17/12/03		11:02:00 AM	37972	4:12:00 PM	5:10	WT			Y		1st holding pond (1 of 3)	5th sample set following rain event of 4/12/03 - 6/12/03
SA	HP1	191203	286	B01303	Friday	19/12/2003	19/12/03		10:23:00 AM	37974	11:47:00 AM	1:24	WT			Y		1st holding pond (1 of 3)	6th sample set following rain event of 4/12/03 - 6/12/03
SA	HP1	191203	287	B01300	Friday	19/12/2003	19/12/03		10:23:00 AM	37974	2:15:00 PM	3:52	WT			Y		1st holding pond (1 of 3)	6th sample set following rain event of 4/12/03 - 6/12/03
SA	HP1	191203	288	B01294	Friday	19/12/2003	19/12/03		10:23:00 AM	37974	3:30:00 PM	5:07	WT			Y		1st holding pond (1 of 3)	6th sample set following rain event of 4/12/03 - 6/12/03
SA	HP1	221203	291	B01274	Monday	22/12/2003	22/12/03		9:25:00 AM	37977	12:27:00 PM	3:02	WT			Y		1st holding pond (1 of 3)	7th sample set following rain event of 4/12/03 - 6/12/03
SA	HP1	221203	292	B01279	Monday	22/12/2003	22/12/03		9:25:00 AM	37977	3:47:00 PM	6:22	WT			Y		1st holding pond (2 of 3)	7th sample set following rain event of 4/12/03 - 6/12/03
SA	HP1	80104	302	B01337	Thursday	8/01/2004	8/01/04		10:21:00 AM	37994	11:49:00 AM	1:28	WT			Y		Holding pond 1 (1 of 3)	8th sample set following inflow event
SA	HP1	80104	303	B01284	Thursday	8/01/2004	8/01/04		10:21:00 AM	37994	12:30:00 PM	2:09	WT			Y		Holding pond 1 (2 of 3)	8th sample set following inflow event
SA	HP1	80104	304	B01320	Thursday	8/01/2004	8/01/04		10:21:00 AM	37994	3:00:00 PM	4:39	WT			Y		Holding pond 1 (1 of 3)	8th sample set following inflow event
SA	HP2	81203	248	B01238	Monday	8/12/2003	8/12/03		10:23:00 AM	37963	2:24:00 PM	4:01	WT			Y		2nd holding pond (1 of2)	1 st sample set following rain event of 4/12/03 - 6/12/03
SA	HP2	81203	249	B01253	Monday	8/12/2003	8/12/03		10:23:00 AM	37963	3:10:00 PM	4:47	WT			Y		2nd holding pond (2 of2)	1 st sample set following rain event of 4/12/03 - 6/12/03
SA	HP2	121203	258	B01121	Friday	12/12/2003	12/12/03		8:59:00 AM	37967	12:40:00 PM	3:41	WT			Y		2nd holding pond (1 of2)	3rd sample set following rain event of 4/12/03 - 6/12/03
SA	HP2	121203	259	B01268	Friday	12/12/2003	12/12/03		8:59:00 AM	37967	2:14:00 PM	5:15	WT			Y		2nd holding pond (2 of2)	3rd sample set following rain event of 4/12/03 - 6/12/03
SA	HP2	151203	265	B01266	Friday	15/12/2003	15/12/03		8:48:00 AM	37970	12:08:00 PM	3:20	WT			Y		2nd holding pond (1 of2)	4th sample set following rain event of 4/12/03 - 6/12/03
SA	HP2	151203	266	B01271	Friday	15/12/2003	15/12/03		8:48:00 AM	37970	5:10:00 PM	8:22	WT			Y		2nd holding pond (2 of2)	4th sample set following rain event of 4/12/03 - 6/12/03
SA	HP2	191203	284	B01299	Friday	19/12/2003	19/12/03		8:58:00 AM	37974	12:34:00 PM	3:36	WT			Y		2nd holding pond (1 of2)	6th sample set following rain event of 4/12/03 - 6/12/03
SA	HP2	191203	285	B01290	Friday	19/12/2003	19/12/03		8:58:00 AM	37974	2:40:00 PM	5:42	WT			Y		2nd holding pond (2 of2)	6th sample set following rain event of 4/12/03 - 6/12/03
SA	HP2	80104	300	B01317	Thursday	8/01/2004	8/01/04		9:19:00 AM	37994	1:02:00 PM	3:43	WT			Y		Holding pond 2 (1 of 2)	8th sample set following inflow event
SA	HP2	80104	301	B01280	Thursday	8/01/2004	8/01/04		9:19:00 AM	37994	3:18:00 PM	5:59	WT			Y		Holding pond 2 (2 of 2)	8th sample set following inflow event
SA	SED	81203	252	B01252	Monday	8/12/2003	8/12/03		12:23:00 PM	37963	2:52:00 PM	2:29	WT			Y		Sedimentation basin (1 of2)	1 st sample set following rain event of 4/12/03 - 6/12/03
SA	SED	81203	253	B01254	Monday	8/12/2003	8/12/03		12:23:00 PM	37963	3:20:00 PM	2:57	WT			Y		Sedimentation basin (2 of2)	1 st sample set following rain event of 4/12/03 - 6/12/03
SA	SED	101203	256	B01236	Wednesad	10/12/2003	10/12/03		11:24:00 AM	37965	3:26:00 PM	4:02	WT			Y		Sedimentation basin (1 of2)	2 nd sample set following rain event of 4/12/03 - 6/12/03
SA	SED	101203	267	B01237	Wednesad	10/12/2003	10/12/03		11:24:00 AM	37965	3:52:00 PM	4:28	WT			Y		Sedimentation basin (2 of2)	2 nd sample set following rain event of 4/12/03 - 6/12/03
SA	SED	121203	263	B01227	Friday	12/12/2003	12/12/03		11:26:00 AM	37967	3:40:00 PM	4:14	WT			Y		Sedimentation basin (1 of2)	3rd sample set following rain event of 4/12/03 - 6/12/03
SA	SED	121203	264	B01101	Friday	12/12/2003	12/12/03		11:26:00 AM	37967	4:15:00 PM	4:49	WT			Y		Sedimentation basin (2 of2)	3rd sample set following rain event of 4/12/03 - 6/12/03
SA	SED	151203	273	B01288	Friday	15/12/2003	15/12/03		12:13:00 PM	37970	3:38:00 PM	3:25	WT			Y		Sedimentation basin (1 of2)	4th sample set following rain event of 4/12/03 - 6/12/03
SA	SED	151203	274	B01295	Friday	15/12/2003	15/12/03		12:13:00 PM	37970	5:44:00 PM	5:31	WT			Y		Sedimentation basin (2 of2)	4th sample set following rain event of 4/12/03 - 6/12/03
SA	SED	171203	282	B01305	Wednesda	17/12/2003	17/12/03		12:31:00 PM	37972	4:47:00 PM	4:16	WT			Y		Sedimentation basin (1 of2)	5th sample set following rain event of 4/12/03 - 6/12/03
SA	SED	171203	283	B01264	Wednesda	17/12/2003	17/12/03		12:31:00 PM	37972	5:30:00 PM	4:59	WT			Y		Sedimentation basin (2 of2)	5th sample set following rain event of 4/12/03 - 6/12/03
SA	SED	191203	289	B0969	Friday	19/12/2003	19/12/03		12:16:00 PM	37974	3:45:00 PM	3:29	WT			Y		Sedimentation basin (1 of2)	6th sample set following rain event of 4/12/03 - 6/12/03
SA	SED	191203	290	B01297	Friday	19/12/2003	19/12/03		12:16:00 PM	37974	4:15:00 PM	3:59	WT			Y		Sedimentation basin (2 of2)	6th sample set following rain event of 4/12/03 - 6/12/03
SA	SED	221203	298	B01275	Monday	22/12/2003	22/12/03		11:58:00 AM	37977	4:39:00 PM	4:41	WT			Y		Sedimentation basin (1 of 2)	7th sample set following rain event of 4/12/03 - 6/12/03
SA	SED	221203	299	B01282	Monday	22/12/2003	22/12/03		11:58:00 AM	37977	5:15:00 PM	5:17	WT			Y		Sedimentation basin (2 of 2)	7th sample set following rain event of 4/12/03 - 6/12/03
SA	SED	80104	305	B01338	Thursday	8/01/2004	8/01/04		12:15:00 PM	37994	4:00:00 PM	3:45	WT			Y		Sedimentation basin (1 of 2)	8th sample set following inflow event
SA	SED	80104	306	B01308	Thursday	8/01/2004	8/01/04		12:15:00 PM	37994	5:50:00 PM	5:35	WT			Y		Sedimentation basin (2 of 2)	8th sample set following inflow event

Figure B.1: Feedlot A – Odour Emission Rate Data Analysis Spreadsheet (Page 1)



Results

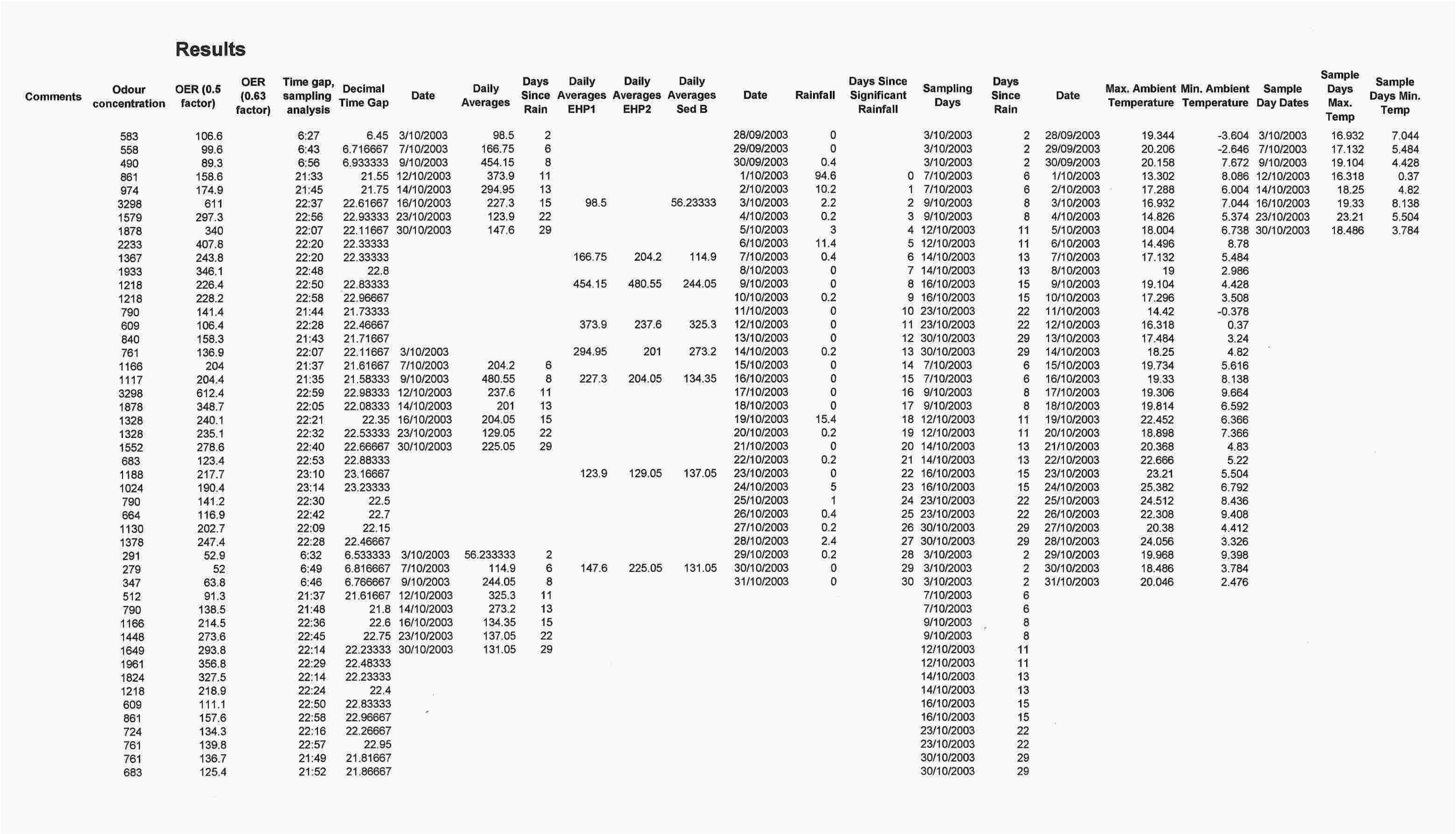
Comments	B	Odour concentration	OER (0.5 factor)	OER (0.63 factor)	OER (FC)	Time gap, sampling - analysis	Decimal Time Gap	Date	Daily Averages	Days Since Rain	Daily Averages EHP1	Daily Averages EHP2	Daily Averages Sed B	Date	Rainfall	Days Since Significant Rainfall	Sampling Days	Days Since Rain	Sample Day Dates	Sample Days Max. Temp	Sample Days Min. Temp
		724	131.9			4:32	4.533333333	81203	131.9	3				3/12/2003	0.2		8/12/03	3	8/12/03	27.856	16.786
Bag burst - sample lost						5:02	5.033333333	101203	578.1	5				4/12/2003	2.6		8/12/03	3	10/12/03	29.512	18.268
		1328	652.8			4:09	4.15	121203	268.85	7				5/12/2003	73.6		10/12/03	5	12/12/03	31.412	18.782
		1024	503.4			5:09	5.15	151203	161.3333	10				6/12/2003	37.2		10/12/03	5	15/12/03	30.074	18.244
ASAP		1248	243.1			1:25	1.416666667	171203	121.6	12				7/12/2003	11.2		12/12/03	7	17/12/03	26.238	15.262
RANDOM TIME		1512	294.6			2:03	2.05	191203	76.1	14	131.9	77.4	102.2	8/12/2003	0		12/12/03	7	19/12/03	28.68	14.304
T+ 5 hours		1448	282.1			5:08	5.133333333	221203	105	17				9/12/2003	0		12/12/03	7	22/12/03	35.482	22.506
ASAP		899	162.2			2:10	2.166666667	80104	57.05	34	578.1		327.6	10/12/2003	0		15/12/03	10	8/01/04	35.876	21.982
RANDOM TIME		512	92.4			3:55	3.916666667							11/12/2003	0		15/12/03	10			
T+ 5 hours		1272	229.4			5:29	5.483333333				268.85	195.7	197.85	12/12/2003	0		15/12/03	10			
		609	108.5			4:35	4.583333333							13/12/2003	3.2		17/12/03	12			
		756	134.7			5:10	5.166666667							14/12/2003	0		17/12/03	12			
ASAP		380	68			1:24	1.4				161.3333	91.15	70.25	15/12/2003	0		19/12/03	14			
RANDOM TIME		279	49.9			3:52	3.866666667							16/12/2003	0.8		19/12/03	14			
T+ 5 hours		617	110.4			5:07	5.116666667				121.6		64.1	17/12/2003	0		19/12/03	14			
		609	108.9			3:02	3.033333333							18/12/2003	0		22/12/03	17			
		565	101.1			6:22	6.366666667				76.1	52.75	43.95	19/12/2003	0		22/12/03	17			
ASAP		279	50.6			1:28	1.466666667							20/12/2003	0		8/01/04	34			
RANDOM TIME		317	57.6			2:09	2.15							21/12/2003	0		8/01/04	34			
5 HOUR		312	56.5			4:39	4.65				105		59.15	22/12/2003	0		8/01/04	34			
		724	129.6			4:01	4.016666667							23/12/2003	1		8/12/03	3			
		141	25.2			4:47	4.783333333	81203	77.4	3				24/12/2003	0		8/12/03	3			
		939	177.6			3:41	3.683333333	121203	195.7	7				25/12/2003	0		12/12/03	7			
		1130	213.8			5:15	5.25	151203	91.15	10				26/12/2003	0		12/12/03	7			
		347	59			3:20	3.333333333	191203	52.75	14				27/12/2003	0		15/12/03	10			
		724	123.3			8:22	8.366666667	80104	39.7	34				28/12/2003	0		15/12/03	10			
		297	52.7			3:36	3.6							29/12/2003	0		19/12/03	14			
		297	52.8			5:42	5.7							30/12/2003	0		19/12/03	14			
		200	36.5			3:43	3.716666667							31/12/2003	0		8/01/04	34			
		234	42.9			5:59	5.983333333							1/01/2004	0		8/01/04	34			
		724	136.3			2:29	2.483333333	81203	102.2	3				2/01/2004	0		8/12/03	3			
		362	68.1			2:57	2.95	101203	327.6	5				3/01/2004	0		8/12/03	3			
		609	299.3			4:02	4.033333333	121203	197.85	7				4/01/2004	0		10/12/03	5			
		724	355.9			4:28	4.466666667	151203	70.25	10				5/01/2004	0		10/12/03	5			
		1218	231.8			4:14	4.233333333	171203	64.1	12				6/01/2004	0		12/12/03	7			
		861	163.9			4:49	4.816666667	191203	43.95	14				7/01/2004	0		12/12/03	7			
		441	77.2			3:25	3.416666667	221203	59.15	17	57.05	39.7	42.9	8/01/2004	9.2		15/12/03	10			
		362	63.3			5:31	5.516666667	80104	42.9	34				9/01/2004	0		15/12/03	10			
		388	68.2			4:16	4.266666667							10/01/2004	16.4		17/12/03	12			
		342	60			4:59	4.983333333							11/01/2004	24.6		17/12/03	12			
		269	48.3			3:29	3.483333333							12/01/2004	0		19/12/03	14			
		220	39.6			3:59	3.983333333							13/01/2004	1.4		19/12/03	14			
		231	40.2			4:41	4.683333333										22/12/03	17			
		450	78.1			5:17	5.283333333										22/12/03	17			
		297	51.9			3:45	3.75										8/01/04	34			
		194	33.9			5:35	5.583333333										8/01/04	34			

Figure B.2: Feedlot A – Odour Emission Rate Data Analysis Spreadsheet (Page 2)

FEEDLOT B (2 pages)

Sample Number				Sample details															
F/lot	Pen No.	Date	No.	Bag No.	Day of week	Scheduled collection date	Actual collection date	Scheduled collection time	Actual collection time	Analysis date	Analysis time	Time elapsed since collection	Sampling device	Proposed duct velocity	Actual duct velocity	Duplicate?	Proposal Stage no.	Sample descriptor	Sample intention descriptor
RV	EHP1	21003	203	B01160	Friday	3/10/2003	3/10/2003		9:33	3/10/2003	16:00	6:27:00	WT			N		East holding pond 1	First sample set following inflow event
RV	EHP1	21003	204	B01179	Friday	3/10/2003	3/10/2003		9:53	3/10/2003	16:36	6:43:00	WT			N		East holding pond 2	First sample set following inflow event
RV	EHP1	21003	205	B01173	Friday	3/10/2003	3/10/2003		10:15	3/10/2003	17:11	6:56:00	WT			N		East holding pond 2	First sample set following inflow event
RV	EHP1	71003	208	B01201	Tuesday	7/10/2003	7/10/2003		13:18	8/10/2003	10:51	21:33:00	WT			N	2b	East holding pond 1	2nd sample set following inflow event
RV	EHP1	71003	209	B01163	Tuesday	7/10/2003	7/10/2003		13:48	8/10/2003	11:33	21:45:00	WT			N	2b	East holding pond 1	2nd sample set following inflow event
RV	EHP1	91003	214	B01193	Thursday	9/10/2003	9/10/2003		12:15	10/10/2003	10:52	22:37:00	WT			N	2b	East holding pond 1	3rd sample set following inflow event
RV	EHP1	91003	215	B01147	Thursday	9/10/2003	9/10/2003		12:41	10/10/2003	11:37	22:56:00	WT			N	2b	East holding pond 1	3rd sample set following inflow event
RV	EHP1	121003	220	B01210	Sunday	12/10/2003	12/10/2003		12:53	13/10/2003	11:00	22:07:00	WT			N	2b	East holding pond 1	4th sample set following inflow event
RV	EHP1	121003	221	B01202	Sunday	12/10/2003	12/10/2003		13:14	13/10/2003	11:34	22:20:00	WT			N	2b	East holding pond 1	4th sample set following inflow event
RV	EHP1	141003	226	B01206	Tuesday	14/10/2003	14/10/2003		12:43	15/10/2003	11:03	22:20:00	WT			N	2b	East holding pond 1	5th sample set folllowing inflow event
RV	EHP1	141003	227	B01205	Tuesday	14/10/2003	14/10/2003		13:02	15/10/2003	11:50	22:48:00	WT			N	2b	East holding pond 1	5th sample set folllowing inflow event
RV	EHP1	161003	232	B01216	Thursday	16/10/2003	16/10/2003		12:02	17/10/2003	10:52	22:50:00	WT			N	2b	East holding pond 1	6th sample set following inflow event
RV	EHP1	161003	233	B01211	Thursday	16/10/2003	16/10/2003		12:22	17/10/2003	11:20	22:58:00	WT			N	2b	East holding pond 1	6th sample set following inflow event
RV	EHP1	231003	238	B01229	Thursday	23/10/2003	23/10/2003		12:31	24/10/2003	10:15	21:44:00	WT			N	2b	East holding pond 1	7th sample set following inflow event
RV	EHP1	231003	239	B01130	Thursday	23/10/2003	23/10/2003		12:51	24/10/2003	11:19	22:28:00	WT			N	2b	East holding pond 1	7th sample set following inflow event
RV	EHP1	301003	244	B01224	Thursday	30/10/2003	30/10/2003		13:18	31/10/2003	11:01	21:43:00	WT			N	2b	East holding pond 1	8th sample set following inflow event
RV	EHP1	301003	245	B01231	Thursday	30/10/2003	30/10/2003		13:35	31/10/2003	11:42	22:07:00	WT			N	2b	East holding pond 1	8th sample set following inflow event
RV	EHP2	71003	210	B01199	Tuesday	7/10/2003	7/10/2003		14:30	8/10/2003	12:07	21:37:00	WT			N	2b	East holding pond 2	2nd sample set following inflow event
RV	EHP2	71003	211	B01200	Tuesday	7/10/2003	7/10/2003		15:02	8/10/2003	12:37	21:35:00	WT			N	2b	East holding pond 2	2nd sample set following inflow event
RV	EHP2	91003	216	B01198	Thursday	9/10/2003	9/10/2003		13:30	10/10/2003	12:29	22:59:00	WT			N	2b	East holding pond 2	3rd sample set following inflow event
RV	EHP2	91003	217	B01190	Thursday	9/10/2003	9/10/2003		13:49	10/10/2003	11:54	22:05:00	WT			N	2b	East holding pond 2	3rd sample set following inflow event
RV	EHP2	121003	222	B01140	Sunday	12/10/2003	12/10/2003		14:03	13/10/2003	12:24	22:21:00	WT			N	2b	East holding pond 2	4th sample set following inflow event
RV	EHP2	121003	223	B01204	Sunday	12/10/2003	12/10/2003		14:28	13/10/2003	13:00	22:32:00	WT			N	2b	East holding pond 2	4th sample set following inflow event
RV	EHP2	141003	228	B01213	Tuesday	14/10/2003	14/10/2003		13:40	15/10/2003	12:20	22:40:00	WT			N	2b	East holding pond 2	5th sample set folllowing inflow event
RV	EHP2	141003	229	B01208	Tuesday	14/10/2003	14/10/2003		14:07	15/10/2003	13:00	22:53:00	WT			N	2b	East holding pond 2	5th sample set folllowing inflow event
RV	EHP2	161003	234	B01218	Thursday	16/10/2003	16/10/2003		12:57	17/10/2003	12:07	23:10:00	WT			N	2b	East holding pond 2	6th sample set following inflow event
RV	EHP2	161003	235	B01219	Thursday	16/10/2003	16/10/2003		13:22	17/10/2003	12:36	23:14:00	WT			N	2b	East holding pond 2	6th sample set following inflow event
RV	EHP2	231003	240	B01230	Thursday	23/10/2003	23/10/2003		13:30	24/10/2003	12:00	22:30:00	WT			N	2b	East holding pond 2	7th sample set following inflow event
RV	EHP2	231003	241	B01228	Thursday	23/10/2003	23/10/2003		13:53	24/10/2003	12:35	22:42:00	WT			N	2b	East holding pond 2	7th sample set following inflow event
RV	EHP2	301003	246	B01123	Thursday	30/10/2003	30/10/2003		14:15	31/10/2003	12:24	22:09:00	WT			N	2b	East holding pond 2	8th sample set following inflow event
RV	EHP2	301003	247	B01143	Thursday	30/10/2003	30/10/2003		14:32	31/10/2003	13:00	22:28:00	WT			N	2b	East holding pond 2	8th sample set following inflow event
RV	ESED	21003	200	B01174	Friday	3/10/2003	3/10/2003		7:49	3/10/2003	14:21	6:32:00	WT			N		East sedimenttion	First sample set following inflow event
RV	ESED	21003	201	B01162	Friday	3/10/2003	3/10/2003		8:11	3/10/2003	15:00	6:49:00	WT			N		East sedimenttion	First sample set following inflow event
RV	ESED	21003	202	B01182	Friday	3/10/2003	3/10/2003		8:41	3/10/2003	15:27	6:46:00	WT			N		East holding pond 1	First sample set following inflow event
RV	ESED	71003	206	B01194	Tuesday	7/10/2003	7/10/2003		12:08	8/10/2003	9:45	21:37:00	WT			N	2b	East sedimenttion	2nd sample set following inflow event
RV	ESED	71003	207	B01192	Tuesday	7/10/2003	7/10/2003		12:33	8/10/2003	10:21	21:48:00	WT			N	2b	East sedimenttion	2nd sample set following inflow event
RV	ESED	91003	212	B01191	Thursday	9/10/2003	9/10/2003		11:05	10/10/2003	9:41	22:36:00	WT			N	2b	East sedimenttion	3rd sample set following inflow event
RV	ESED	91003	213	B01141	Thursday	9/10/2003	9/10/2003		11:28	10/10/2003	10:13	22:45:00	WT			N	2b	East sedimenttion	3rd sample set following inflow event
RV	ESED	121003	218	B01178	Sunday	12/10/2003	12/10/2003		11:36	13/10/2003	9:50	22:14:00	WT			N	2b	East sedimenttion	4th sample set following inflow event
RV	ESED	121003	219	B01203	Sunday	12/10/2003	12/10/2003		12:01	13/10/2003	10:30	22:29:00	WT			N	2b	East sedimenttion	4th sample set following inflow event
RV	ESED	141003	224	B01207	Tuesday	14/10/2003	14/10/2003		11:41	15/10/2003	9:55	22:14:00	WT			N	2b	East sedimenttion	5th sample set folllowing inflow event
RV	ESED	141003	225	B01214	Tuesday	14/10/2003	14/10/2003		12:02	15/10/2003	10:26	22:24:00	WT			N	2b	East sedimenttion	5th sample set folllowing inflow event
RV	ESED	161003	230	B01233	Thursday	16/10/2003	16/10/2003		10:58	17/10/2003	9:48	22:50:00	WT			N	2b	East sedimenttion	6th sample set following inflow event
RV	ESED	161003	231	B01223	Thursday	16/10/2003	16/10/2003		11:20	17/10/2003	10:18	22:58:00	WT			N	2b	East sedimenttion	6th sample set following inflow event
RV	ESED	231003	236	B01234	Thursday	23/10/2003	23/10/2003		11:28	24/10/2003	9:44	22:16:00	WT			N	2b	East sedimenttion	7th sample set following inflow event
RV	ESED	231003	237	B01215	Thursday	23/10/2003	23/10/2003		11:46	24/10/2003	10:43	22:57:00	WT			N	2b	East sedimenttion	7th sample set following inflow event
RV	ESED	301003	242	B01217	Thursday	30/10/2003	30/10/2003		12:11	31/10/2003	10:00	21:49:00	WT			N	2b	East sedimenttion	8th sample set following inflow event
RV	ESED	301003	243	B01220	Thursday	30/10/2003	30/10/2003		12:32	31/10/2003	10:24	21:52:00	WT			N	2b	East sedimenttion	8th sample set following inflow event

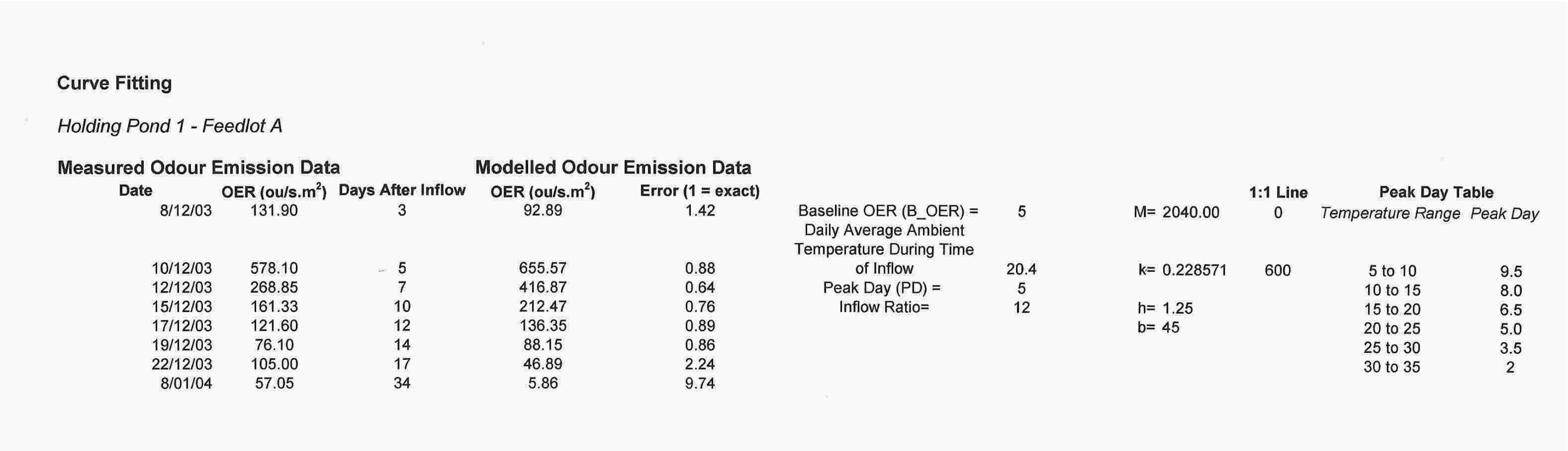
Figure B.3: Feedlot B – Odour Emission Rate Data Analysis Spreadsheet (Page 1)



Results

Comments	Odour concentration	OER (0.5 factor)	OER (0.63 factor)	Time gap, sampling analysis	Decimal Time Gap	Date	Daily Averages	Days Since Rain	Daily Averages EHP1	Daily Averages EHP2	Daily Averages Sed B	Date	Rainfall	Days Since Significant Rainfall	Sampling Days	Days Since Rain	Date	Max. Ambient Temperature	Min. Ambient Temperature	Sample Day Dates	Sample Days Max. Temp	Sample Days Min. Temp
	583	106.6		6:27	6.45	3/10/2003	98.5	2				28/09/2003	0		3/10/2003	2	28/09/2003	19.344	-3.604	3/10/2003	16.932	7.044
	558	99.6		6:43	6.716667	7/10/2003	166.75	6				29/09/2003	0		3/10/2003	2	29/09/2003	20.206	-2.646	7/10/2003	17.132	5.484
	490	89.3		6:56	6.933333	9/10/2003	454.15	8				30/09/2003	0.4		3/10/2003	2	30/09/2003	20.158	7.672	9/10/2003	19.104	4.428
	861	158.6		21:33	21.55	12/10/2003	373.9	11				1/10/2003	94.6	0	7/10/2003	6	1/10/2003	13.302	8.086	12/10/2003	16.318	0.37
	974	174.9		21:45	21.75	14/10/2003	294.95	13				2/10/2003	10.2	1	7/10/2003	6	2/10/2003	17.288	6.004	14/10/2003	18.25	4.82
	3298	611		22:37	22.61667	16/10/2003	227.3	15	98.5		56.23333	3/10/2003	2.2	2	9/10/2003	8	3/10/2003	16.932	7.044	16/10/2003	19.33	8.138
	1579	297.3		22:56	22.93333	23/10/2003	123.9	22				4/10/2003	0.2	3	9/10/2003	8	4/10/2003	14.826	5.374	23/10/2003	23.21	5.504
	1878	340		22:07	22.11667	30/10/2003	147.6	29				5/10/2003	3	4	12/10/2003	11	5/10/2003	18.004	6.738	30/10/2003	18.486	3.784
	2233	407.8		22:20	22.33333							6/10/2003	11.4	5	12/10/2003	11	6/10/2003	14.496	8.78			
	1367	243.8		22:20	22.33333				166.75	204.2	114.9	7/10/2003	0.4	6	14/10/2003	13	7/10/2003	17.132	5.484			
	1933	346.1		22:48	22.8							8/10/2003	0	7	14/10/2003	13	8/10/2003	19	2.986			
	1218	226.4		22:50	22.83333				454.15	480.55	244.05	9/10/2003	0	8	16/10/2003	15	9/10/2003	19.104	4.428			
	1218	228.2		22:58	22.96667							10/10/2003	0.2	9	16/10/2003	15	10/10/2003	17.296	3.508			
	790	141.4		21:44	21.73333							11/10/2003	0	10	23/10/2003	22	11/10/2003	14.42	-0.378			
	609	106.4		22:28	22.46667				373.9	237.6	325.3	12/10/2003	0	11	23/10/2003	22	12/10/2003	16.318	0.37			
	840	158.3		21:43	21.71667							13/10/2003	0	12	30/10/2003	29	13/10/2003	17.484	3.24			
	761	136.9		22:07	22.11667	3/10/2003			294.95	201	273.2	14/10/2003	0.2	13	30/10/2003	29	14/10/2003	18.25	4.82			
	1166	204		21:37	21.61667	7/10/2003	204.2	6				15/10/2003	0	14	7/10/2003	6	15/10/2003	19.734	5.616			
	1117	204.4		21:35	21.58333	9/10/2003	480.55	8	227.3	204.05	134.35	16/10/2003	0	15	7/10/2003	6	16/10/2003	19.33	8.138			
	3298	612.4		22:59	22.98333	12/10/2003	237.6	11				17/10/2003	0	16	9/10/2003	8	17/10/2003	19.306	9.664			
	1878	348.7		22:05	22.08333	14/10/2003	201	13				18/10/2003	0	17	9/10/2003	8	18/10/2003	19.814	6.592			
	1328	240.1		22:21	22.35	16/10/2003	204.05	15				19/10/2003	15.4	18	12/10/2003	11	19/10/2003	22.452	6.366			
	1328	235.1		22:32	22.53333	23/10/2003	129.05	22				20/10/2003	0.2	19	12/10/2003	11	20/10/2003	18.898	7.366			
	1552	278.6		22:40	22.66667	30/10/2003	225.05	29				21/10/2003	0	20	14/10/2003	13	21/10/2003	20.368	4.83			
	683	123.4		22:53	22.88333							22/10/2003	0.2	21	14/10/2003	13	22/10/2003	22.666	5.22			
	1188	217.7		23:10	23.16667				123.9	129.05	137.05	23/10/2003	0	22	16/10/2003	15	23/10/2003	23.21	5.504			
	1024	190.4		23:14	23.23333							24/10/2003	5	23	16/10/2003	15	24/10/2003	25.382	6.792			
	790	141.2		22:30	22.5							25/10/2003	1	24	23/10/2003	22	25/10/2003	24.512	8.436			
	664	116.9		22:42	22.7							26/10/2003	0.4	25	23/10/2003	22	26/10/2003	22.308	9.408			
	1130	202.7		22:09	22.15							27/10/2003	0.2	26	30/10/2003	29	27/10/2003	20.38	4.412			
	1378	247.4		22:28	22.46667							28/10/2003	2.4	27	30/10/2003	29	28/10/2003	24.056	3.326			
	291	52.9		6:32	6.533333	3/10/2003	56.233333	2				29/10/2003	0.2	28	3/10/2003	2	29/10/2003	19.968	9.398			
	279	52		6:49	6.816667	7/10/2003	114.9	6	147.6	225.05	131.05	30/10/2003	0	29	3/10/2003	2	30/10/2003	18.486	3.784			
	347	63.8		6:46	6.766667	9/10/2003	244.05	8				31/10/2003	0	30	3/10/2003	2	31/10/2003	20.046	2.476			
	512	91.3		21:37	21.61667	12/10/2003	325.3	11							7/10/2003	6						
	790	138.5		21:48	21.8	14/10/2003	273.2	13							7/10/2003	6						
	1166	214.5		22:36	22.6	16/10/2003	134.35	15							9/10/2003	8						
	1448	273.6		22:45	22.75	23/10/2003	137.05	22							9/10/2003	8						
	1649	293.8		22:14	22.23333	30/10/2003	131.05	29							12/10/2003	11						
	1961	356.8		22:29	22.48333										12/10/2003	11						
	1824	327.5		22:14	22.23333										14/10/2003	13						
	1218	218.9		22:24	22.4										14/10/2003	13						
	609	111.1		22:50	22.83333										16/10/2003	15						
	861	157.6		22:58	22.96667										16/10/2003	15						
	724	134.3		22:16	22.26667										23/10/2003	22						
	761	139.8		22:57	22.95										23/10/2003	22						
	761	136.7		21:49	21.81667										30/10/2003	29						
	683	125.4		21:52	21.86667										30/10/2003	29						

Figure B.4: Feedlot B – Odour Emission Rate Data Analysis Spreadsheet (Page 2)



Curve Fitting

Holding Pond 1 - Feedlot A

Measured Odour Emission Data			**Modelled Odour Emission Data**	
Date	**OER (ou/s.m^2)**	**Days After Inflow**	**OER (ou/s.m^2)**	**Error (1 = exact)**
8/12/03	131.90	3	92.89	1.42
10/12/03	578.10	5	655.57	0.88
12/12/03	268.85	7	416.87	0.64
15/12/03	161.33	10	212.47	0.76
17/12/03	121.60	12	136.35	0.89
19/12/03	76.10	14	88.15	0.86
22/12/03	105.00	17	46.89	2.24
8/01/04	57.05	34	5.86	9.74

Baseline OER (B_OER) =	5
Daily Average Ambient Temperature During Time of Inflow	20.4
Peak Day (PD) =	5
Inflow Ratio=	12

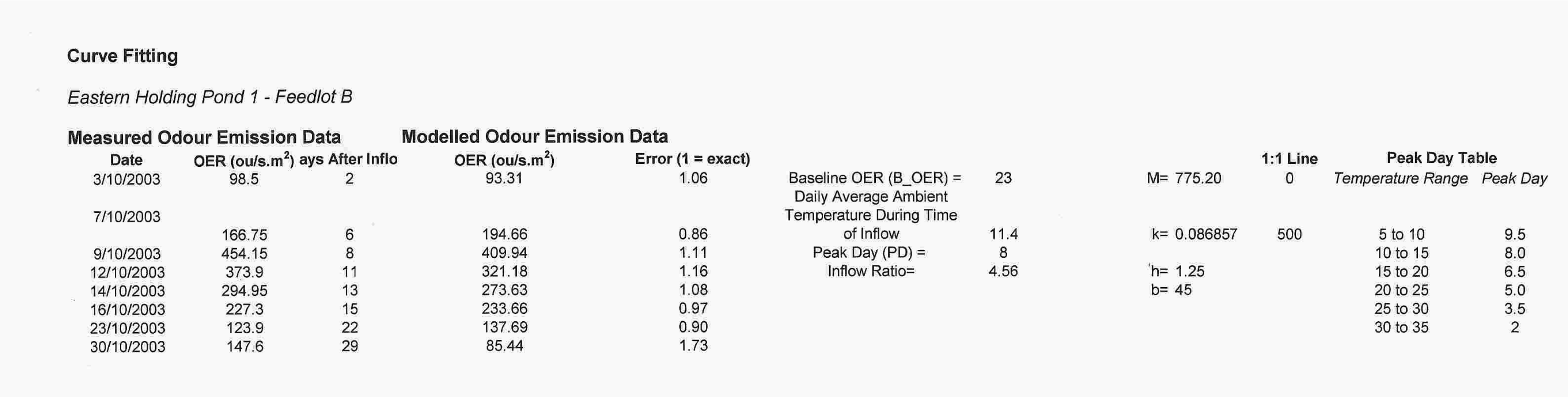
M= 2040.00
k= 0.228571
h= 1.25
b= 45

1:1 Line
0
600

Peak Day Table

Temperature Range	*Peak Day*
5 to 10	9.5
10 to 15	8.0
15 to 20	6.5
20 to 25	5.0
25 to 30	3.5
30 to 35	2

Figure B.5: Feedlot A – Model Analysis Spreadsheet

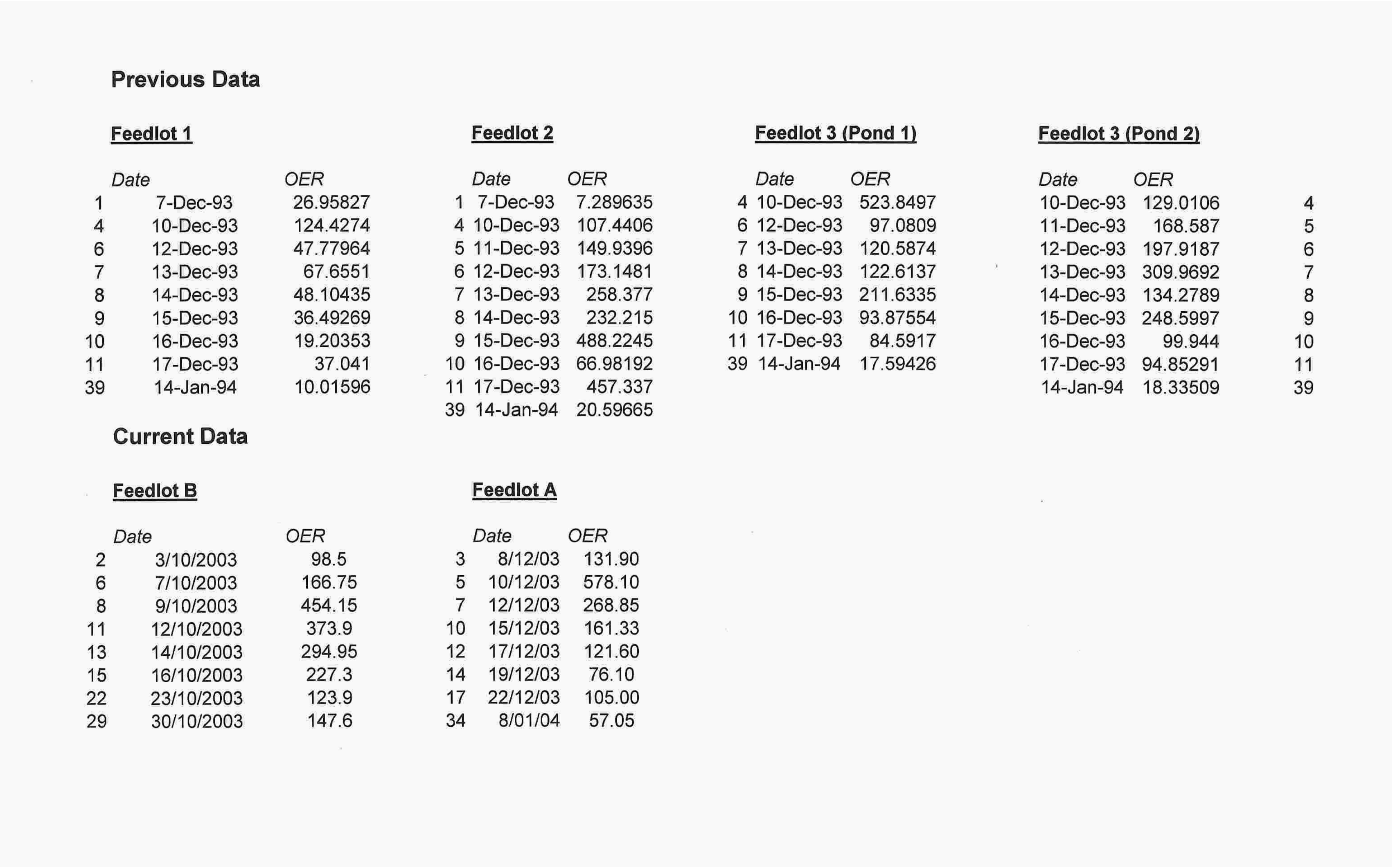


Curve Fitting

Eastern Holding Pond 1 - Feedlot B

Measured Odour Emission Data			**Modelled Odour Emission Data**							
Date	**OER (ou/s.m^2)**	**ays After Inflo**	**OER (ou/s.m^2)**	**Error (1 = exact)**				**1:1 Line**	**Peak Day Table**	
3/10/2003	98.5	2	93.31	1.06	Baseline OER (B_OER) =	23	M= 775.20	0	*Temperature Range*	*Peak Day*
7/10/2003										
	166.75	6	194.66	0.86	Daily Average Ambient Temperature During Time of Inflow	11.4	k= 0.086857	500	5 to 10	9.5
9/10/2003	454.15	8	409.94	1.11	Peak Day (PD) =	8			10 to 15	8.0
12/10/2003	373.9	11	321.18	1.16	Inflow Ratio=	4.56	h= 1.25		15 to 20	6.5
14/10/2003	294.95	13	273.63	1.08			b= 45		20 to 25	5.0
16/10/2003	227.3	15	233.66	0.97					25 to 30	3.5
23/10/2003	123.9	22	137.69	0.90					30 to 35	2
30/10/2003	147.6	29	85.44	1.73						

Figure B.6: Feedlot B – Model Analysis Spreadsheet



Previous Data

Feedlot 1

	Date	OER
1	7-Dec-93	26.95827
4	10-Dec-93	124.4274
6	12-Dec-93	47.77964
7	13-Dec-93	67.6551
8	14-Dec-93	48.10435
9	15-Dec-93	36.49269
10	16-Dec-93	19.20353
11	17-Dec-93	37.041
39	14-Jan-94	10.01596

Feedlot 2

	Date	OER
1	7-Dec-93	7.289635
4	10-Dec-93	107.4406
5	11-Dec-93	149.9396
6	12-Dec-93	173.1481
7	13-Dec-93	258.377
8	14-Dec-93	232.215
9	15-Dec-93	488.2245
10	16-Dec-93	66.98192
11	17-Dec-93	457.337
39	14-Jan-94	20.59665

Feedlot 3 (Pond 1)

	Date	OER
4	10-Dec-93	523.8497
6	12-Dec-93	97.0809
7	13-Dec-93	120.5874
8	14-Dec-93	122.6137
9	15-Dec-93	211.6335
10	16-Dec-93	93.87554
11	17-Dec-93	84.5917
39	14-Jan-94	17.59426

Feedlot 3 (Pond 2)

Date	OER	
10-Dec-93	129.0106	4
11-Dec-93	168.587	5
12-Dec-93	197.9187	6
13-Dec-93	309.9692	7
14-Dec-93	134.2789	8
15-Dec-93	248.5997	9
16-Dec-93	99.944	10
17-Dec-93	94.85291	11
14-Jan-94	18.33509	39

Current Data

Feedlot B

	Date	OER
2	3/10/2003	98.5
6	7/10/2003	166.75
8	9/10/2003	454.15
11	12/10/2003	373.9
13	14/10/2003	294.95
15	16/10/2003	227.3
22	23/10/2003	123.9
29	30/10/2003	147.6

Feedlot A

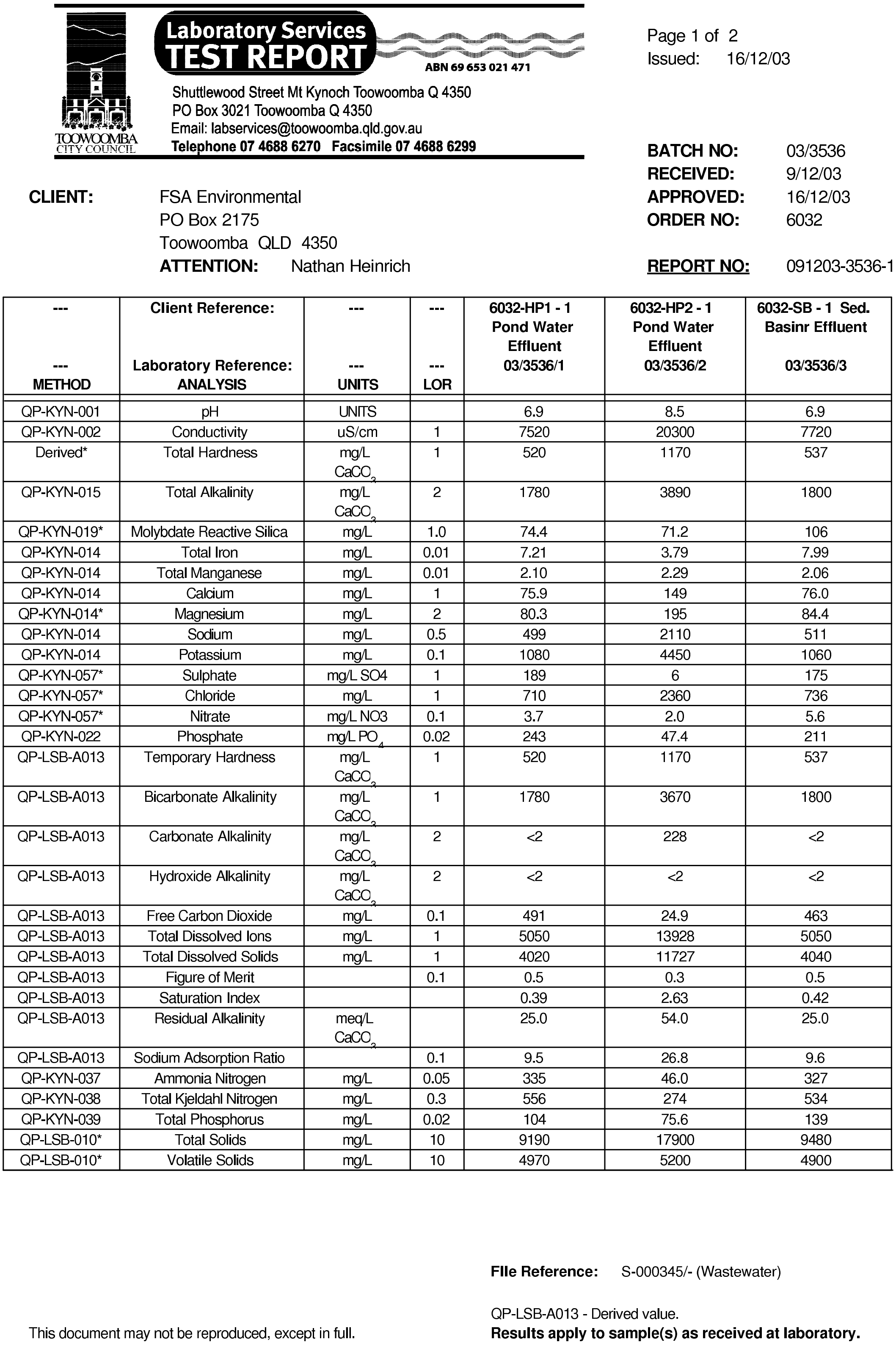
	Date	OER
3	8/12/03	131.90
5	10/12/03	578.10
7	12/12/03	268.85
10	15/12/03	161.33
12	17/12/03	121.60
14	19/12/03	76.10
17	22/12/03	105.00
34	8/01/04	57.05

Figure B.7: MRC Project Odour Emission Rate Data

Appendix C

Effluent Analyses from Primary Holding Ponds - Post Inflow

Figure C.1: Feedlot A – Effluent Analysis(2 pages)



Laboratory Services TEST REPORT

ABN 69 653 021 471

Shuttlewood Street Mt Kynoch Toowoomba Q 4350
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Page 1 of 2
Issued: 16/12/03

BATCH NO: 03/3536
RECEIVED: 9/12/03
APPROVED: 16/12/03
ORDER NO: 6032

CLIENT: FSA Environmental
PO Box 2175
Toowoomba QLD 4350
ATTENTION: Nathan Heinrich

REPORT NO: 091203-3536-1

---	Client Reference:	---	---	6032-HP1 - 1 Pond Water Effluent	6032-HP2 - 1 Pond Water Effluent	6032-SB - 1 Sed. Basinr Effluent
---	Laboratory Reference:	---	---	03/3536/1	03/3536/2	03/3536/3
METHOD	**ANALYSIS**	**UNITS**	**LOR**			
QP-KYN-001	pH	UNITS		6.9	8.5	6.9
QP-KYN-002	Conductivity	uS/cm	1	7520	20300	7720
Derived*	Total Hardness	mg/L $CaCO_3$	1	520	1170	537
QP-KYN-015	Total Alkalinity	mg/L $CaCO_3$	2	1780	3890	1800
QP-KYN-019*	Molybdate Reactive Silica	mg/L	1.0	74.4	71.2	106
QP-KYN-014	Total Iron	mg/L	0.01	7.21	3.79	7.99
QP-KYN-014	Total Manganese	mg/L	0.01	2.10	2.29	2.06
QP-KYN-014	Calcium	mg/L	1	75.9	149	76.0
QP-KYN-014*	Magnesium	mg/L	2	80.3	195	84.4
QP-KYN-014	Sodium	mg/L	0.5	499	2110	511
QP-KYN-014	Potassium	mg/L	0.1	1080	4450	1060
QP-KYN-057*	Sulphate	mg/L SO4	1	189	6	175
QP-KYN-057*	Chloride	mg/L	1	710	2360	736
QP-KYN-057*	Nitrate	mg/L NO3	0.1	3.7	2.0	5.6
QP-KYN-022	Phosphate	mg/L PO_4	0.02	243	47.4	211
QP-LSB-A013	Temporary Hardness	mg/L $CaCO_3$	1	520	1170	537
QP-LSB-A013	Bicarbonate Alkalinity	mg/L $CaCO_3$	1	1780	3670	1800
QP-LSB-A013	Carbonate Alkalinity	mg/L $CaCO_3$	2	<2	228	<2
QP-LSB-A013	Hydroxide Alkalinity	mg/L $CaCO_3$	2	<2	<2	<2
QP-LSB-A013	Free Carbon Dioxide	mg/L	0.1	491	24.9	463
QP-LSB-A013	Total Dissolved Ions	mg/L	1	5050	13928	5050
QP-LSB-A013	Total Dissolved Solids	mg/L	1	4020	11727	4040
QP-LSB-A013	Figure of Merit		0.1	0.5	0.3	0.5
QP-LSB-A013	Saturation Index			0.39	2.63	0.42
QP-LSB-A013	Residual Alkalinity	meq/L $CaCO_3$		25.0	54.0	25.0
QP-LSB-A013	Sodium Adsorption Ratio		0.1	9.5	26.8	9.6
QP-KYN-037	Ammonia Nitrogen	mg/L	0.05	335	46.0	327
QP-KYN-038	Total Kjeldahl Nitrogen	mg/L	0.3	556	274	534
QP-KYN-039	Total Phosphorus	mg/L	0.02	104	75.6	139
QP-LSB-010*	Total Solids	mg/L	10	9190	17900	9480
QP-LSB-010*	Volatile Solids	mg/L	10	4970	5200	4900

File Reference: S-000345/- (Wastewater)

QP-LSB-A013 - Derived value.

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APPROVED: 16/12/03

ORDER NO: 6032

REPORT NO: 091203-3536-1

CLIENT:

FSA Environmental
PO Box 2175
Toowoomba QLD 4350
ATTENTION: Nathan Heinrich

Comments

A. C. KLEINSCHMIDT
Manager, Laboratory Services

FIle Reference: S-000345/- (Wastewater)

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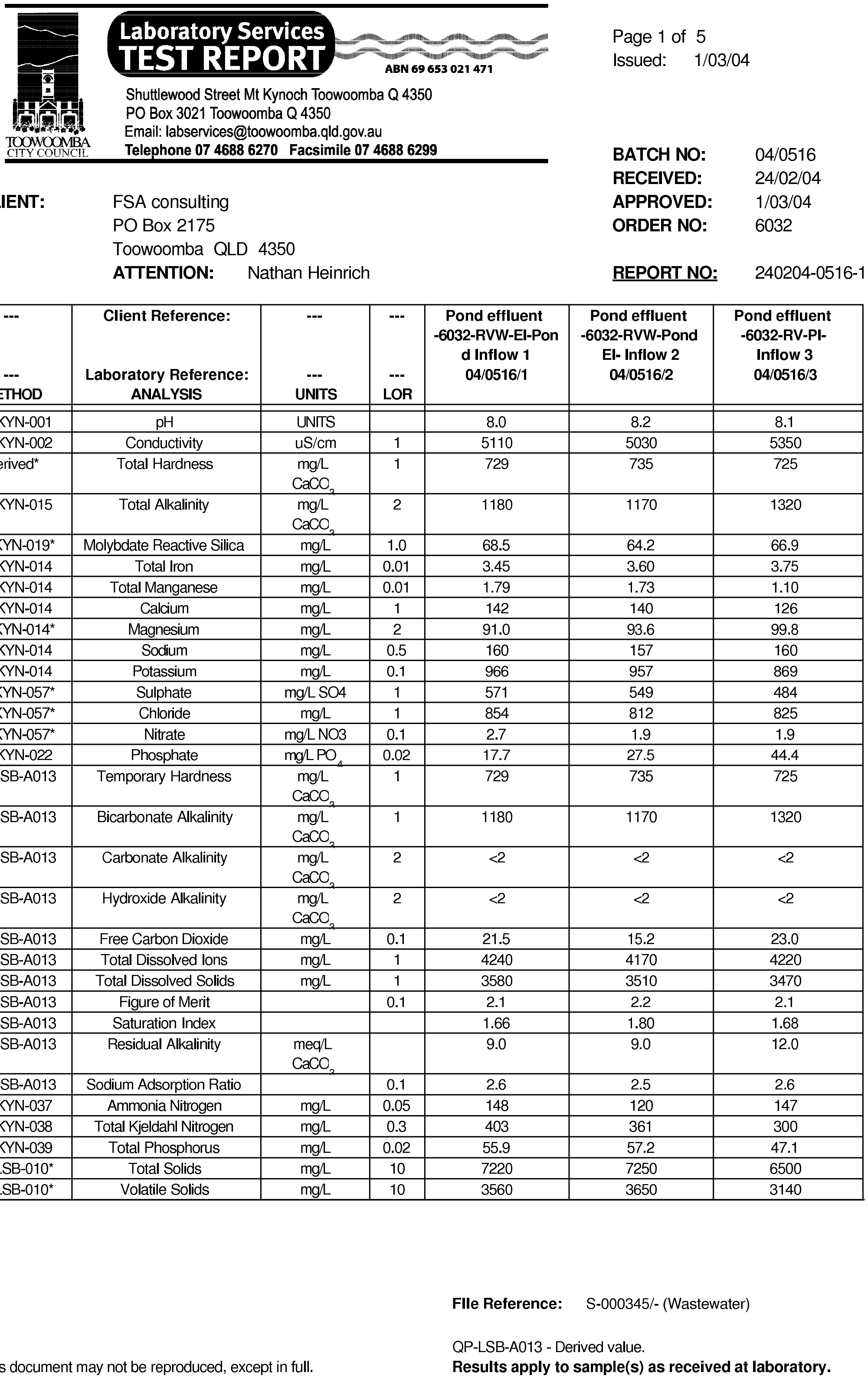

Figure C.2: Feedlot B – Effluent Analysis (5 pages)

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Page 1 of 5
Issued: 1/03/04

BATCH NO: 04/0516
RECEIVED: 24/02/04
APPROVED: 1/03/04
ORDER NO: 6032

REPORT NO: 240204-0516-1

CLIENT: FSA consulting
PO Box 2175
Toowoomba QLD 4350
ATTENTION: Nathan Heinrich

---	**Client Reference:**	**---**	**---**	**Pond effluent -6032-RVW-EI-Pond Inflow 1**	**Pond effluent -6032-RVW-Pond EI- Inflow 2**	**Pond effluent -6032-RV-PI-Inflow 3**
---	**Laboratory Reference:**	**---**	**---**	**04/0516/1**	**04/0516/2**	**04/0516/3**
METHOD	**ANALYSIS**	**UNITS**	**LOR**			
QP-KYN-001	pH	UNITS		8.0	8.2	8.1
QP-KYN-002	Conductivity	uS/cm	1	5110	5030	5350
Derived*	Total Hardness	mg/L $CaCO_3$	1	729	735	725
QP-KYN-015	Total Alkalinity	mg/L $CaCO_3$	2	1180	1170	1320
QP-KYN-019*	Molybdate Reactive Silica	mg/L	1.0	68.5	64.2	66.9
QP-KYN-014	Total Iron	mg/L	0.01	3.45	3.60	3.75
QP-KYN-014	Total Manganese	mg/L	0.01	1.79	1.73	1.10
QP-KYN-014	Calcium	mg/L	1	142	140	126
QP-KYN-014*	Magnesium	mg/L	2	91.0	93.6	99.8
QP-KYN-014	Sodium	mg/L	0.5	160	157	160
QP-KYN-014	Potassium	mg/L	0.1	966	957	869
QP-KYN-057*	Sulphate	mg/L SO4	1	571	549	484
QP-KYN-057*	Chloride	mg/L	1	854	812	825
QP-KYN-057*	Nitrate	mg/L NO3	0.1	2.7	1.9	1.9
QP-KYN-022	Phosphate	mg/L PO_4	0.02	17.7	27.5	44.4
QP-LSB-A013	Temporary Hardness	mg/L $CaCO_3$	1	729	735	725
QP-LSB-A013	Bicarbonate Alkalinity	mg/L $CaCO_3$	1	1180	1170	1320
QP-LSB-A013	Carbonate Alkalinity	mg/L $CaCO_3$	2	<2	<2	<2
QP-LSB-A013	Hydroxide Alkalinity	mg/L $CaCO_3$	2	<2	<2	<2
QP-LSB-A013	Free Carbon Dioxide	mg/L	0.1	21.5	15.2	23.0
QP-LSB-A013	Total Dissolved Ions	mg/L	1	4240	4170	4220
QP-LSB-A013	Total Dissolved Solids	mg/L	1	3580	3510	3470
QP-LSB-A013	Figure of Merit		0.1	2.1	2.2	2.1
QP-LSB-A013	Saturation Index			1.66	1.80	1.68
QP-LSB-A013	Residual Alkalinity	meq/L $CaCO_3$		9.0	9.0	12.0
QP-LSB-A013	Sodium Adsorption Ratio		0.1	2.6	2.5	2.6
QP-KYN-037	Ammonia Nitrogen	mg/L	0.05	148	120	147
QP-KYN-038	Total Kjeldahl Nitrogen	mg/L	0.3	403	361	300
QP-KYN-039	Total Phosphorus	mg/L	0.02	55.9	57.2	47.1
QP-LSB-010*	Total Solids	mg/L	10	7220	7250	6500
QP-LSB-010*	Volatile Solids	mg/L	10	3560	3650	3140

FIle Reference: S-000345/- (Wastewater)

QP-LSB-A013 - Derived value.

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RECEIVED: 24/02/04
APPROVED: 1/03/04

ORDER NO: 6032

REPORT NO: 240204-0516-1

CLIENT:

FSA consulting
PO Box 2175
Toowoomba QLD 4350
ATTENTION: Nathan Heinrich

---	**Client Reference:**	---	---	**Pond effluent -6032-RV-PI-Inflow 4**	**Pond effluent -6032-RV-PI-Inflow 5**	**Pond effluent -6032-RV-PI-Inflow 6**
--- METHOD	**Laboratory Reference: ANALYSIS**	**--- UNITS**	**--- LOR**	**04/0516/4**	**04/0516/5**	**04/0516/6**
QP-KYN-001	pH	UNITS		8.2	8.0	8.0
QP-KYN-002	Conductivity	uS/cm	1	5400	5880	5350
Derived*	Total Hardness	mg/L $CaCO_3$	1	768	714	696
QP-KYN-015	Total Alkalinity	mg/L $CaCO_3$	2	1300	1420	1340
QP-KYN-019*	Molybdate Reactive Silica	mg/L	1.0	66.7	77.5	76.3
QP-KYN-014	Total Iron	mg/L	0.01	3.46	2.43	2.41
QP-KYN-014	Total Manganese	mg/L	0.01	1.24	1.01	1.11
QP-KYN-014	Calcium	mg/L	1	148	121	117
QP-KYN-014*	Magnesium	mg/L	2	96.8	100	98.1
QP-KYN-014	Sodium	mg/L	0.5	160	161	163
QP-KYN-014	Potassium	mg/L	0.1	948	946	995
QP-KYN-057*	Sulphate	mg/L SO4	1	321	429	444
QP-KYN-057*	Chloride	mg/L	1	827	817	838
QP-KYN-057*	Nitrate	mg/L NO3	0.1	<0.5	<0.5	<0.5
QP-KYN-022	Phosphate	mg/L PO_4	0.02	40.4	43.3	46.7
QP-LSB-A013	Temporary Hardness	mg/L $CaCO_3$	1	768	714	696
QP-LSB-A013	Bicarbonate Alkalinity	mg/L $CaCO_3$	1	1300	1420	1340
QP-LSB-A013	Carbonate Alkalinity	mg/L $CaCO_3$	2	<2	<2	<2
QP-LSB-A013	Hydroxide Alkalinity	mg/L $CaCO_3$	2	<2	<2	<2
QP-LSB-A013	Free Carbon Dioxide	mg/L	0.1	18.0	31.8	28.7
QP-LSB-A013	Total Dissolved Ions	mg/L	1	4130	4350	4330
QP-LSB-A013	Total Dissolved Solids	mg/L	1	3390	3550	3580
QP-LSB-A013	Figure of Merit		0.1	2.2	2.0	2.0
QP-LSB-A013	Saturation Index			1.84	1.58	1.56
QP-LSB-A013	Residual Alkalinity	meq/L $CaCO_3$		11.0	14.0	13.0
QP-LSB-A013	Sodium Adsorption Ratio		0.1	2.5	2.6	2.7
QP-KYN-037	Ammonia Nitrogen	mg/L	0.05	167	186	187
QP-KYN-038	Total Kjeldahl Nitrogen	mg/L	0.3	292	316	352
QP-KYN-039	Total Phosphorus	mg/L	0.02	42.4	53.1	37.3

FIle Reference: S-000345/- (Wastewater)

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--- --- **METHOD**	**Client Reference:** **Laboratory Reference:** **ANALYSIS**	--- --- **UNITS**	--- --- **LOR**	**Pond effluent -6032-RV-PI-Inflow 4** **04/0516/4**	**Pond effluent -6032-RV-PI-Inflow 5** **04/0516/5**	**Pond effluent -6032-RV-PI-Inflow 6** **04/0516/6**
QP-LSB-010*	Total Solids	mg/L	10	6390	6200	6220
QP-LSB-010*	Volatile Solids	mg/L	10	3070	2920	2960

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ATTENTION: Nathan Heinrich

---	Client Reference:	---	---	Pond effluent -6032-RV-PI-Inflow 7	Pond effluent -6032-RV-PI-Inflow 8	Pond effluent -6032-RV-PI-Inflow 9
---	Laboratory Reference:	---	---	04/0516/7	04/0516/8	04/0516/9
METHOD	**ANALYSIS**	**UNITS**	**LOR**			
QP-KYN-001	pH	UNITS		8.3	8.2	8.8
QP-KYN-002	Conductivity	uS/cm	1	5490	5640	5380
Derived*	Total Hardness	mg/L $CaCO_3$	1	743	784	760
QP-KYN-015	Total Alkalinity	mg/L $CaCO_3$	2	1440	1710	1400
QP-KYN-019*	Molybdate Reactive Silica	mg/L	1.0	82.8	88.0	83.2
QP-KYN-014	Total Iron	mg/L	0.01	1.86	2.06	2.28
QP-KYN-014	Total Manganese	mg/L	0.01	0.99	0.68	0.65
QP-KYN-014	Calcium	mg/L	1	121	126	113
QP-KYN-014*	Magnesium	mg/L	2	107	114	116
QP-KYN-014	Sodium	mg/L	0.5	162	168	168
QP-KYN-014	Potassium	mg/L	0.1	955	986	975
QP-KYN-057*	Sulphate	mg/L SO4	1	323	243	198
QP-KYN-057*	Chloride	mg/L	1	865	899	892
QP-KYN-057*	Nitrate	mg/L NO3	0.1	<0.5	0.7	0.9
QP-KYN-022	Phosphate	mg/L PO_4	0.02	16.0	38.3	8.78
QP-LSB-A013	Temporary Hardness	mg/L $CaCO_3$	1	743	784	760
QP-LSB-A013	Bicarbonate Alkalinity	mg/L $CaCO_3$	1	1440	1710	1190
QP-LSB-A013	Carbonate Alkalinity	mg/L $CaCO_3$	2	<2	<2	214
QP-LSB-A013	Hydroxide Alkalinity	mg/L $CaCO_3$	2	<2	<2	<2
QP-LSB-A013	Free Carbon Dioxide	mg/L	0.1	14.7	23.1	4.2
QP-LSB-A013	Total Dissolved Ions	mg/L	1	4300	4660	4050
QP-LSB-A013	Total Dissolved Solids	mg/L	1	3490	3690	3400
QP-LSB-A013	Figure of Merit		0.1	2.1	2.1	2.1
QP-LSB-A013	Saturation Index			1.93	1.90	2.35
QP-LSB-A013	Residual Alkalinity	meq/L $CaCO_3$		14.0	18.0	13.0
QP-LSB-A013	Sodium Adsorption Ratio		0.1	2.6	2.6	2.7
QP-KYN-037	Ammonia Nitrogen	mg/L	0.05	189	188	185
QP-KYN-038	Total Kjeldahl Nitrogen	mg/L	0.3	249	329	323
QP-KYN-039	Total Phosphorus	mg/L	0.02	30.4	55.9	56.2

FIle Reference: S-000345/- (Wastewater)

QP-LSB-A013 - Derived value.

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REPORT NO: 240204-0516-1

CLIENT:

FSA consulting
PO Box 2175
Toowoomba QLD 4350
ATTENTION: Nathan Heinrich

--- **---** **METHOD**	**Client Reference:** **Laboratory Reference:** **ANALYSIS**	**---** **---** **UNITS**	**---** **---** **LOR**	**Pond effluent -6032-RV-PI-Inflow 7** **04/0516/7**	**Pond effluent -6032-RV-PI-Inflow 8** **04/0516/8**	**Pond effluent -6032-RV-PI-Inflow 9** **04/0516/9**
QP-LSB-010*	Total Solids	mg/L	10	5900	6110	5810
QP-LSB-010*	Volatile Solids	mg/L	10	2860	2920	2670

Comments

A. C. KLEINSCHMIDT
Manager, Laboratory Services

File Reference: S-000345/- (Wastewater)

QP-LSB-A013 - Derived value.
Results apply to sample(s) as received at laboratory.

Appendix D

Effluent Analyses – Comparison of Current and MRC Project Data

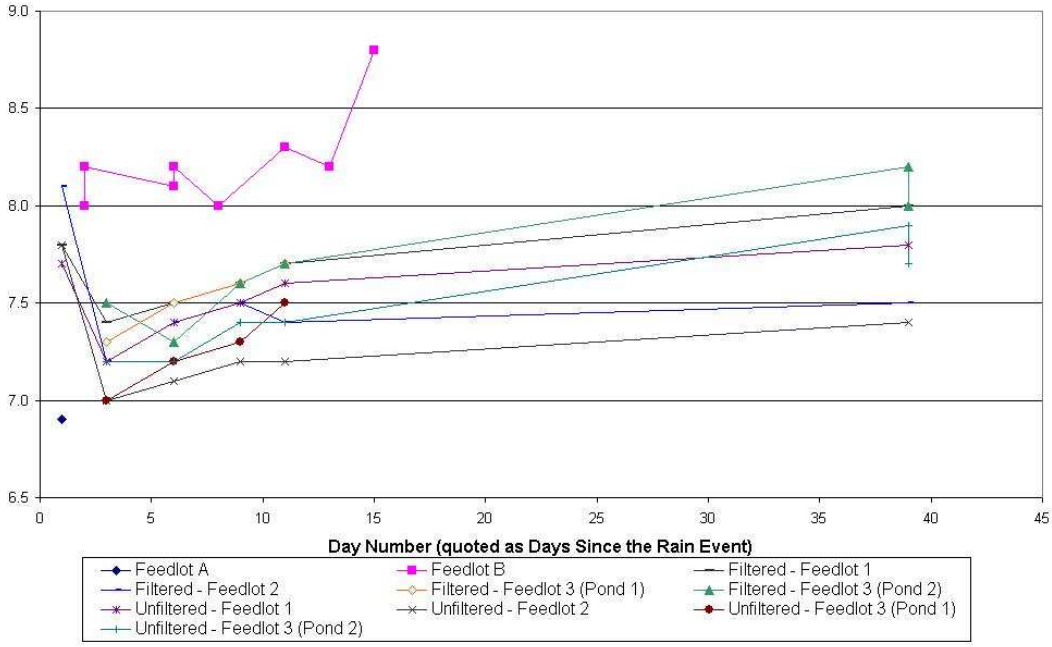


Figure D.1: Comparison between Current Project and MRC Project – pH

The comparison of the effluent data does show differences in all the parameters, as shown graphically in Figures D.1 to D.7. The actual data is included in Figure D.8.

The pH was approximately 1 point higher in this project, and the EC was lower by around 10 dS/m.

The lower EC value in the current projects' data was expected, as the inflow was very large at both feedlots, thereby diluting the initial pond contents significantly with fresh (lower EC) effluent.

The ammonia nitrogen was lower in this project than all cases from the MRC data. There was no discernable difference in the total phosphorous or suspended (or dissolved) solids content, however the volatile solids was lower in the current data, as with the total Kjedahl nitrogen.

These comparisons suggest that the organic load on the effluent was less in this project than in the MRC project. This shows the change in pad surface management that has occurred in the past decade (increased pen cleaning frequency, less manure depth on pad) as there is less manure (organic matter) in the runoff.

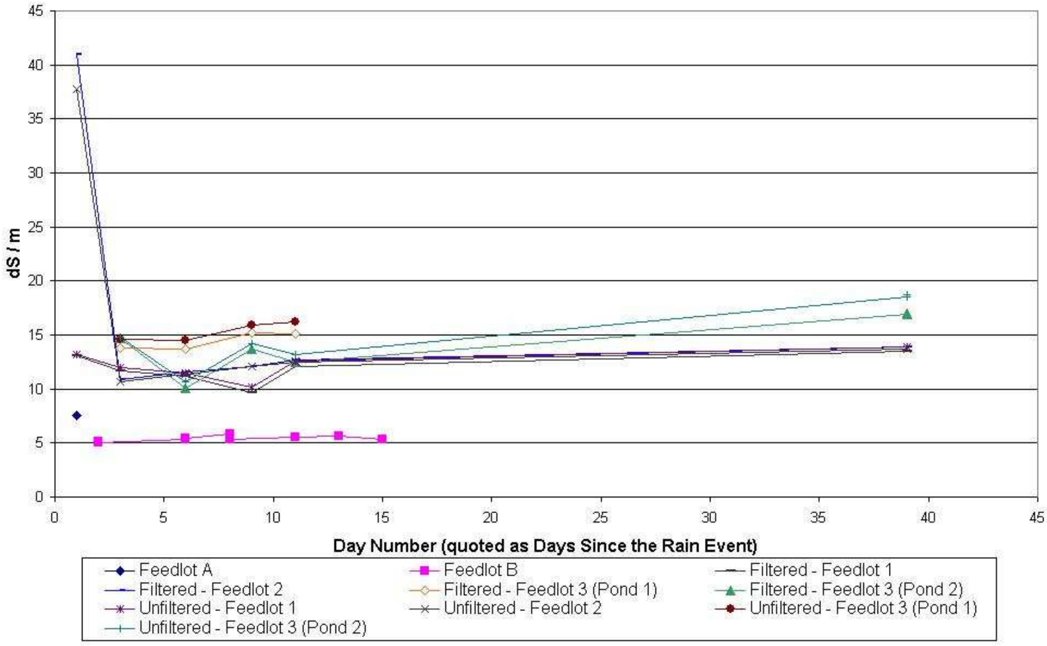


Figure D.2: Comparison between Current Project and MRC Project – EC

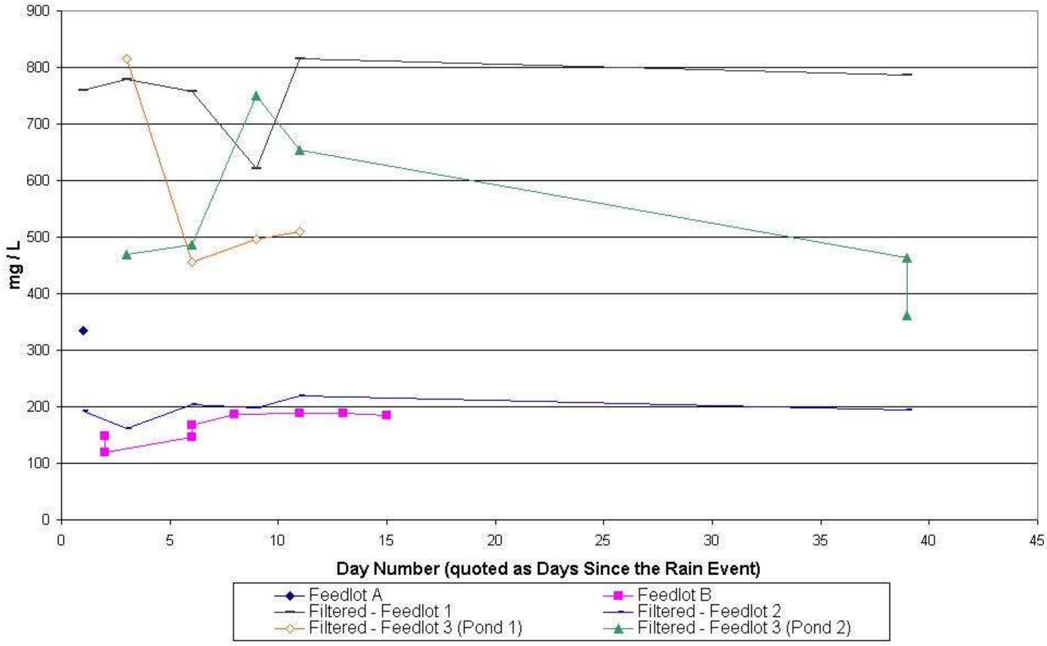


Figure D.3: Comparison between Current Project and MRC Project – Ammonia Nitrogen

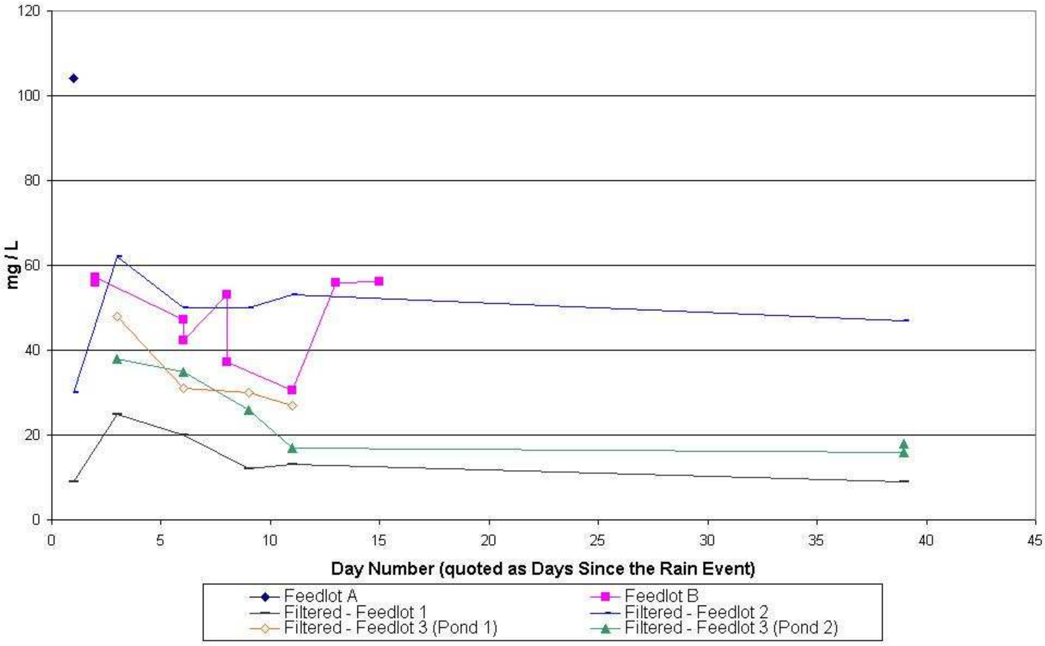


Figure D.4: Comparison between Current Project and MRC Project – Total Phosphorous

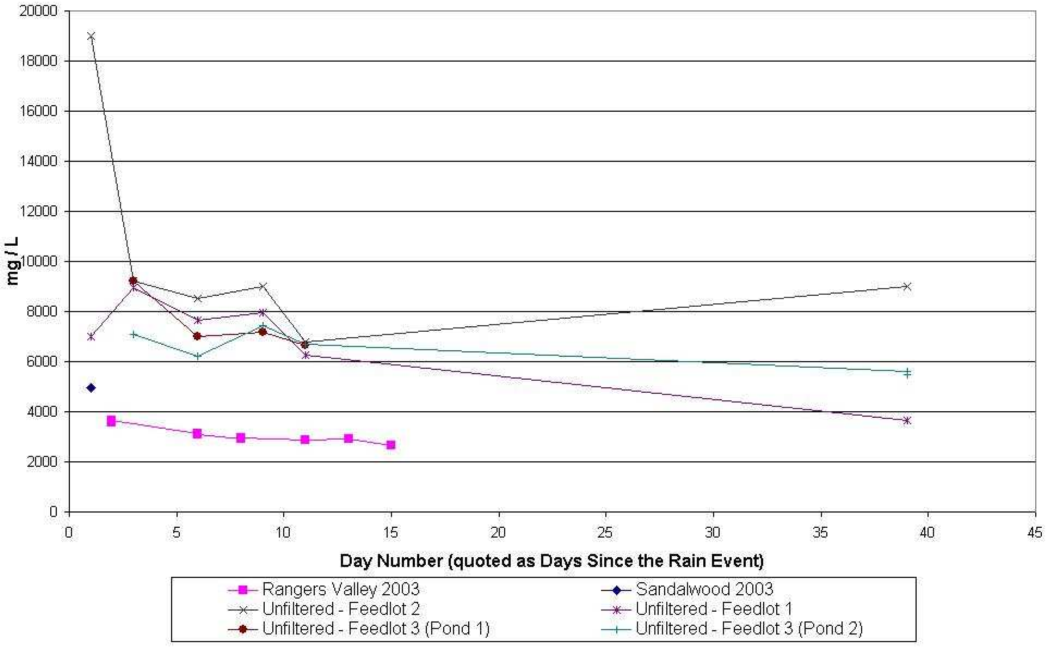


Figure D.5: Comparison between Current Project and MRC Project – Volatile Solids

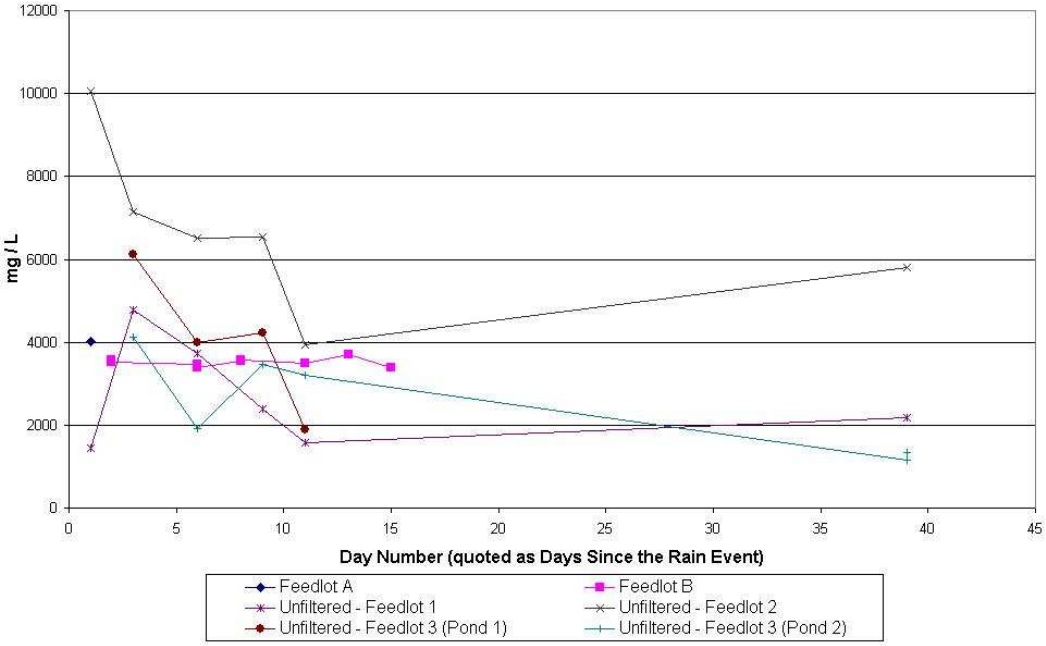


Figure D.6: Comparison between Current Project and MRC Project – Suspended Solids

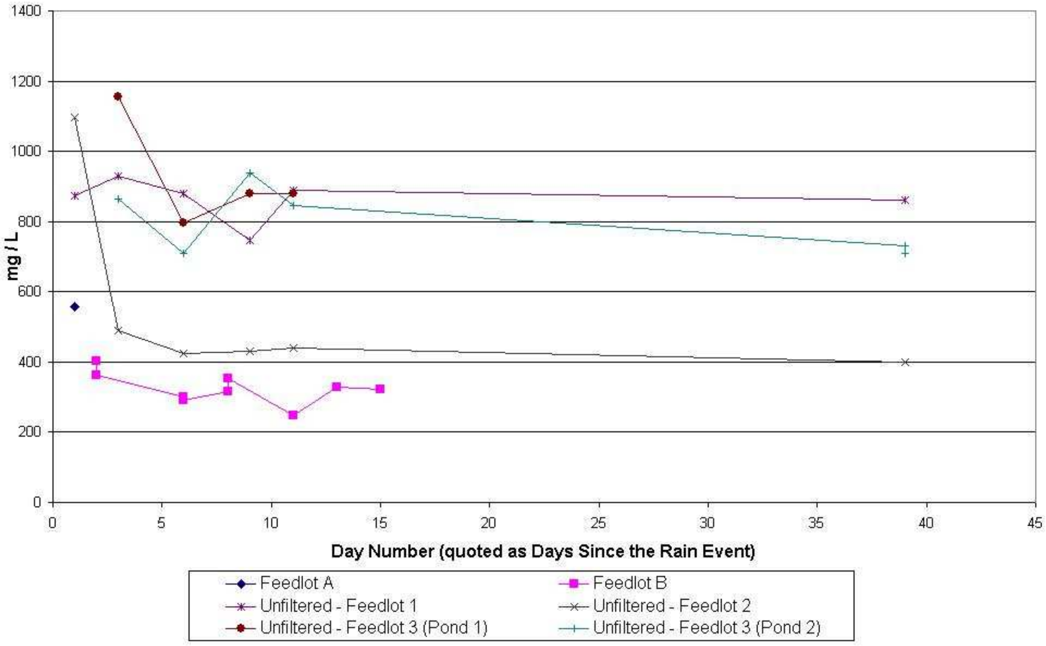
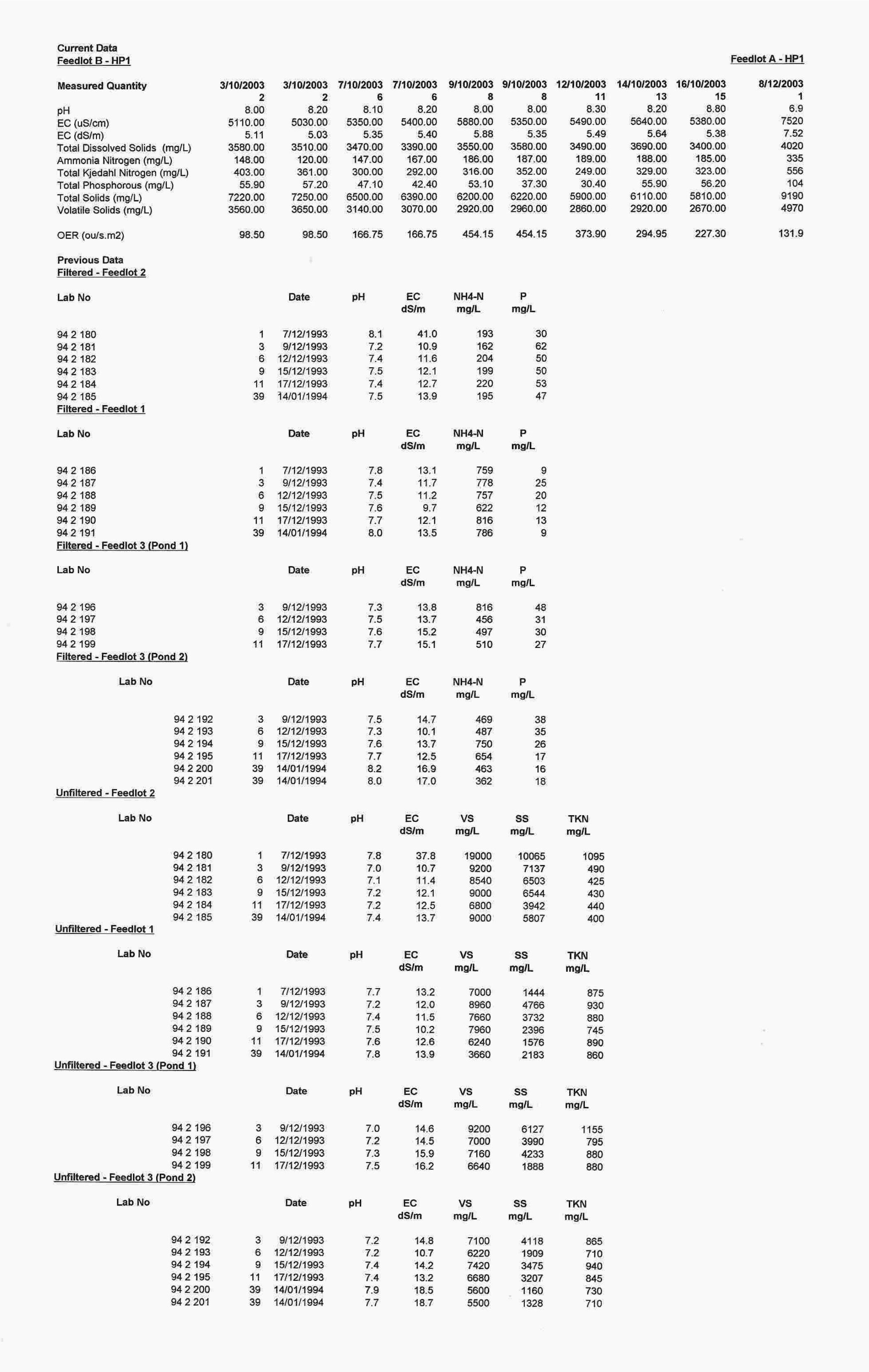


Figure D.7: Comparison between Current Project and MRC Project – Total Kjedahl Nitrogen



Current Data
Feedlot B - HP1

Feedlot A - HP1

Measured Quantity	**3/10/2003**	**3/10/2003**	**7/10/2003**	**7/10/2003**	**9/10/2003**	**9/10/2003**	**12/10/2003**	**14/10/2003**	**16/10/2003**	**8/12/2003**
	2	**2**	**6**	**6**	**8**	**8**	**11**	**13**	**15**	**1**
pH	8.00	8.20	8.10	8.20	8.00	8.00	8.30	8.20	8.80	6.9
EC (uS/cm)	5110.00	5030.00	5350.00	5400.00	5880.00	5350.00	5490.00	5640.00	5380.00	7520
EC (dS/m)	5.11	5.03	5.35	5.40	5.88	5.35	5.49	5.64	5.38	7.52
Total Dissolved Solids (mg/L)	3580.00	3510.00	3470.00	3390.00	3550.00	3580.00	3490.00	3690.00	3400.00	4020
Ammonia Nitrogen (mg/L)	148.00	120.00	147.00	167.00	186.00	187.00	189.00	188.00	185.00	335
Total Kjedahl Nitrogen (mg/L)	403.00	361.00	300.00	292.00	316.00	352.00	249.00	329.00	323.00	556
Total Phosphorous (mg/L)	55.90	57.20	47.10	42.40	53.10	37.30	30.40	55.90	56.20	104
Total Solids (mg/L)	7220.00	7250.00	6500.00	6390.00	6200.00	6220.00	5900.00	6110.00	5810.00	9190
Volatile Solids (mg/L)	3560.00	3650.00	3140.00	3070.00	2920.00	2960.00	2860.00	2920.00	2670.00	4970
OER (ou/s.m2)	98.50	98.50	166.75	166.75	454.15	454.15	373.90	294.95	227.30	131.9

Previous Data
Filtered - Feedlot 2

Lab No		**Date**	**pH**	**EC** **dS/m**	**NH4-N** **mg/L**	**P** **mg/L**
94 2 180	1	7/12/1993	8.1	41.0	193	30
94 2 181	3	9/12/1993	7.2	10.9	162	62
94 2 182	6	12/12/1993	7.4	11.6	204	50
94 2 183	9	15/12/1993	7.5	12.1	199	50
94 2 184	11	17/12/1993	7.4	12.7	220	53
94 2 185	39	14/01/1994	7.5	13.9	195	47

Filtered - Feedlot 1

Lab No		**Date**	**pH**	**EC** **dS/m**	**NH4-N** **mg/L**	**P** **mg/L**
94 2 186	1	7/12/1993	7.8	13.1	759	9
94 2 187	3	9/12/1993	7.4	11.7	778	25
94 2 188	6	12/12/1993	7.5	11.2	757	20
94 2 189	9	15/12/1993	7.6	9.7	622	12
94 2 190	11	17/12/1993	7.7	12.1	816	13
94 2 191	39	14/01/1994	8.0	13.5	786	9

Filtered - Feedlot 3 (Pond 1)

Lab No		**Date**	**pH**	**EC** **dS/m**	**NH4-N** **mg/L**	**P** **mg/L**
94 2 196	3	9/12/1993	7.3	13.8	816	48
94 2 197	6	12/12/1993	7.5	13.7	456	31
94 2 198	9	15/12/1993	7.6	15.2	497	30
94 2 199	11	17/12/1993	7.7	15.1	510	27

Filtered - Feedlot 3 (Pond 2)

Lab No		**Date**	**pH**	**EC** **dS/m**	**NH4-N** **mg/L**	**P** **mg/L**
94 2 192	3	9/12/1993	7.5	14.7	469	38
94 2 193	6	12/12/1993	7.3	10.1	487	35
94 2 194	9	15/12/1993	7.6	13.7	750	26
94 2 195	11	17/12/1993	7.7	12.5	654	17
94 2 200	39	14/01/1994	8.2	16.9	463	16
94 2 201	39	14/01/1994	8.0	17.0	362	18

Unfiltered - Feedlot 2

Lab No		**Date**	**pH**	**EC** **dS/m**	**VS** **mg/L**	**SS** **mg/L**	**TKN** **mg/L**
94 2 180	1	7/12/1993	7.8	37.8	19000	10065	1095
94 2 181	3	9/12/1993	7.0	10.7	9200	7137	490
94 2 182	6	12/12/1993	7.1	11.4	8540	6503	425
94 2 183	9	15/12/1993	7.2	12.1	9000	6544	430
94 2 184	11	17/12/1993	7.2	12.5	6800	3942	440
94 2 185	39	14/01/1994	7.4	13.7	9000	5807	400

Unfiltered - Feedlot 1

Lab No		**Date**	**pH**	**EC** **dS/m**	**VS** **mg/L**	**SS** **mg/L**	**TKN** **mg/L**
94 2 186	1	7/12/1993	7.7	13.2	7000	1444	875
94 2 187	3	9/12/1993	7.2	12.0	8960	4766	930
94 2 188	6	12/12/1993	7.4	11.5	7660	3732	880
94 2 189	9	15/12/1993	7.5	10.2	7960	2396	745
94 2 190	11	17/12/1993	7.6	12.6	6240	1576	890
94 2 191	39	14/01/1994	7.8	13.9	3660	2183	860

Unfiltered - Feedlot 3 (Pond 1)

Lab No		**Date**	**pH**	**EC** **dS/m**	**VS** **mg/L**	**SS** **mg/L**	**TKN** **mg/L**
94 2 196	3	9/12/1993	7.0	14.6	9200	6127	1155
94 2 197	6	12/12/1993	7.2	14.5	7000	3990	795
94 2 198	9	15/12/1993	7.3	15.9	7160	4233	880
94 2 199	11	17/12/1993	7.5	16.2	6640	1888	880

Unfiltered - Feedlot 3 (Pond 2)

Lab No		**Date**	**pH**	**EC** **dS/m**	**VS** **mg/L**	**SS** **mg/L**	**TKN** **mg/L**
94 2 192	3	9/12/1993	7.2	14.8	7100	4118	865
94 2 193	6	12/12/1993	7.2	10.7	6220	1909	710
94 2 194	9	15/12/1993	7.4	14.2	7420	3475	940
94 2 195	11	17/12/1993	7.4	13.2	6680	3207	845
94 2 200	39	14/01/1994	7.9	18.5	5600	1160	730
94 2 201	39	14/01/1994	7.7	18.7	5500	1328	710

Figure D.8: Current Project and MRC Project – Effluent Data