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Irrigation Management Plan

Wellard Darwin Integrated Live Export Facility

Report Number 23919.82966



Prepared for



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Executive Summary

Wellard Rural Exports in Darwin have proposed an Integrated Livestock Export Facility (ILEF). Stage 1 of the facility will operate a 12,000 SCU¹ ("Peak") short term Pre Export Quarantine (PEQ) holding facility, and an average capacity of about 1,814 SCU.

The ILEF is characterised by several key land uses;

- (i) Large areas of roof;
- (ii) Large areas of open road and hard stand; and ancillary land uses;
- (iii) Open stock holding pen areas for the PEQ and small feedlot;
- (iv) Sedimentation basins and waste water holding ponds;
- (v) Irrigable area; and,
- (vi) Tail water capture system (grassed water ways, drains and pond)

The total irrigable area is about 40ha and is located on the upslope sections of the property on the northern and easternmost portions of the property. They lie behind 20-50m wide tree lines placed along the boundary.

Irrigation water is sourced from the ILEF wastewater storage ponds, the tail water storage ponds, and an on-site bore to meet expected water deficits.

Any tail water run-off from the irrigation area will be captured within the controlled drainage area, and then re-used on the irrigable areas.

It is proposed that frequent, moderate irrigation events will be undertaken so as to avoid excess leaching of nutrients to the environment. Irrigation of wastewater to the irrigation area will be at a rate of annual median amounts of 1ML/ha/year. About 1.1ML/ha/year (on average) of fresh water would be applied. Maximum rates would be 6ML/ha. Based on these irrigation rates there will be an average of 65 days of plant stress per year; due to the water deficit. Wellard will aim to increase recycled and fresh water supply to supplement the irrigation area.

The irrigation area has a nutrient deficit. The irrigation area will need fresh and recycled water and inorganic fertiliser to supplement plant requirements.

Soil investigations conclude a negative nutrient balance, provided the irrigation management measures are employed. There is potential for nutrients such as nitrogen to accumulate within the profile and pose a leaching risk, and this will be assessed regularly through agronomic and environmental monitoring.

¹ A standard Cattle Unit (SCU) is a 600kg steer or an equivalent number of animals with different weights

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1. Objectives of the Irrigation Management Plan

1.1 Potential Impacts

Potential impacts of Waste Water Irrigation are;

- Nutrient accumulation in soils
- Odour from wet weather storage or excessive applications of inadequately treated effluent
- Surface runoff resulting from over-application, irrigation during rain or poor site selection
- Impacts on groundwater underlying the irrigation site
- Salinity issues in vulnerable soils with inadequate leaching; and,
- Soil structural damage

1.2 Objectives

The objectives of the Irrigation Management Plan (IMP) are to;

- Protect Surface Waters;
- Protect Ground waters; and,
- Prevent destruction of soil quality (structure, chemistry and productive use).

1.3 Purpose

The purpose of the Irrigation Management Plan (IMP) is to ensure that irrigation applications do not result in

- (a) Excess runoff;
- (b) Excessive subsurface infiltration and acceleration of leaching of nutrients to the environment; and,
- (c) Maximisation of crop production and, consequently, maximisation of crop uptake of applied nutrient and water.

The plan addresses the following items:

- Water balance;
- Subsurface drainage;
- Nutrient balance; and,
- Irrigation strategy.

2. Location and Site Description

This Irrigation Management Plan refers to a proposed Integrated Live Export Facility (ILEF) site in Darwin, located on Lot 5544 Hundred of Strangways, 2658 Stuart Highway (Figure 1).

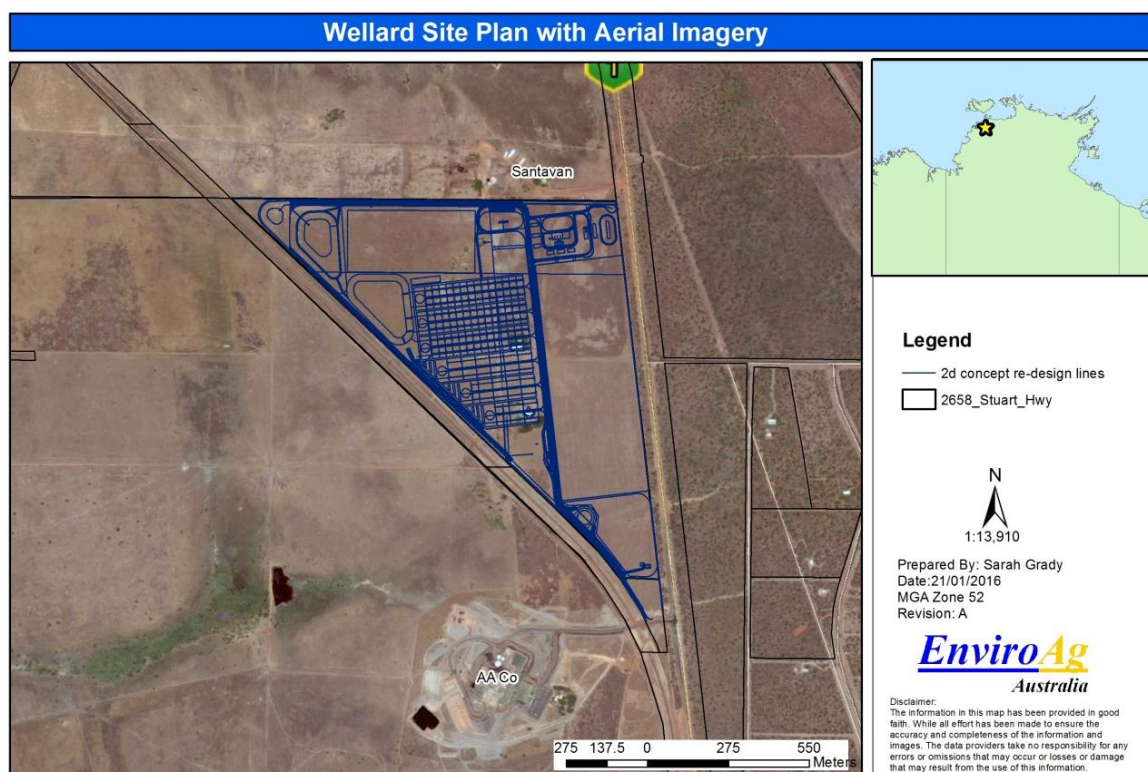


Figure 1 Wellard ILEF Site Plan (Full Development) with Aerial Image

2.1 Site Description

The site is located on the western side of a plateau. Its location is such that it is at the top of the foothill slope adjoining the plateau. Onsite water drains to the west. The site has no creeks and sits at the top of a watershed. The site does not flood.

The total irrigable area is approximately 40ha and comprises one location (300m by 800m) on the easternmost portion of the property (the upslope section of the property) and another location on the northern boundary (430m by 210m). The later will be irrigated using an automated low pressure poly lined lateral move irrigator with drop hoses. This system will have no spray effect, what so ever, onto the highway. The remaining irrigation area includes tree buffers along the boundaries and within the site. This area will be irrigated using drip irrigation.

The facility is located at 48m AHD (Australian Height Datum) while the Stuart Highway is at 54m AHD. There is little to no chance that any runoff will occur onto the Stuart Highway.

The site is approximately 1km from the nearest water course (Hardy Creek). Adjacent downslope properties have tributaries of Blackmore River - Berry Creek on AA Co. and Hardy Creek on Santavan respectively. Hardy Creek is a tributary of Berry Creek, which runs into Blackmore River (15km west from the site).

2.2 Description of the Development: Integrated Live Export Facility (ILEF)

The layout of the ILEF, including irrigable areas, is detailed in **Appendix A**. The ILEF is characterised by several key land uses;

- (i) Large areas of roof;

- (ii) Large areas of open road and hard stand; and ancillary land uses;
- (iii) Open stock holding pen areas for the PEQ and small feedlot;
- (iv) Sedimentation basins and waste water holding ponds;
- (v) Irrigable area; and,
- (vi) Tail water capture system (grassed water ways, drains and pond).

All potentially contaminated water generated from the ILEF (pens etc.) is diverted through a controlled drainage area (CDA), and will collect in a primary pond. This contaminated water is then pumped to a wet weather storage pond and further pumped and re-used in the irrigation of 40 ha of cropping area.

Any tail water run-off from the irrigation area will be captured by the CDA drainage network, and stored in the tail water storage pond. This water will be recycled in the irrigation areas, along with additional supplemented clean water from an on-site bore, and captured rainwater.

These design features reduce the potential environmental impacts of the ILEF substantially.

2.3 Management Practices

If not properly designed and managed this irrigation area could represent a source for nutrient with the potential to cause environmental harm to soil and water resources.

There are a number of key irrigation management measures which will be implemented to minimise the leaching of nutrients to the environment. These include;

- (i) Frequent, moderate irrigation applications to prevent over wetting of the soil;
- (ii) Implementation of a carefully monitored irrigation program with consideration of leaching fractions and associated loss of nutrients;
- (iii) Maintaining active plant growth;
- (iv) Recovery of nutrients by crop harvest; and,
- (v) Regular monitoring of weather, wastewater quality, physical and chemical properties of the soil, and regular inspection of piezometers in the irrigation areas.

This management plan makes recommendations on the management of the ILEF irrigable areas. It sets out some specific monitoring that is required to ensure it meets its objectives. Site specific operations and climatic criteria apply.

3. Land Utilisation of Wastewater by Irrigation: Review of Regulations and Guidelines

The sections below set out a brief overview of various State and industry guidelines. These are summarised in Table 1.

3.1 Queensland

The Queensland government has several guidelines for wastewater management. These are:

- Queensland Water Recycling Guidelines (2005); and,
- Water quality guidelines for recycled water schemes (2008).

For land irrigation of agricultural wastewater, the QLD Government recommends the National Beef Cattle Feedlot Guidelines and Environmental Code of Conduct (Meat and Livestock Australia (MLA), 2012).

3.2 NSW

The NSW Government relies on the following guidelines for the land utilisation of wastewaters by irrigation:

- Environmental Guidelines: Use of effluent by irrigation (2004); and,
- Strategic environmental compliance and performance review: effluent reuse management (2010).

These guidelines set out criteria for low, medium and high strength wastes and their storage and reuse. The guidelines are broad and provide a more holistic consideration of waste waters (other than sewage treatment plant waste waters).

3.3 Victoria

The Victorian Government relies on the following guidelines for the land utilisation of wastewaters by irrigation:

- Guidelines for wastewater irrigation (1991); and,
- Guidelines for Environmental Management: Use of reclaimed water (2003).

While the Guideline for Waste Water Irrigation is some 25 years old it remains fundamentally correct and is well applied over this period of time.

3.4 SA Guidelines

The South Australian guidelines have been cited by the NT Environmental Protection Authority (EPA) for consideration in the Environmental Impact Statement. The SA Acts and regulations that are notable are;

- Environment Protection Act (1993),
- Environment Protection (Water Quality) Policy (2003); and,
- Reclaimed Water guidelines, Treated Effluent, (1999).

They provide a detailed guideline of soil and effluent characteristics suitable for livestock effluent irrigation. These guidelines require a discussion on:

- Soil suitability or limitations for wastewater irrigation, and any soil treatment required to improve the soil;
- Limiting wastewater constituents for disposal to land, any pollutant reduction strategy or pre-treatment requirements, and the minimum land area required to remove the most limiting constituent;
- Hydraulic, organic, nutrient and salt mass balance calculations (kg/Ha/yr) that support the determination of limiting factors to crop growth, and long-term soil loadings;

- Suitable crops, including harvesting requirements to prevent pollutant accumulation in soil and crops;
- Sustainable application rate that maximises nutrient removal and water use efficiency;
- Suitable soil moisture monitoring system to schedule irrigation to crop moisture requirements;
- Appropriate irrigation system layout, controllers and other equipment required to differentiate irrigation application rates between soils of varying capabilities;
- The capacity of the wastewater storage to cope with a 1:10 wet year, and any additional storage capacity requirement to cope with a 1:10 Average Recurrence Indicator (ARI) storm of 20 minute duration falling on the catchment; and,
- Potential long-term impact of wastewater irrigation on soil structure or nutrient accumulation.

3.5 WA Guidelines

The Western Australian Government relies on the following guidelines for the land utilisation of wastewaters by irrigation:

- Environmental Protection Act (1986)
- Environmental Protection Regulations (1987);
- Environmental Protection (Abattoirs) Regulations (2001); and,
- Guidelines for the Environmental Management of Beef Cattle Feedlots in WA.

3.6 Northern Territory

The NT Government does not have specific regulations or guidelines for the management of wastewater and the application to land by irrigation and utilisation by crop growth and harvest.

3.7 National Feedlot Guidelines

National Beef Cattle Feedlot Environmental Code of Practice (MLA, 2012) set out in detail management practices for the operation of wastewater utilisation areas.

Notwithstanding these guidelines and their underlining principals, the most applicable guidelines for the proposed development of the ILEF are the National Guidelines for the beef cattle lot feeding industry (MLA, 2012).

3.8 Application of Guidelines

The NT EPA has in their “Statement of Reasons”/ Terms of Reference requested that the Environmental Assessment use the South Australian WIMP guidelines published by the South Australian Government. However, these guidelines are not very specific and do not have suggested values for soil chemical characteristics, rather it indicates what analysis need to be done. The Qld, NSW and Victorian regulations and guidelines provide useful guidance of appropriate waste water irrigation practices.

The National Water Management Strategy sets the scene for a National approach to effluent irrigation. The detail of policies, licensing and reporting requirements is carried out at the state level with each State having its own regulatory approach and set of minimum standards for effluent irrigation. Table 1 below provides a summary of the relevant state authorities, legislation, acts and guidelines for effluent irrigation.

Table 1 Summary of National and State Acts, regulations and Guidelines (AMPC, 2009)

STATE	RELEVANT AUTHORITY	LEGISLATION, ACTS & GUIDELINES	LICENCES & APPROVALS
National	Department of Environment & Heritage (DEH)	- National Water Quality Management Strategy Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000) - National Beef Cattle Feedlot Environmental Code of Practice	None
ACT	ACT Environmental Management Authority	- Environment Protect Act 1997 - Water Pollution Protection Policy (1999) - ACT Environment and Health Wastewater Reuse Guidelines (1997)	Environmental Protection Agreement
NSW	Department of Environment and Conservation(DEC) Environment Protection Authority (EPA)	- Protection of the Environment Operations Act 1997 - Protection of the Environment Operations (General) Regulation 1998 - Environmental Guidelines, Use of Effluent by Irrigation (2004) - Abattoir Industry Guidelines	Environmental Protection Agreement
NT	Department of Infrastructure, Planning & Development (No NT P and E) Office of Environment & Heritage (Now NT EPA)	- Waste Management & Pollution Control Act (2003) - Water Act (2004)	Environmental Protection Licence Best Practice License Waste Discharge License
QLD	Environmental Protection Agency (EPA)	- Environmental Protection Act 1994 - Draft Queensland Guidelines for the Safe Use of Recycled Water (2004) - The Establishment and Operation of Beef Cattle Feedlots (2000)	Registration Certificate Registered activities under Section 619 of the Act
SA	Department of Environment & Heritage Environmental Protection Authority (EPA)	- Environment Protection Act 1993 - Environment Protection (Water Quality) Policy 2003 - Reclaimed Water Guidelines, Treated Effluent, 1999	Licence required
TAS	Department of Primary Industries, Water & Environment (DPIWE)	- Environmental Management & Pollution Control Act 1994 - Environmental Guidelines for the use of Recycled Water in Tasmania (2002) - Wastewater Management Guidelines for Meat Premises and Pet Food Works	Environmental Agreement
VIC	Environment Protection Authority (EPA)	- Environment Protection Act 1970 - Environment Protection (Prescribed Waste) Regulations 1987 - Guidelines for Environmental Management: Use of Reclaimed Water (2002)	Licence or Permit required
WA	Department of Environment (DOE) (incorporates Dept Environment Protection and Water and Rivers Commission) Environmental Protection Authority	- Environmental Protection Act 1986 - Environmental Protection Regulations 1987 - Environmental Protection (Abattoirs) Regulations 2001 - Guidelines for the Environmental Management of Beef Cattle Feedlots in WA - Guidelines for the Environmental Management of Beef Cattle Feedlots in WA - Guidelines for the Environmental Management of Beef Cattle Feedlots in WA	Licence Approved Treated Waste Water Irrigation Management Plan

4. Modelling of Wastewater Applications

Various models exist for modelling wastewater application to land areas (for example MEDLI; Wasteload and others).

The models do not account for the following management practices and soil development and soil-crop interactions:

- Soil temperature and pH directly affect the availability of soil nutrients. Increasing soil pH will result in an increase in bound nutrients and a reduction in availability of some key macro nutrients that are of environmental concern (e.g. Phosphorus);
- Soil organic matter (SOM) holds both water and nutrients. In well managed wastewater irrigation systems general increases in SOM are observed. This holds nutrients in complexes reducing the likelihood that they will go into the soil water solution and be leached from the soil profile. The increase in SOM is achieved through soil health management focused on the same;
- Gypsum and lime applications to the soil increase the abundance of calcium. While calcium displaces hydrogen and sodium ions from exchange sites (clays, reactive silts and organic colloids) they also bind with ions such as phosphorus and sulphur to form calcium phosphate and gypsum in the soil. This process essentially builds the soil and removes nutrients from the exchangeable pool of nutrients; and,
- Where nutrients are abundant, crops will luxuriantly uptake nutrients at rates above those generally reported in the literature.

The above models are based on traditional assessments of “nutrient” deficit agronomy in subtropical, temperate or Mediterranean climates where soil nutrient availabilities are based on a lack of nutrient and crop uptake being limited by the same. None account for nutrient complexing, soil development (soil building) and luxuriant uptake; where applicable.

Some models are physically based and deterministic. None have been separately calibrated, and validated. This is a fundamental deficiency of all the models. It means that that no scientific reliability can be placed on them, and, at best, they can only be used for “decision support”.

No models exist for assessment of the application of wastewater to land for crop utilisation in tropical areas. Consequently, the models have been set aside as they are known to diverge from actual soil monitoring outcomes.

Given the above, the land capability assessment has focused on considering the hydraulic loading rates using standard irrigation modelling techniques and then the application of simple nutrient mass balances given potential additions, losses, storage and sorption of phosphorus. This approach has proven to be conservative and is considered most appropriate for the assessment.

5. Climate

The climate of the site is best described as wet tropical. It is warm to hot through the year. The site has a defined dry season and wet season. The site has relative constant day time maximum temperatures.

Detailed climatic data are available for Bureau of Meteorology Darwin Airport (AP) some 30km to the north. It has the longest and best quality data record in proximate to the site.

A Bureau of Meteorology (BoM) weather station is located at Berry Springs about 8 km from the site. Its data is similar to Darwin AP.

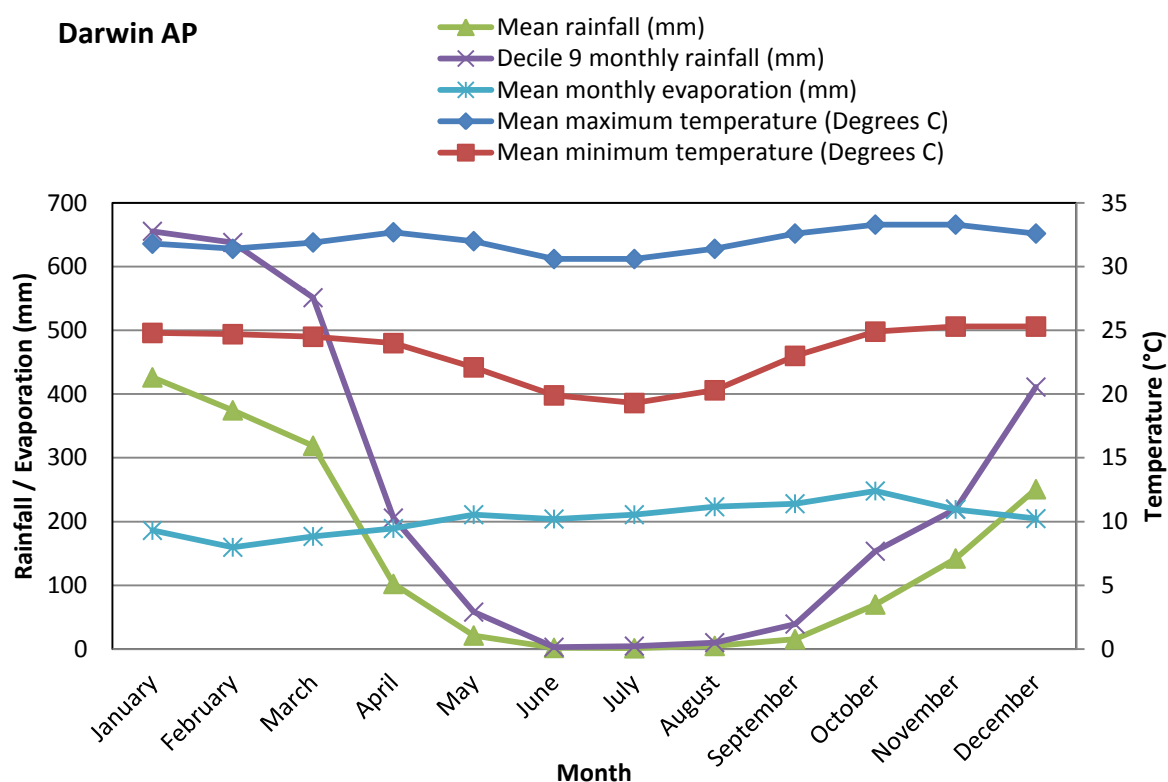


Figure 2 Graph of Temperature and Rainfall and Evaporation for Darwin AP

5.1 Temperature

Average temperature data are presented in Table 2; these show the low level of variation in temperatures. During winter minimums are as low as 15°C overnight.

Table 2 Monthly Average Temperatures for Berry Springs (~6km away) (1971-2013) (BoM, 2014)

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lowest	31.1	30.5	31.4	32.6	31.7	29.8	29.4	29.9	31.2	32.5	32.2	32.3
Highest	31.8	32.2	32.4	32.9	31.8	30.2	29.7	30.3	32.1	32.8	33.0	33.2

5.2 Rainfall

Rainfall data for Berry Springs are provided in Table 3. Most rain is received from October to April. The dry season is from May to September. It would be reasonable to expect an average rainfall of 1,800mm per year.

Table 3 Rainfall Data for Berry Springs (~6km away) (1971-2013) (BoM, 2014)

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	394.1	309.1	299.9	97.7	14.3	0.1	0.7	1.7	15.6	67.3	157.1	339.7	1779.9
Lowest	119.1	33.0	58.8	1.2	0.0	0.0	0.0	0.0	0.0	0.0	37.2	64.6	1156.1
5th %ile	235.1	73.2	71.9	17.1	0.0	0.0	0.0	0.0	0.0	6.7	46.9	70.4	1198.3
10th %ile	243.2	123.9	103.7	24.9	0.0	0.0	0.0	0.0	0.0	10.8	55.3	105.0	1283.0
Median	371.6	328.0	309.6	60.2	2.2	0.0	0.0	0.0	5.0	53.9	145.1	343.4	1807.5
90th %ile	554.5	449.4	480.5	160.3	30.9	0.0	0.0	6.1	43.1	142.9	240.2	541.9	2067.2
95th %ile	622.6	515.5	562.8	194.4	71.9	0.0	0.9	10.9	47.5	150.2	259.1	552.0	2169.8
Highest	797.6	534.8	814.4	675.3	85.2	1.6	14.8	15.2	92.7	179.5	367.6	630.0	2309.6

5.3 Evaporation

Evaporation data are collected at Darwin Airport. The annual average evaporation at Darwin is about 2460mm. Thus the site generally has a moisture deficit on an annualised basis of about 660mm. The greatest deficit occurs through the dry season; moisture surpluses occur in the wet season. The wind data from site is in Appendix B.

5.4 Moisture Deficit

The annual average rainfall for Berry Springs is 1807.5mm, and the annual average evaporation for Darwin is 2460mm. Thus the average moisture deficit at the site is in excess of 600 mm/year. This is equivalent to an annual average water deficit of 6ML/ha.

However this is misleading with regard to actual deficits applicable to the crop. While moisture surpluses occur over summer, every dry season has a significant deficit. The deficit over the dry season is the key variable in sustainable re-use of wastewater. The dry season moisture deficit is about 1375 mm (on average) (April to November).

6. Soil Characteristics

6.1 Overview

Fourteen soil tests were taken to assess the chemical characteristics in determining suitable qualities for irrigation and cropping. These details are described in the Appendices attached to the Environmental Impact Statement (EIS). Figures 3 and 4 show examples of the soil profiles in the eastern irrigable area.



Figure 3 Test Pit 1



Figure 4 Test Pit 2 Ferricrete (Iron precipitate formed Laterite) is visible at depths below 600-1000mm

In summary the investigations found that:

- The soils at the site were a yellow earth. This assessment applies the current and valid Northcote soil classification system. The Australian Soil Classification (Isbell, 2002) would consider the soil a Kandosol. This is consistent with the soil classifications mapped by the NT Government;
- Surface soils had a low CEC (organic matter and clay content), were well structured and permeable, and had a low nutrient (and especially) phosphorus content; and,
- Surface soils were not suitable for construction of water and wastewater storages, but did have some pasture and crop production capacity.

6.2 Agronomic Characteristics

In summary it is noted that:

- Conductivity levels are very low throughout the profile and indicate non-saline conditions.
- Soil pH is slightly acidic to neutral throughout the profile with pH ranging from 5.1 to 6.1. The soil will benefit from the application of lime and or gypsum.
- The cation exchange capacity of this soil is low, both in surface and subsoils except in Test Pit 3 at 0.15-0.35 m where a thin band of clayier material was found and sampled. This corroborates field soil texture assessments that identified silts and sands throughout the soil horizons.
- Organic carbon levels range from low to very low in surface and subsoils respectively with soil nitrate levels deficient throughout the soil profile. The soil will benefit significantly from the application of composted manures.
- Available nitrogen levels are extremely low, reducing through the profile.

- Colwell-P, a measure of plant-available phosphorus in soils, shows very low phosphorus levels at the surface of the soil which decreased with increasing soil depth. Calculations of plant available Phosphorus is not obtainable due to the insignificant results of Ortho P Cowell.
- The exchangeable sodium percentages of these soils are also low throughout the profile and provide no risk of soil dispersion. Surface soils exhibited high exchangeable calcium percentages in Test Pit 1 compared with Test Pit 2 and 3.

The soils indicate low fertility with very low cation exchange capacity in the surface soils. The soils are clearly well drained and while this will promote good plant growing conditions due to reductions in water logging, potential for leaching of nutrients to lower in the soil profile exists. Nutrients, when applied, need to be applied frequently in low amounts.

Organic matter contents need to be increased to assist in retention of soil moisture and nutrients. Composted manure can be utilised for this purpose.

The deepest soils with the greatest opportunity for rooting depth were found in the eastern ridge soils. These soils are currently used for improved pasture production. The large majority of the irrigable area has been apportioned to these soils.

Soils on the lower slope are not suitable for pasture and crop production due to their shallow depth.

6.3 Water Holding Capacity and Irrigation Frequency

Modelling of the moisture characteristics indicated that the water holding capacity of the soil is expected to be about 0.8mm/cm of soil or 0.08mm/mm (Hazleton and Murphy, 2007). Based on the soil texture of the soils in the proposed irrigation area and a root depth of about 0.9m the expected plant available water holding capacity is about 80mm/m of soil or 72mm in the 0.9m deep soil profile. The percentage of this water that will be available to the plant is expected to be about 50% given the relatively high sand and silt content of the soil (Burk and Dalgliesh, 2008). Thus the available water for a pasture or crop is expected to be about 36mm. Given irrigation efficiencies and potential need to completely wet the soil irrigation applications will be to a maximum of 50mm and more generally in 25mm applications.

The frequency of the irrigation events will be determined on the rate of uptake by the crop, evapotranspiration rates, and effective rainfall (minus run-off). These factors are discussed in greater detail through the report, and will need to be verified in the field through monitoring (e.g. piezometers in irrigation areas, rainfall records and water balances). If irrigation events are too frequent they are likely to cause infiltration rates that exceed the field capacity of the soil and as a consequence some water (and nutrients) will leach into the environment.

6.4 Capability of Soils for Irrigation

The soils are Kandosols. They deliver a useful soil to sustain irrigated agriculture. The wet season delivers a moisture surplus. This significant episodic event provides a leaching fraction.

The SALF program (Carlin and Truong, 1999) was used to assess the leaching fraction of the soil profile in the proposed irrigation area.

Parameters consistent with the soil profile as it is were used. Based on the model, the leaching fraction is estimated to be 11mm/yr on average. In the wettest month (Feb 2011) 38mm of deep drainage occurred. In an extreme wet year deep drainage may total up to 200mm/year.

The modelling shows that this will adequately remove deleterious salts (sodium) from the soil profile so that they do not accumulate. The expected soil water concentration of the salts is also very low and no salinity impacts are expected. These outcomes can be attributed to the well-drained nature of the soil, its silt and sand (and low clay content) and the high rainfall.

Given the leaching fraction; ongoing careful management of potential loss of nitrogen and phosphorus is important. This is best achieved by:

- Frequent moderate applications of irrigation;

- Maintaining an active plant growth;
- Maximising organic matter content to maximise nutrient holding capacity; and,
- Maximising nutrient recovery by crop harvest.

7. Crop Production

7.1 Crop Type

The proposed irrigation area is currently dominated by the summer topical grass, Jarra grass (*Digitaria milanijana* cv Jarra). This grass does not grow over the northern winter. It is critical that a crop is grown that grows through winter and summer and provides year round water demand and maximum dry matter production so that it can be harvested in dry breaks in the wet season (silage), as early as possible after the wet season for silage and hay, and then through the dry season as hay so it provides a dry fodder supply for the operations.

To achieve this it is proposed to use a grass / legume mix common in tropical and subtropical Queensland being a Setaria, Rhodes Grass and Siratro pasture mix; or similar. This provides an improved pasture of grass and legume that is extremely competitive, stoloniferous (a prostrate stem, that produces new plants from buds at its tips or nodes, thereby improving soil holding capability) and that takes up appreciable amounts of N, P, K and Sulfur (S).

Maintenance of the improved pastures by separating out undesirable grass species and resowing or oversowing of land areas with improved pasture seed will be required.

Where appropriate the additional introduction of hybrid forage species will be added to the pasture mix to increase dry matter production (forage sorghum / millets).

7.2 Dry Matter Production

The dry matter production from improved pastures in the irrigable area is anticipated to be 10-15T DM/ha/year as hay through multiple cuts.

With a total annual DM harvest of 15T/ha hay production will use about;

- 420 kg/ha of Nitrogen (N),
- 45 kg/ha of Phosphorus (P) and
- Over 450 kg/ha of Potassium (K) each year.

7.3 Crop Water Requirements

The annual average rainfall for Berry Springs is 1807.5mm. The annual average evaporation for Darwin is 2460mm. Thus the average moisture deficit at the site is in excess of 600 mm/year. This is equivalent to an annual average water deficit of 6ML/ha.

However this is misleading with regard to actual deficits applicable to the crop. While moisture surpluses occur over summer, every dry season has a significant deficit. The deficit over the dry season is the key variable in sustainable re-use of wastewater. The dry season moisture deficit is about 1375 mm (on average) (April to November).

Crop water use is proportionate to the evaporation and consequent transpiration of the environment. A Crop Factor is applied to the evaporation to determine a transpiration rate. The Crop Factor considers soil and climatic factors to accurately determine the transpiration rates in different conditions.

Given the soil type, selected cropping regime, and considering the climatic data, a crop factor of 0.9 has been applied for all months.

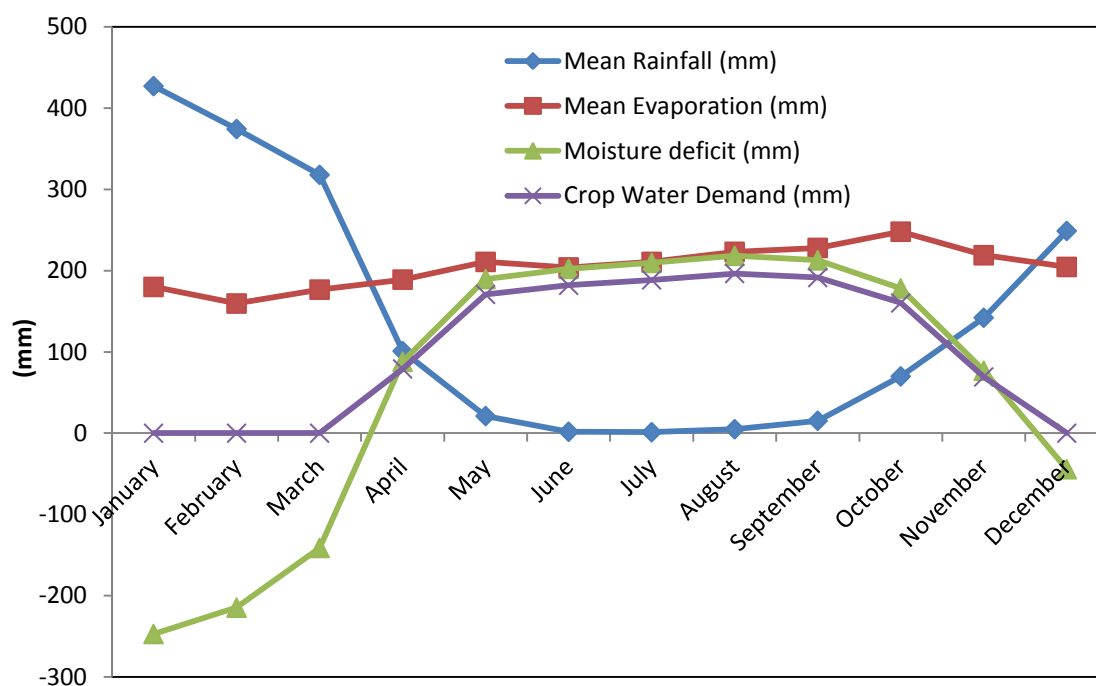


Figure 5 Crop Water Demand: Improved Pasture (Mixed)

Given crop factors for improved pasture, the expected irrigation demand is in the order of 10-12 ML/ha/ year; through the dry season.

Effective rainfall must also be taken into consideration when determining irrigation demand. While the wet season shows a moisture surplus, most of this surplus runs off. Between monsoonal rainfall events dry conditions do occur; these do create short term moisture deficits an analysis of daily rainfall through each month (wet days and likely runoff versus, dry days and crop evapotranspiration) shows that between 50-100mm of irrigation (on average) can be undertaken on an opportunity basis each month. Over the wet season it is expected that about 1-3 ML/ha on an opportunistic basis. Thus, a total water demand of some 11-15ML/ha can be expected.

The 36ML/yr of available waste when applied across 35ha (dedicated area) with an efficiency of 90% will supply only about 1ML of water per ha per year. This is not sufficient to meet the irrigation demand for an improved pasture. There is a critical moisture deficit in spring. It is proposed to use clean waters captured on site to supplement the irrigation in this period.

8. Irrigation

8.1 Irrigation System Design

Waste water will be captured and stored in the primary pond and the wet weather storage. This has been sized using a daily time step model using 126 years of climate data. The model has been calibrated and verified and is known to be reliable. It has been used to develop National and State guidelines.

The total irrigable area proposed is 40 ha. This includes the large irrigable area for fodder production and tree lines, and, garden areas. The dedicated irrigable area under lateral moves and treat lines is 35ha.

The irrigation water will be delivered by a pump station and pipeline. It has been formally designed and certified by registered engineers.

The application rate of the proposed lateral move irrigation systems is 5-25mm/day. The lateral move will be set up as a trunk irrigator to minimise aerosols and reduce the risk of odour emissions. Water will be applied either through a “trunk”, “sock” or “dripper”.



Figure 6 Example of “Trunk” or “Sock” Irrigation

Waste waters from septic systems (house, office, yard facilities) will be applied to gardens through drip irrigation systems.

8.2 Methods

Irrigation will be undertaken when a soil moisture deficit occurs. The water deficit will be established by direct measurements by the farm manager. Irrigation is low pressure irrigation by lateral moves with trunks or drip irrigation.

Irrigation will only be undertaken when rainfall is not imminent. Irrigation will not occur in the 4 days prior to crop harvest (hay cutting and bailing).

Tailwater will only be generated by rainfall runoff.

8.3 Wastewater Irrigable Irrigation

The Hydrological Assessment Report 23919.80836 shows that the annual average yield of wastewater from the facility is expected to be 36.2ML/year (annual average). The application in the wettest year in 10 years is expected to be 170ML/year. This is an extreme amount and is equivalent to about 4-5ML/ha. This would occur very infrequently.

The expected average nutrient content of the treated wastewater is shown in Table 4 below. It is, generally, considered to be a medium strength waste water (NSW Waste Water Irrigation Guidelines) as the biological oxygen demand will be below 1000mg/L.

Table 4 Expected Average Nutrient Content of Treated Wastewater

Attribute	pH	EC	TDS (%)	TN (mg/L)	TP (mg/L)	K (mg/L)	Na (mg/L)
Average	7.2	2000	0.1	150	15	300	100
Average Annual WW Generation (ML)				36.2			
Mass (kg/ha)	NA	NA	1,034 kg/ha	155.14	15.50	310	103.4
Losses in Wastewater (sludge)	NA	NA	50%	40-70% (50%)^	10-40 (10%)#	(10%)#	
(Wet Weather Storage) (kg/ha)				356.25	17.9	142.5	
Irrigation Application (kg/ha)	NA	NA	517	77.57	13.95	279	103.4

^ Volatilization (denitrification and evaporation)

Chemical precipitation and deposition in algae detritus (sludges)

8.4 Other Irrigation Water Supply

About 1.2ML/ha of fresh water will be applied to the irrigable area from return and re-use of tail waters. This amounts to about 38ML per year (on average).

The property has permits for 3 production bores of up to 15L/s. One bore has been established.

Groundwater for the site will be accessed from the production bore holes. One has been drilled in the North East corner of the property. This bore was drilled to 114m. It has standing water level of 6 m below ground level and flows of up to 5-7 litres per second. The well has screened off the upper aquifer that is used locally.

The available flow rate provides for up to 160ML at 5L/s through to 220ML/year at 7L/s. This will adequately supply stage 1 of the development and potentially stage 2; and some irrigation. If another production bore needs to be drilled it will be drilled to depth given that deep aquifers have been identified in the drilling program.

8.5 Deep Drainage

Waste water will be applied to the land area when there is a crop water deficit. It is mostly applied in the period April – October each year: the “dry season”. Fresh water will be applied to maintain crop growth when there is no waste water for irrigation. Fresh water can be applied together with the waste water as a shandy; if required.

Table 5 shows the data for the monthly SALF modelling results. The SALF modelling shows that the annual average deep drainage is only 11mm/ha/yr. Most occurs in the wet season; little occurs in the dry season associated with the irrigation.

Table 5 Monthly SLAF Modelling Results

Month	Av Monthly Rain + Irrigation (mm)	Leaching Fraction	Deep Drain (mm)	Avg EC _{SE} # #	WU W EC _{SE}	Crop	Potential Yield (%) Salinity Effect:
Jan	394.1	0.01	2.85	3.28	1.71	Rhodes grass-Pioneer	100
Feb	309.1	0.01	1.9	3.35	1.73	Rhodes grass-Pioneer	100
Mar	299.9	0.01	1.81	3.36	1.74	Rhodes grass-Pioneer	100
Apr	158.7	0	0.62	3.53	1.78	Rhodes grass-Pioneer	100
May	75.3	0	0.18	3.66	1.81	Rhodes grass-Pioneer	100
Jun	61.1	0	0.13	3.69	1.82	Rhodes grass-Pioneer	100
Jul	61.7	0	0.13	3.69	1.82	Rhodes grass-Pioneer	100
Aug	62.7	0	0.13	3.69	1.82	Rhodes grass-Pioneer	100
Sep	76.6	0	0.18	3.66	1.81	Rhodes grass-Pioneer	100
Oct	128.3	0	0.44	3.57	1.79	Rhodes grass-Pioneer	100
Nov	157.1	0	0.61	3.53	1.78	Rhodes grass-Pioneer	100
Dec	326.2	0.01	2.08	3.34	1.73	Rhodes grass-Pioneer	100
Total	2110.8	0.04	11.06				

Electrical conductivity saturated extract

The highest monthly rainfall on record for Darwin AP was 1110mm in February 2011. For extreme wet seasons such as this, deep drainage was predicted by SALF to exceed 35mm. The deep drainage is restricted by the clay layers in sub soil and the ferricrete at depth. These data show that in extreme wet seasons most water runs off.

8.6 Nutrient Budget

A nutrient budget is provided in Table 6 below. It shows the input and outputs for the proposed irrigation area, given the proposed wastewater application rate and the crop production from the area.

Expected wastewater constituents are expressed in Table 6 (per the Hydrological Assessment report 23919.80836). It is from these data that application rates can be calculated.

With the P sorption, evapotranspiration rates and the removal of nutrients through harvesting of the improved pasture for silage and hay, removal rates can be determined.

At the current rates of application and concentrations of wastewater, deficits are observed for water, Nitrogen and Phosphorous. For the pasture to be viable, additional water will need to be applied in conjunction with a fertiliser as the Phosphorous will be insufficient to supply the pasture.

Table 6 Annual Nutrient Budget (kg/ha/year)

	Total Solids kg/ha	N kg/ha	P kg/ha	K kg/ha	Na Kg/ha
Inputs					
Fertiliser (Urea N@46%N)	0	100	0	0	0
Wastewater	517	78	14	279	103
Manure (compost) ^(a)	20,000	200	60	500	60
Outputs					
Runoff ^(b)	500	10	5	>1000	>100
Loss from field ^(c)	5,000	300			
LF ^(d) (allowable)	0	5	0.1	~100	~200
Harvest	15,000	420	45	450	1.5
Phosphorus Sorption			100		
Change	17	-357	-76	-771	-138.50

(a) 20T DM/ha yearly;

(b) Annual average runoff will be >300mm/ha or 3ML/ha in wet season. Runoff will carry some organics containing some nutrient, and, will preferentially dissolve and carry dissolvable ions especially potassium and sodium (that dissolve readily);

(c) Loss from field; decomposition and respiration, and volatilisation / evaporation

(d) LF = Leaching Fraction. Av = 14mm/ha/yr. Quantities based on concentrations in ANZECC guideline values for waters.

The following assumptions were made in the preparation of Table 6:

- Runoff from the wastewater utilisation areas is to be captured in the tail water system; some of this will be returned to sustain the crop if insufficient wastewater is captured and available for irrigation; only the anticipated loss is included which mainly includes monovalent ions of K and Na that dissolve and are readily lost;
- Nitrogen fertiliser is applied to the wastewater utilisation areas to promote and sustain dry matter production; it is applied in spring when wastewater irrigation is expected to stop, and fresh water irrigation is to commence;
- Composted manure is applied based on agronomic advices and if a nutrient deficit exists;
- Harvest of pasture crops removes 15,000kg of dry matter per ha per year; and,
- The design life is 50 years (for exhaustion of P sorption in surface soils).

From Table 6 above it is concluded that:

- The application of wastewater to the wastewater utilisation areas will not result in excess nutrient availability;
- A fresh water supply will be required to support crop growth in spring; and,
- The health of the soil will be directly related to management of organic matter (to prevent a decline) and use of lime and gypsum to manage the cation exchange balance.

Annual soil monitoring will be undertaken check nutrient levels in the soil. The crop type and application rates can be adjusted accordingly.

8.7 Nutrient Management

The water available via the CDA catchment is not expected to be sufficient to meet the irrigation volume requirements of the irrigable areas. The water deficit will be met by use of rain, recycled water, tail waters, and some bore water.

The nutrient demand substantially exceeds the nutrient application from wastewaters and as such the irrigable area will require supplementing with composted manure or inorganic fertilisers. Degradation of land and the soils within the irrigable areas is not expected.

9. Irrigation Management and Monitoring

9.1 Environmental Risks of Improper Waste Water Irrigation

Improper management of the irrigation area could potentially result in:

- Contamination of surface water downslope causing, eutrophication, degradation of aquatic ecosystems;
- Generation of offensive odours;
- Contamination of groundwater aquifers, particularly during the wet season when groundwater levels are close to the surface;
- Degradation of the soils of the irrigation block (increased salinity, acidification, breakdown of soil structure);
- Altering the nutrient balance in the soils causing nutrient accumulation; and,
- Insufficient uptake of nutrients by the irrigated crops due to nutrient overload, insufficient water, waterlogging, salinity, sodicity, and soil degradation, or other factors affecting plant growth such as disease, pests, or toxic chemicals in the irrigation water.

9.2 Summary of Irrigation Design and Operations

The 36.2ML/yr of available waste water when applied across 35ha with an efficiency of 90% will supply only 1ML/ha/yr. This is not sufficient to meet the total water demand of 11-15ML/ha/yr for an improved pasture. There is a critical moisture deficit in spring. It is proposed to use clean waters captured on site to supplement the irrigation in this period.

The application rate of the proposed lateral move irrigation systems is 5-25mm/day. The lateral moves will be set up as a trunk irrigator to eliminate aerosols and reduce the risk of odour emissions. A lime dosing systems is available for dosing of waste waters to eliminate any odour if any is observed. Any odour generation from waste water irrigation is expected to be unlikely.

At the current rates of application and concentrations of wastewater, over a year, deficits are observed for water, Nitrogen and Phosphorous. For the pasture to be viable, additional water will need to be applied in conjunction with a fertiliser as the Phosphorous will be insufficient to supply the pasture.

- Provided the irrigation management measures are complied with, the application of wastewater to the wastewater utilisation areas should not result in excess nutrient availability;
- The nutrient budget is calculated over a timeframe of a year. Mixing rates of waste water and supplement water will need to be determined to ensure that the immediate crop nutrient demand is not exceeded.
- A water supply will be required to support crop growth in spring; and,
- The health of the soil will be directly related to management of organic matter (to prevent a decline) and use of lime and gypsum to manage the cation exchange balance.

9.3 Protect Surface Waters

The amenable topography (uniform gentle slope) and design of the ILEF irrigable areas (low pressure drip) are contributing factors to minimise the potential for surface water impact. Further;

- The site has no creeks and sits at the top of a watershed;
- Vegetation buffer along roadside;
- The site does not flood and,
- The site has a comprehensive tailwater system.

The soils on site are well structured in the top soil and permeable. They are unsuitable for construction but suitable for pasture and crop production. Due to the soil permeability, management of irrigation applications and amount is crucial to safe utilisation of waste water. The key monitoring variables are;

- Maintaining an active plant growth; and,
- Application rate and timing of irrigation.

By monitoring these variables it will ensure that no excess water is flowing into the surrounding areas and creeks, eliminating any impact on surrounding creeks and river tributaries.

9.4 Protection of Groundwater

The soils are nutrient poor and have a high permeability, both factors which increase the potential for nutrients leaching into the soil and water. Given the leaching fraction; ongoing careful management of potential loss of nitrogen and phosphorus is important. This is best achieved by:

- Maximising organic matter content to maximise nutrient holding capacity; and,
- Maximising nutrient recovery by crop harvest.

By monitoring these variables it will ensure that the nutrient balance and structure in soils are maintained; no issues arise on the facility or surrounding land and no impacts on groundwater underlying the irrigation site and surrounding land.

9.5 Soil Management

Each year soils will be tested for physical and chemical attributes. The resultant data will be used to build a sustainable crop program and adjust the nutrient management.

Soil condition will be managed by applying the following;

- (i) Minimising traffic across the paddock to minimise / reduce compaction
- (ii) Traffic the paddock when soils are as dry as possible
- (iii) Use low bearing pressure equipment
- (iv) Alleviate compaction by aeration and ripping; if required.
- (v) Applying composted manure and gypsum and lime to improve soil conditions.

9.6 Monitoring

Key irrigation management features will include careful management of an irrigation program with consideration of the leaching fraction and potential loss of nitrogen and phosphorus offsite. This is best achieved by:

- Daily weather conditions on site;
- Frequent moderate applications of irrigation;
 - The actual frequency of the irrigation events will be determined on the rate of uptake by the crop, evapotranspiration rates, and effective rainfall.
 - It is estimated that irrigation applications will be to a maximum of 50mm and more generally in 25mm applications. Groundwater will be closely monitored via a piezometer in each irrigation area. This will be conducted on a monthly basis for the first year, and then an assessment for further analysis will be undertaken based on the initial results.
- Nutrients, when applied, will be applied frequently in low amounts;
 - Given the leaching fraction; ongoing careful management of potential loss of nitrogen and phosphorus is important.
 - The physical and chemical properties (including soil nutrients) will be closely monitored via regular agronomic tests (annually), to adjust nutrient application rates.

- The quality of wastewater applied to the irrigation block (nutrients, salts, etc.) will also be monitored (annually).
- Maintenance of a site water balance, including harvested water and water applied to the irrigation area. This will include a record of incoming water (stored rain water, stored waste water, stored tail water) and outgoing irrigated water (irrigated rain water, irrigated bore water, irrigated waste water, irrigated tail water).
- Groundwater will be monitored through the installation of 1 piezometer above the irrigable area, 2 piezometers within the irrigable area and at least two below the site.
- Maintaining an active plant growth and dominance of improved pastures;
 - Dry matter production from improved pastures is anticipated to be 10-15T DM/ha/year as hay through multiple cuts. This will use about 420kg/ha/yr of nitrogen (N), 45 kg/ha/yr of phosphorus (P), over 450 kg/ha/yr of potassium (K).
- Maintenance of improved pastures;
- Maximising organic matter content to maximise soil moisture and nutrient holding capacity;
- Maximising nutrient recovery by crop harvest;
- Planting of fast growing tree species on northern and eastern boundaries of the ILEF as an additional buffer for water uptake;
- Compliance with the Solid and Liquid Waste Management Plan 23919.80251; and,
- Compliance with the Soil Survey and Land Capability Assessment Report 23870.77886.

10. Incidents and Reporting

Incidents/Compliance Failures	Any non-compliance, complaints or incidents will be dealt with as described in the EMP section 2.3, 2.4 and 2.5, respectively.
Environmental Emergency (e.g. water/ soil contamination)	In the case of environmental pollution, the ILEF Manager will decide whether the NT EPA needs to be notified based on the extent of the environmental harm (see <i>Waste Management and Pollution Control Act</i> for the types of emergencies that are notifiable). • Ensure that site and personnel are safe • Notify supervisor and ILEF Manager • Dial 000, if required • IF SAFE TO DO SO, prevent any further pollution from occurring • ILEF Manager must inform the NT EPA within 24 hours of becoming aware of the incident by calling their Pollution Hotline 1800 064 567. An incident report form must then be completed to ensure that the incident can be reviewed, followed by a corrective action report.
Corrective Action	The ILEF manager will ensure that corrective actions are taken within an appropriate time frame to ensure that this management plan is adhered to in future.
Reporting	The ILEF Manager will document details of all non-conformances, incidents, corrective actions and complaints. Where an incident causes, or is threatening to or may threaten to cause, environmental nuisance or pollution resulting in material or serious environmental harm, EPA must be informed within 24 hours of first becoming aware of the incident as per the requirements of the <i>Waste Management and Pollution Control Act</i>. This Surface Water Management Plan will be reviewed as required, and in accordance with the audit schedule of the Environmental Management Plan.
Relevant legislation, standards and guidelines	Water Act (NT) Waste Management and Pollution Control Act (NT)

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12. Appendices

Appendix A.	Site Plan	A-1
Appendix B.	Wind Roses	B-1

Appendix A. Site Plan

Appendix B. Wind Roses

Rose of Wind direction versus Wind speed in km/h (01 Jan 1942 to 30 Sep 2010)

Custom times selected, refer to attached note for details

DARWIN AIRPORT

Site No: 014015 • Opened Jan 1941 • Still Open • Latitude: -12.4239° • Longitude: 130.8925° • Elevation 30.m

