Soil quality monitoring and management

Report 2 – Irrigation
(Activities from 1 April to 30 June 2013)

Tiedman Irrigation Trial

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for AGL Upstream Investments Pty Ltd

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Attachments

Executive Summary

This is Compliance Report 2 of a series of four (4) reports that will be undertaken during the Tiedman Irrigation Trial and covers the baseline soils analysis, subsequent soil improvement and re-testing of those soils, establishment of all data collection and monitoring equipment and establishment of the crops to be irrigated. This report covers the period from 1st April 2013 to 30th June 2013, although there were some irrigation activities in late 2012 which are also reported here..

This report and subsequent reports (Reports 3 and 4) will provide further information on the effect of irrigated blended water on the natural and improved soils over the period of the irrigation trial. These reports are submitted in compliance with the approved Soil Quality Monitoring and Management Program.

The Tiedman Irrigation Trial (trial) is being carried out across two areas within the AGL Tiedman property known as Stage 1A and Stage 1B.

The Stage 1A trial is the major focus of the approved Soil Quality Monitoring and Management Program. There has been extensive sampling and analysis of the quality of the parent and treated soils. This area is being intensively monitored for soil, water and crop performance.

The Stage 1A trial area is 12 hectares in size and is made up of 16 equal sized plots, 0.74 hectares in size, where two crop systems (annuals and perennials) and four soil treatment types have been installed. These are being monitored and analysed to establish an optimum design for any blended water irrigation scheme adopted under the Extracted Water Management Plan (EWMP) for the Gloucester Gas Project (GGP).

In relation to the Stage 1A trial area, this report sets out:

- the trial plot layout, crop selection and planting;
- the mass balance results for the reporting period;
- the performance of soils on the Stage 1A irrigation area;
- the performance of soils on the Stage 1B irrigation area;
- the performance of the sedimentation, runoff and erosion control measures; and
- the critical control points and any necessary responses.

The Stage 1B trial area is approximately 40 hectares of which around 10 to 20 hectares may be irrigated during the trial. The main irrigation area for the next 18 months is made up of 4 plots that total approximately 4 hectares.

Limited amounts of blended water were applied to the trial plots during the period due to low crop water demand caused by cool temperatures and a comparatively wet June. Blended water with a salinity of 1380µS/cm was applied to Stage 1A (4.66 megalitres) and Stage 1B (1.72 megalitres) during the period. During the same period some 24.7 ML of rain occurred across the Stage 1A area and 8.45 ML on the Stage 1B area.

In total, the majority (84%) of the water received by the Stage 1A trial area fell as rain, while the balance (16%) was applied by irrigation.

In late 2012, a volume of 14.5 ML of the lowest salinity produced water stored in the Tiedman South dam was applied across the Stage 1B area to create ‘air space’ in the produced water storage dams for blending.

There was no salinity impact on soils in ether the Stage 1A or Stage 1B areas during this initial irrigation period and consequently the effect of this blended water quality on the receiving soils is considered to be negligible.

1. Introduction

AGL Upstream Investments Pty Ltd (AGL) engaged Fodder King Ltd (FK) to provide technical advisory services (including soil investigations and the preparation of compliance reports) associated with the Tiedmans irrigation trial. The irrigation trial involves two main irrigation areas (the Stage 1A and Stage 1B areas). This report is the second compliance report for the irrigation program being the assessment of soils after the soil treatments, establishment of crops within the Stage 1A area and after the commencement of irrigation of blended water. The report covers the period from 1 April to 30 June 2013 and also describes the soil conditions within the Stage 1B irrigation area. The two primary irrigation areas are shown in Figure 1.

The Stage 1A area is the major focus of the Soil Quality Monitoring and Management Program (SQMMP). This area is undergoing intensive monitoring of soil, water and crops, and application (after blending) of most of the produced water for irrigation. The Stage 1A area is about 22 hectares (ha) in total, of which 12 ha is being irrigated. Crop types are lucerne, forage sorghum, triticale and oats. It is expected that between 100 and 180 megalitres (ML) of blended water will be irrigated across this area during the trial period.

The Stage 1B area is where the lower salinity water in the produced water storage dams was irrigated in late 2012. Some additional irrigation using blended water will occur for the balance of the trial period on a smaller 4.1ha area within the Stage 1B area. The Stage 1B area is approximately 40ha, of which around 10-20 ha of pasture is planned to be irrigated. Individual areas are expected to be rotated with the main pasture types to be grown to include a mix of annual and perennial species.

There is an additional approved irrigation area (the Stage 2 area) which is approximately 15ha. This area was not irrigated during the reporting period and will only be used if irrigation application rates on the Stage 1A and Stage 1B areas are less than anticipated.

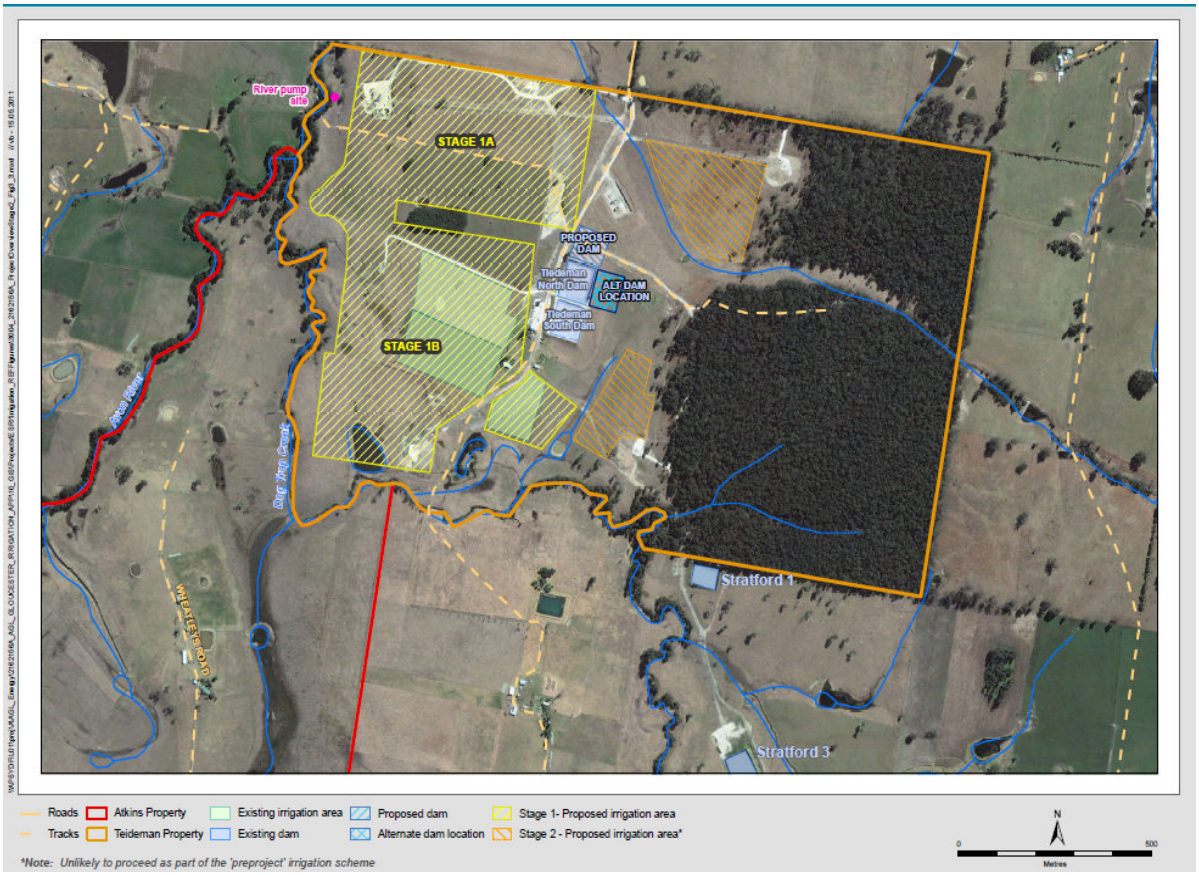


Figure 1: Gloucester Irrigation Areas for Exploration Produced Water

The Stage 1A, Stage 1B and Stage 2 irrigation areas are all located off the floodplain of the Avon River. The irrigation trial was approved in July 2012 after the Tiedman Irrigation Trial REF (PB, 2011) and supplementary documents were submitted to NSW Trade and Investment (Division of Resources and Energy (DRE)) during 2011/12.

1.1. Requirements under the Soil Quality Monitoring and Management Program.

The Soil Quality Monitoring and Management Program (SQMMP) was approved by DRE in October 2012 for the two irrigation areas and for the irrigation of up to 70 ML of produced water across an area of up to 40 ha.

Overall objectives

The overall objectives of the SQMMP are to:

a) Develop and monitor the performance of soils on the irrigation area against baseline soil quality parameters;
b) Develop, manage and monitor the water and salt balance; and
c) Monitor, act and report on any adverse trends or impacts on soil structure and quality parameters.

Stage 1A objectives

The objectives of the Stage 1A Irrigation Trial are to:

a) Derive information about the use of blended water on improved soils in order to optimise the beneficial use of produced water. This trial will provide support data for the preparation of the main Extracted Water Management Plan (EWMP) for the Gloucester Gas Project;
b) Provide information to optimise the design of a water treatment and storage system to match the beneficial re-use system; and
c) In order to minimise the overall 'footprint' of the project on the surrounding landscape, the trial is aiming to achieve blended water application rates in the range of 3-5 megalitres/hectare/year.

Stage 1B objectives

The objectives of the Stage 1B area are to:

a) Allow for the irrigation of the lowest salinity produced water stored in the holding dams to provide improved pasture for stock grazing across the property (which is the traditional land use);
b) Provide additional irrigated land area (to the intensive Stage 1A area) in the early stages of irrigation so that "air space" can be provided in the holding dams for the blending of the more brackish produced water that is in storage.

1.2. Stage 1A Irrigation Trial description

In brief, the Stage 1A Irrigation Trial involves the addition and mixing of ameliorants with the parent soils, the application of blended water (CSG water and fresh water) to those soils with the aid of an accurate irrigation system, the regular sampling and testing of the soils, the regular analysis of mass and water balances, analysis of results and reporting on the results.

The main activities are outlined as follows:

Baseline 1 soil study

Carry out a comprehensive baseline soil study to ascertain the characteristics of the parent soils in the trial irrigation area. This data was collected and reported as part of the irrigation trial design during 2011 (FK, 2011).

Baseline 2 soil study

On completion of the soil amelioration, repeat the soil sampling and analysis to ascertain the baseline characteristics of the treated soil prior to irrigation.

Compliance Report 1 (FK (2013) *Soil quality monitoring and management, Report 1- Pre irrigation (Activities to 31 March 2013),* covered the site soil investigations up to and including the Baseline 2 soil study and prior to the commencement of irrigation of the Stage 1A area.

Baseline 3 soil study

On completion of irrigation of blended water during the reporting period (1st April 2013 to 30th June 2013), repeat the soil sampling and analysis to ascertain the characteristics of the treated soil and assess any trends.

Compliance Report 2 (this report), covers the site soil investigation carried out at the end of the reporting period.

Perched water piezometers

Paired piezometers to monitor the potential for the development of perched water zones have been installed inside and immediately outside (ie downgradient) of each of the soil treatment types. Details are provided in FK (2013) *Soil quality monitoring and management, Report 1- Pre irrigation (Activities to 31 March 2013.*

Irrigation Trial

Carry out the irrigation trial, including installation of all soil moisture monitoring equipment.

Carry out monitoring and data gathering

Undertake all detailed monitoring and data gathering, including regular soil sampling and testing, and provide 6 monthly reports to NSW Trade and Investment (Division of Resources and Energy [DRE]) in accordance with REF approval conditions 3 and 6.

Compliance Report 3 will be carried out after the soil sampling and testing in November/December 2013. On completion of the trial in mid 2014, comprehensive soil sampling and testing will be undertaken (similar to the FK baseline study done in 2011) to establish the effect of irrigation on the ameliorated soil, prior to submission of a final report (Compliance Report 4) to DRE.

1.3. Soil quality monitoring and management program requirements

In order to manage the ameliorated soils during the Stage 1A irrigation trial, a number of soil quality attributes are being monitored. These include water balance, salt balance, nutrient balance, carbon balance and soil structure. Crop yield, crop persistence and crop health will also be monitored.

Water balance

The water balance provides the framework for tracking inputs to calculate salt, nutrient and carbon balances in the receiving soil and for detecting trigger points to prevent adverse impacts on soil quality. The water balance will be based on the *Environmental Guidelines: Use of Effluent by Irrigation (DECC, 2004).*

The aim of irrigation management during the trial is to maintain a soil moisture deficit within the optimal soil moisture range for crop growth which is between wilting point and field capacity. Soil moisture will be continually monitored to track soil moisture patterns (surplus or deficit) due to both rainfall and irrigation. Irrigation was only applied when there was both a daily irrigation deficit and a soil moisture deficit (with respect to soil field capacity). The AGL on-site weather station data and available rainfall forecasts are used to guide the applied irrigation water and to monitor the water balance.

Salt, nutrient and carbon balances

The salt (sodium), nutrient (nitrogen and phosphorous) and soil carbon (Total C) balances are determined during the Stage 1A Trial Irrigation Program. Monitoring and analysis of blended CSG water applied, soil chemistry and soil-water allow the determination of inputs and outputs, and

sources and sinks, to interpret mass balance processes and the management implications for short and long-term irrigation.

Soil structure

Apart from the physical causes of soil erosion, such as loss of groundcover, key soil chemistry parameters such as soil pH, Cation Exchange Capacity (CEC) and the soil Exchangeable Sodium Percentage (ESP) indicate the potential for loss of soil structure when irrigated with waters of a given electrolyte concentration. The relationship between ESP, the Sodium Adsorption Ratio (SAR) of permeating soil water, and the potential impact on soil structure is summarised in the *Environmental Guidelines: Use of Effluent by Irrigation* (DECC, 2004), and detailed in Lucas (2009).

Crop growth, persistence and health

Crop growth is determined from measuring dry matter yield after harvest over successive cropping cycles. An important aspect of the trial was to establish ground cover as quickly as possible after installation to minimise the risk of erosion of bare ameliorated soil. During the reporting period the improved soil enabled rapid establishment of crops after seeding.

Crop persistence is measured by plant counts and monitored at regular intervals and crop health is measured by leaf tissue analysis and monitored at regular intervals.

No harvesting activities occurred during this initial irrigation and reporting period.

1.4. Stage 1B irrigation trial description

The principal use of the Stage 1B area is to:

i. Initially directly irrigate the lower salinity produced water in the Tiedman South dam so as to create freeboard in the dam for blending of the larger volumes of produced water. Relatively minor volumes of produced water (up to 20 ML over the whole period of irrigation) are expected to be irrigated across the Stage 1B area.

ii. As part of the trial, establish some shallow rooted pasture species on a 4.1 ha area to evaluate irrigation application rates and irrigability of these traditional pastures in comparison with the more salt tolerant and deeper rooted crops that are established in the Stage 1A area. Blended irrigation water is to be used for this part of the trial.

In the period from October to December 2012, approximately 14.5 ML of produced water was irrigated across the Stage 1B area to grow improved pasture. This water was taken from the Tiedman South dam and applied using a small travelling irrigator. The salinity of the irrigated water was approximately 2700 µS/cm. This reuse of approximately 75% of the 'fresher' produced water stored in the southern dam has created sufficient 'air space' for blending of the remaining higher salinity produced water with fresh water sources.

The Stage 1B improved pasture/grazing area is currently being managed by a lessee. The lessee is using rotational grazing as a method to finish his EU accredited cattle prior to slaughter. There are 12-14 head of cattle on this area at any one time. MNC Agronomy (independent agronomist) has calculated the carrying capacity has been increased by 400% since pasture improvement of this area.

2. Trial layout, crop selection and planting

2.1. Stage 1A irrigation area

2.1.1. Trial layout

The Stage 1A trial irrigation layout was designed to ensure minimum buffer distances from the Avon River (40m), boundaries (10m), power lines (15m) and a copse of trees (10m).

This created an irrigable area of 587m (oriented east-west) and 322m (oriented north-south). From within this area the final trial irrigation area was selected to satisfy the following trial requirements:

- Four soil treatments;
- Two crop systems (annuals and perennial);
- An individual plot size that could accommodate the typical range of agricultural operations;
- Irrigated by a low pressure overhead spray linear irrigator, creating a rectangular shaped irrigation zone with a central road for the linear cart to traverse; and
- The need to have a trial area as close as possible to final scale.

This resulted in a trial plot area measuring approximately 395 metres from east to west and 313 metres from north to south. See Attachment 1.

There are 16 equal-sized trial plots. Each individual trial plot is approximately 0.75 hectares in size, measuring 47.85 metres by 156.62 metres. This size enables most agricultural equipment to operate within the plot.

Factoring in non-productive crop areas taken up by bund walls the 'green' crop area is 0.73 hectares (46.85m x 155.62m).

Due to the selection of a centre feed linear move irrigator as the method for applying irrigation water, each treatment and crop combinaton was split evenly on either side of the centreline of the linear irrigator, resulting in 8 plots (Plots 1-8) under the northern leg of the irrigator and 8 plots (Plots 9-16) under the southern leg of the irrigator.

This accommodated the need for 2 crop types and 4 treatment depths on either side of the cart track.

2.1.2. Crop selection

Due to the expected year-round flow characteristics of produced water, perennials and annuals are being trialled to develop crop combinations that will maximise the utilisation of water. Further details regarding this strategy are included in FK (2011) *Preliminary Investigations and Design of an Irrigation Trial on land in the Gloucester Basin for irrigation of CSG water*.

The crop types being trialled for the 18 month trial are:

- Perennials (lucerne) – 8 plots x 4 treatment depths
- Annuals - 8 plots x 4 treatment depths
    - winter forage cereals, eg oats, barley, triticale
    - followed by summer forages, eg millet, forage sorghum

The winter annual chosen for the period April to October 2013 was triticale.

2.1.3. Planting

The Stage 1A crops and varieties were planted as follows:

- Triticale
  - Planted - 27/03/2013
  - Variety – "Monstress"
  - Seeding rate - 120kg/ha
- Lucerne
  - Planted - 12/04/2013
  - Variety – "L91"
  - Seeding rate - 20kg/ha.

2.1.4. Crop performance since planting

Triticale is a winter active crop and developed quickly during the transition to winter. A satisfactory crop density had been established by the end of the reporting period.

Lucerne is a winter dormant crop so, as expected, crop establishment was much slower than the triticale. However all plots had germinated and had reasonable coverage at the end of the reporting period.

2.2. Stage 1B irrigation area

The Stage 1B trial plots are located just to the south of the Stage 1A trial plots and are sized and named as follows:

- AL1 – 0.97 hectares
- AL2 – 0.89 hectares
- AL3 – 1.13 hectares
- AL4 – 1.10 hectares

The layout of this area is provided in Attachment 2.

2.2.1. Crop selection

The crop type chosen for this area is a pasture mix (71% Ryegrass, 20% Clover, 9% Chicory) which is the same for all 4 plots. There is no deep soil treatment across any of these four plots

2.2.2. Planting

The pasture mix varieties were planted on 28/03/2013 at a combined rate of 35kg/ha:

- Ryegrass
  - Planted – 28/03/2013
  - Variety – "Knight"
  - Seeding rate – 25kg/ha
- Clover
  - Planted – 28/03/2013
  - Variety – "USA Red Clover"
  - Seeding rate – 7kg/ha
- Chicory
  - Planted – 28/03/2013
  - Variety – "Punter"
  - Seeding rate – 3kg/ha

2.2.3. Crop performance since planting

As they are winter active, the varieties selected developed quickly during the transition to winter. A satisfactory crop density had been established by the end of the reporting period.

3. Mass balance results for the period

3.1. Average rainfall patterns

The trial irrigation site lies within a relatively high rainfall zone, with a mean rainfall of approximately 983 millimetres (mm). The rainfall pattern is slightly summer-dominant with 56% occuring between November and March and 44% occurring between April and October. As a result the consideration of rainfall is a significant factor in determining the timing of when irrigation will be undertaken.

3.2. Rainfall and Evapotranspiration

Figure 3.1 summarises rainfall and evapotranspiration (ETo) between the 1st April – 30th June 2013. Over 200 mm of rain occurred during the period and coupled with the relatively low winter ETo there were minimal windows of opportunity for irrigation. This rainfall across the total plot area of 12 ha is equivalent to 24.7 ML.

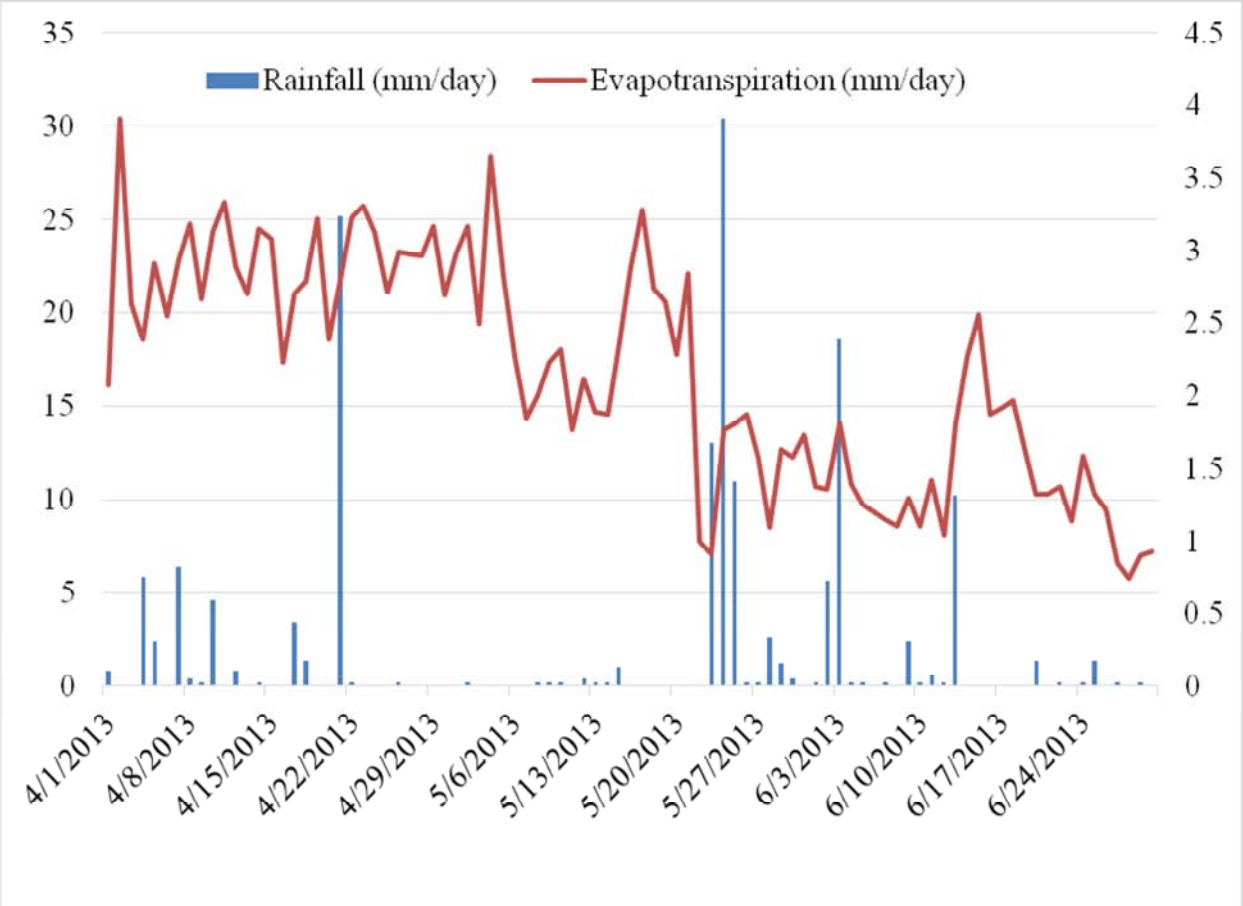


Figure 3.1: Rainfall (left y-axis) and Evapotranspiration (right y-axis) for the Period (1st April – 30th June 2013)

There is no evapotranspiration (see explanation in FK, 2011) data specific to the site so this will be interpolated from regionally available data through the *iWater* service.

During the reporting period 16% of the water received by the trial area came from blended water while 84% came from rainfall. See Table 3.1.

Table 3.1 Rainfall and irrigation for the period – Stage 1A

Units	Rainfall for the period	Irrigation for the period	Total
Mm	205.8	39.0	244.8
Megalitres	24.7	4.66	29.36
%	84	16	100

3.3. Irrigation scheduling and water balance

3.3.1. Stage 1A

The water balance was based on *Environmental Guidelines: Use of Effluent for Irrigation (DECC, 2004)*:
Applied CSG water (Qcsg) + Rainfall (Qr) ≤ Evapotranspiration (ET) + Percolation (P) + Runoff (R) + Interception Loss (IL), where R designed to be zero, therefore the daily water balance is:

- Qcsg ≤ ET + P + IL – Qr
- Daily Irrigation Deficit (DID) = ET + P + IL – (Qr + Qcsg)

Negative values mean irrigation should not be applied.

The cumulative DID (over 6 day periods) was used in conjunction with real-time soil moisture to determine if irrigation was possible at a given time. For example, a 25 mm rainfall event may offset 6 days (or more) of low ETo, and if the rainfall event saturates the soil, then irrigation does not occur.

Figure 3.2 summarises the Daily Irrigation Deficit (DID), cumulative DID (6-day) and applied Irrigation of blended CSG water (1st April – 30th June 2013)

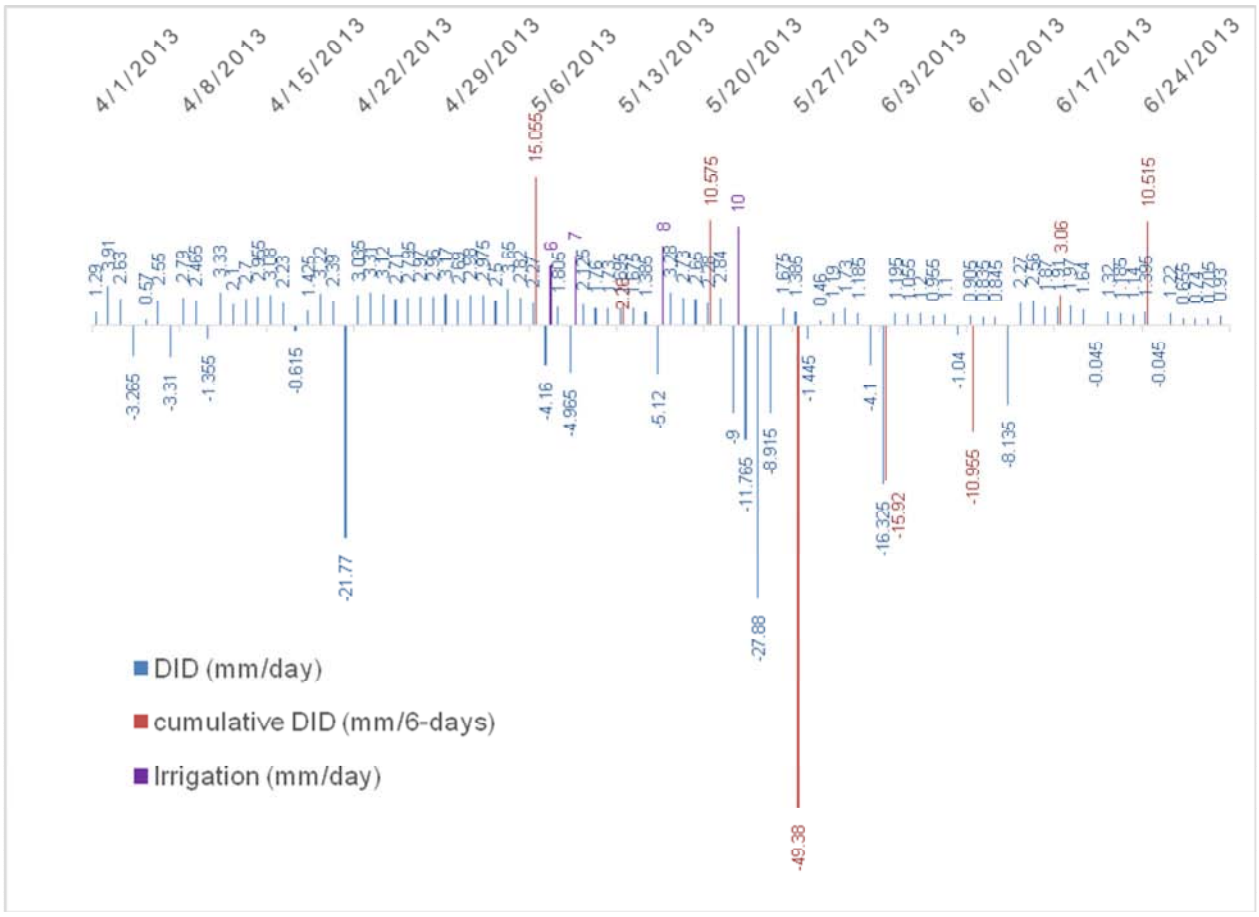


Figure 3.2: Stage 1A - Daily Irrigation Deficit (DID), 6-day cumulative DID and Irrigation applied for the Period (1st April – 30th June 2013)

In addition to the water balance, real-time soil moisture monitoring ensured that irrigation was only applied when there was available "space" in the soil profile. Figure 3.3 shows the patterns in soil moisture over time and response to irrigation and rainfall. The aim was to keep the black line (sum of 10cm, 20cm and 30 cm soil moisture values) in the green zone.

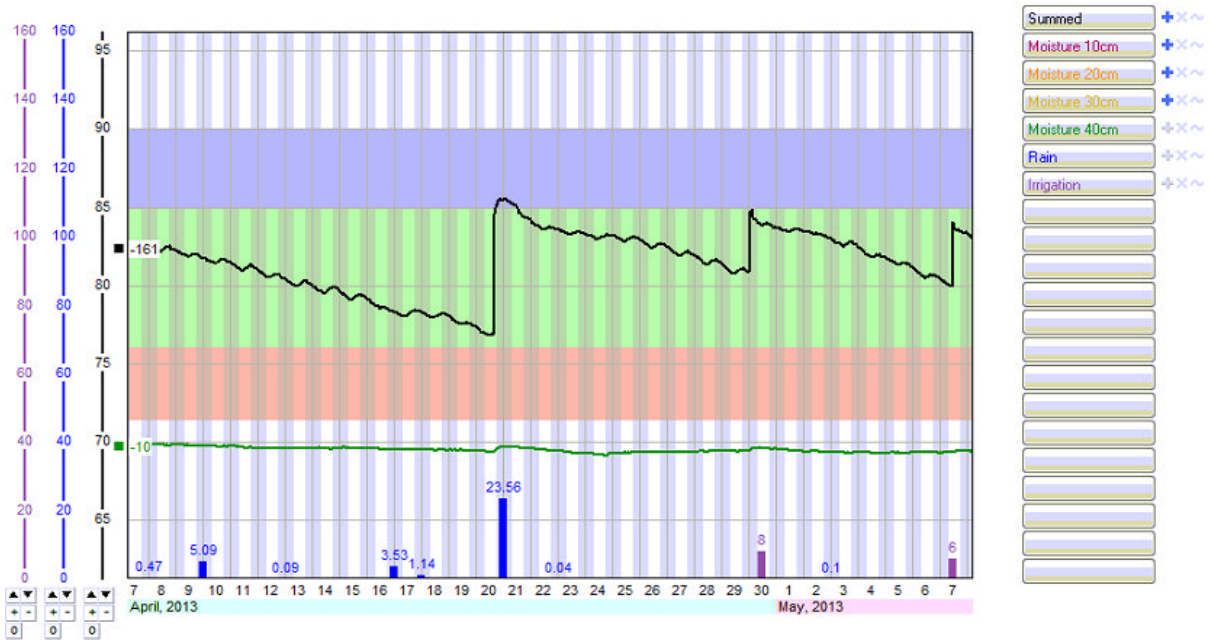


Figure 3.3: Soil moisture monitoring showing suitable times to irrigate to Stage 1A (green zone)

Irrigation of blended CSG water occurred in late April - May 2013 only. The DID, cumulative DID and soil moisture indicated that during this time was the only opportunity to irrigate. Approximately 4.66 ML of blended CSG water was applied to the Stage 1A area during the period.

3.3.2. Stage 1B

The water balance used for Stage 1A was also used for Stage 1B and is shown in Figure 3.4. Approximately 1.716 ML (11.4 mm) was applied to Stage 1B during May 2013.

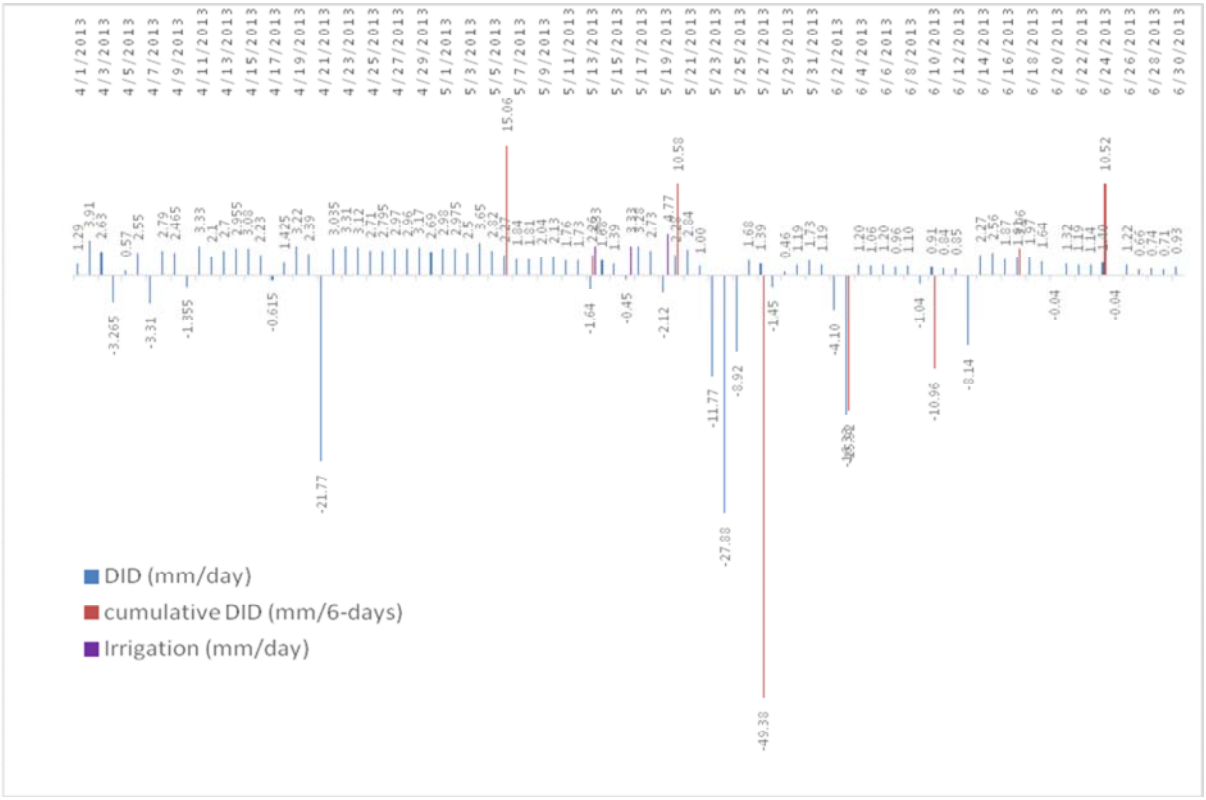


Figure 3.4: Stage 1B - Daily Irrigation Deficit (DID), 6-day cumulative DID and Irrigation applied for the Period (1st April – 30th June 2013)

3.4. Irrigation water quality

Table 3.2 summarises water quality of the blended CSG water prior to irrigation to Stages 1A and 1B

Table 3.2: Water quality of the blended CSG water prior to irrigation

Parameter	Units	Value
Electrical Conductivity (EC)	µS/m	1380
pH	no units	9.28
Chloride (Cl)	mg/L	218
Sodium (Na)	mg/L	200
Sodium Adsorption Ratio (SAR)	-	14.5
Adjusted SAR	-	4.4
Total Alkalinity	mg $CaCO_3$/L	303
Bicarbonate Alkalinity (HCO_3)	mg $CaCO_3$/L	194
Carbonate Alkalinity (CO_3^-)	mg $CaCO_3$/L	109
Calcium Carbonate Saturation Index	-	9.4
Hardness	mg $CaCO_3$/L	36
Aluminium (Al)	mg/L	0.04
Boron (B)	mg/L	0.16
Calcium (Ca)	mg/L	6
Copper (Cu)	mg/L	0.002
Fluoride (F)	mg/L	0.2
Iron (Fe)	mg/L	0.54
Magnesium (Mg)	mg/L	5
Manganese (Mn)	mg/L	0.009
Nitrate nitrogen (NO_3)	mg/L	<0.01
Total Phosphorus (P)	mg/L	0.39
Orthophosphate (PO_4^{3-})	mg/L	<0.01
Potassium (K)	mg/L	160
Sulfur (S)	mg/L	27
Zinc (Zn)	mg/L	0.012
Total Dissolved Solids (TDS)	mg/L	924
Total Organic Carbon (TOC)	mg/L	14

The blended water had an EC < 1500 µS/cm which was the mixing-model design objective for water quality prior to irrigation. The elevated pH (9.3) is of minor concern to site soils at these EC values as the pH can be attributed to carbonate interactions in the blended water. The blended irrigation water had elevated sodium and low calcium and magnesium and this has the potential to cause problems in association with the high alkalinity. The blended irrigation water was generally low in nutrients (nitrate and ortho-phosphate) however at a pH of 9.3 all phosphorous was in the bound form. Adjustment of the pH to around 7.5 would eliminate any alkalinity issues and release phosphorous for crop assimilation. Sodium, nutrients and Total Organic Carbon (TOC) values will be discussed further in section 3.5 with respect to mass balance results and potential impacts on site soils.

3.5. Sodium, nutrient and carbon balance

The aim of using mass balances was to determine if the sodium, nutrient and carbon load in the applied water was accumulating in the receiving soil over time. Mass balance results are presented as mg/kg applied during the period and are compared to soil data to determine changes over time.

3.5.1. Stage 1A

The mass of soil in Stage 1A was calculated as:
11.94 ha = 119,400 m^2 x 0.333 m (average treatment depth) x 1200 kg/m^3 (bulk density of the soil)
= 47,712,240 kg of soil in Stage 1A.

Table 3.3 provides a summary of mass balances for sodium, nitrate nitrogen, total phosphorous and total organic carbon

Table 3.3: Summary of mass balances for sodium, nitrate nitrogen, total phosphorous and total organic carbon

	Dam WQ (mg/L)	Irrigation (ML)	Total Applied (mg)	Site soil mass (kg)	Total Applied (mg/kg)
Sodium (Na)	200	4.66	932,000,000	47,712,240	19.5
Nitrate nitrogen (NO_3^-)	0.01	4.66	46,600	47,712,240	0.001
Total Phosphorus (P)	0.39	4.66	1,817,400	47,712,240	0.038
Total Organic Carbon (TOC)	14	4.66	65,240,000	47,712,240	1.367

For example, 19.5 mg/kg of sodium has been applied during the period. Soil analysis over this period (discussed in Section 4) indicated that Na ranged from approximately 75 mg/kg (10cm depth) to 375 mg/kg (at 40 cm depth). Coupled with excess rainfall and saturated soils the 19.5 mg/kg applied during this period is not likely to significantly increase sodium in the soil profile.

Nitrate nitrogen, total phosphorous and total organic carbon have been applied in negligible quantities through irrigation at this time.

3.5.2. Stage 1B

The mass of soil in Stage 1B was calculated as:
4ha = 400,000 m^2 x 0.15 m (average treatment depth) x 1200 kg/m^3 (bulk density of the soil)
= 7,200,000 kg of soil in Stage 1B

Table 3.4 provides a summary of mass balances for sodium, nitrate nitrogen, total phosphorous and total organic carbon.

Table 3.4: Summary of mass balances for sodium, nitrate nitrogen, total phosphorous and total organic carbon

	Dam WQ (mg/L)	Irrigation (ML)	Total Applied (mg)	Site soil mass (kg)	Total Applied (mg/kg)
Sodium (Na)	200	1.716	343,200,000	7,200,000	47.7
Nitrate nitrogen (NO_3^-)	0.01	1.716	17,160	7,200,000	0.002
Total Phosphorus (P)	0.39	1.716	669,240	7,200,000	0.093
Total Organic Carbon (TOC)	14	1.716	24,024,000	7,200,000	3.337

For example, 47.7 mg/kg of sodium has been applied during the period. Soil analysis over this period (discussed in Section 4) indicated that Na was approximately 165 mg/kg (0-20cm depth). Coupled with high rainfall and saturated soils the 47.7 mg/kg applied during this period is not likely to significantly increase sodium in the soil profile as significant leaching occurred due to high rainfall.

Nitrate nitrogen, total phosphorous and total organic carbon have been applied in minimal quantities through irrigation at this time.

3.6. Perched water piezometer results

Shallow piezometers installed around and within the site also provided data to assist irrigation scheduling. Water levels in the piezometers were recorded every month. Figure 3.4 shows water levels (as mAHD) for sites within the irrigation area and Figure 3.5 shows water levels for corresponding paired sites immediately outside of the irrigation area. Table 3.5 shows the surface elevation of the piezometers and the perched water elevations for June 2013 which indicates how close the water was to the surface.

Table 3.5: Elevation of piezometer sites and perched water levels (June 2013)

Piezometer	Surface Elevation (mAHD)	Perched Water Elevation (mAHD)
SP1A	119.62	119.4
SP1B	119.23	No water present
SP2A	118.09	118.22
SP2B	118.44	117.9
SP3A	112.65	113.04
SP3B	112.05	112.46
SP4A	109.22	No water present
SP4B	108.81	No water present
SP5A	106.95	110.51
SP5B	106.41	No water present
SP6A	105.53	108.83
SP6B	106.10	No water present
SP7A	110.75	106.73
SP7B	109.87	106.34
SP8A	113.24	No water present
SP8B	111.73	105.39

The piezometers within the trial area (those denominated by the letter “A”) were installed to depths that matched the depth of treatment for each location. The piezometers outside of the trial area (those denominated by the letter “B”) were all installed to the same depth of 1.2 metres.

As demonstrated by Figures 3.5 and 3.6, the piezometers within the irrigation area had more water than the outside piezometers. This is due to the substantially improved infiltration rate of the ameliorated soils inside the trial area, resulting in the promotion of downward movement of water into the soil, rather than surface runoff which would occur in the parent soils.

Also most piezometers accumulated perched water during the period because of the high rainfall and relatively low evapotranspiration rates.

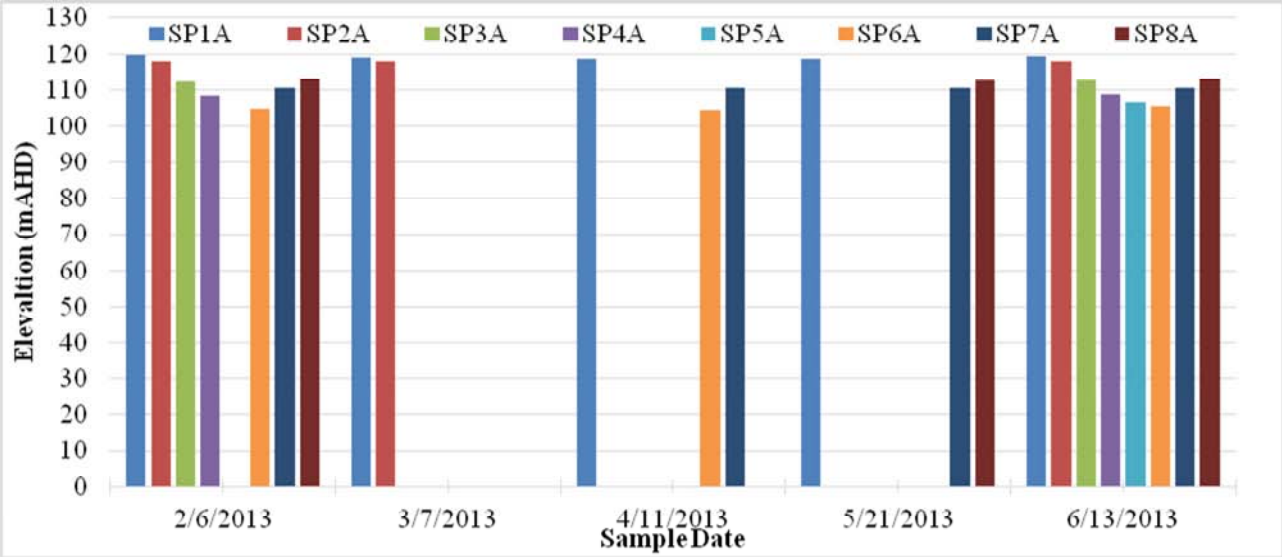


Figure 3.5: Piezometer water levels (as mAHD) for sites within the irrigation area

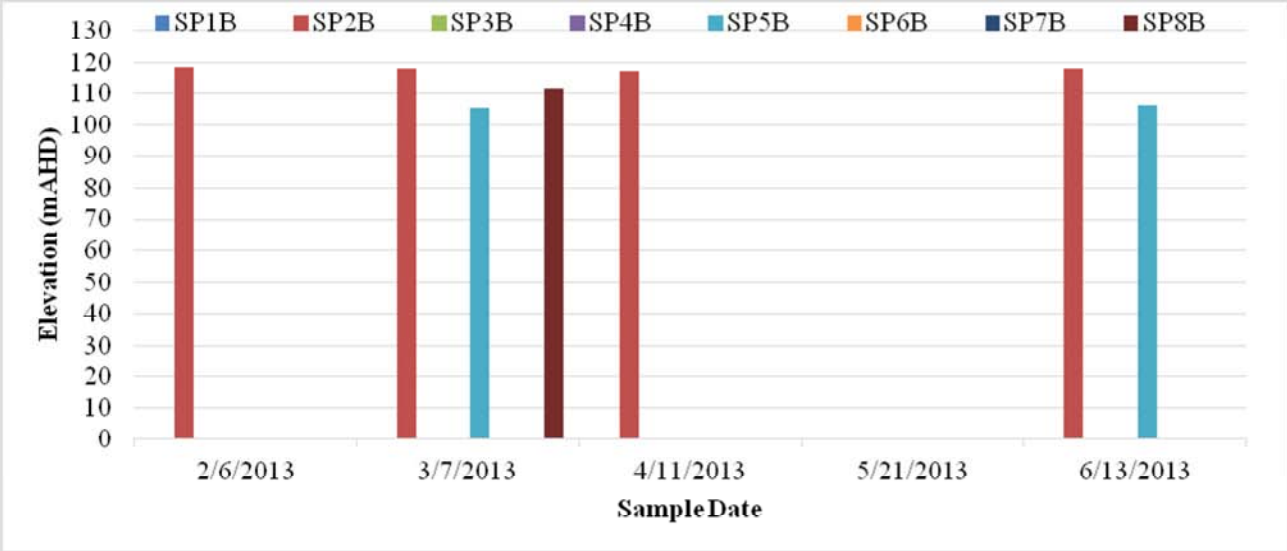


Figure 3.6: Piezometer water levels (as mAHD) for corresponding paired sites outside the irrigation area

4. Performance of soils on the Stage 1A irrigation area

This report (Report 2) was prepared after blended irrigation water was applied to the trial area and after the collection of Baseline 3 soil samples (ie the first samples collected after the irrigation of blended produced water).

4.1. Baseline 1 – Parent soil sampling and test results

Full details are provided in Fodder King (2013) *Soil quality monitoring and management, Report 1- Pre irrigation (Activities to 31 March 2013),* Report for AGL Upstream Investments Pty Ltd.

4.2. Baseline 2 – Target specification for amended soil

Table 4.1 provides a broad summary of the desired target values for amended soils. Whilst this is a desired target specification, it should be noted that it is rare in Australia for soils to concurrently possess all of these values.

Table 4.1 – Desired target soil values for certain parameters

Soil Parameter	Units	Value Range
Electrical conductivity	dS/m	< 0.15
pH ($CaCl_2$)	pH units	5.5.- 7.5
NO_3 – Nitrate Extract	mg/kg	15
Organic Carbon	%	2.5
Potassium	mg/kg	350
Calcium	mg/kg	3500
Magnesium	mg/kg	1800
Sodium	mg/kg	< 100
Aluminium	mg/kg	< 20
Ex Potassium	%	1-5
Ex Calcium	%	65-80
Ex Magnesium	%	10-15
Ex Aluminium	%	< 5
ECEC	meg/100g	12 - 25
Estimated water holding capacity	mm/m	150
Water infiltration rate	mm/hr	25

4.3. Baseline 2 – Amended soil sampling and test results

Following the application of the four treatments, soil sampling and testing were repeated to ascertain the soil quality for the Stage 1A Trial Irrigation Area prior to the commencement of blended water irrigation.

The same 16 soil sampling locations used in Baseline 1 were re-sampled and analysed. Soil samples were taken manually (14th January 2013) using a hand auger in order to minimise disturbance.

Full details are provided in Fodder King (2013) *Soil quality monitoring and management, Report 1- Pre irrigation (Activities to 31 March 2013),* Report for AGL Upstream Investments Pty Ltd.

4.4. Key findings - Baseline 2 (ameliorated soil) vs Baseline 1 (parent soil)

The soil quality characteristics that resulted from the soil treatments showed significant improvements over the parent soil.

See Fodder King (2013) *Soil quality monitoring and management, Report 1- Pre irrigation (Activities to 31 March 2013),* Report for AGL Upstream Investments Pty Ltd.

4.5. Amended soil agronomic adjustments

In the period after taking the Baseline 2 soil samples and subsequent crop establishment shallow (0-100mm) sampling and testing was carried out across the trial area in order to ascertain the need for any final adjustment to soil quality prior to crop establishment.

These final adjustments were carried out subsequent to the collection of Baseline 2 soil samples and their improvement to the overall soil quality is reflected in the Baseline 3 soil test results. The following adjustments were made to each of the four treatment areas.

Treatment 1 adjustment

- Lime – 1.75 tonnes/ha
- Sow crops with Di Ammonium Phosphate fertiliser (DAP)

Treatment 2 adjustment

- Lime – 3.5 tonnes/ha
- Sow crops with DAP

Treatment 3 adjustment

- Lime – 2.5 tonnes/ha
- Sow crops with DAP

Treatment 4 adjustment

- Lime – 2.0 tonnes/ha
- Sow crops with DAP

4.6. Baseline 3 – Amended soil sampling and test results

The 16 soil sampling locations (CS1-CS16) used in Baseline 1 and 2 were re-sampled on the 12th June 2013 and subsequently analysed. Soil samples were taken manually using a hand auger in order to minimise disturbance. Due to the wet soil conditions to depth, resulting from higher than average rainfall coupled with low evapotranspiration during the month, it was not possible to extract a small number of the soil samples. See Table 6.1 for key weather and irrigation information for the period.

The summarised soil test results are shown in Attachment 3.

4.7. Key findings – Baseline 3 (irrigated soils) vs Baseline 2 (pre-irrigated soil)

The changes in average values between Baseline 3 and Baseline 2 are shown in Attachment 4. In addition, Baseline 3 is compared against Baseline 1 (parent soil) values.

Salinity (Ec)

As discussed in Report 1, the salinity 'spike' resulting from the use of compost and the mixing of layer 3 of the parent soil has subsided. Further decreases are expected to be reflected in the Baseline 4 results.

Sodium and Exchangeable Sodium Percentage (ESP)

The sodium values have decreased. As a result the exchangeable sodium percentages have also decreased and currently sit at a desirable level of less than 6% to 80cm depth. See Figure 4.1.

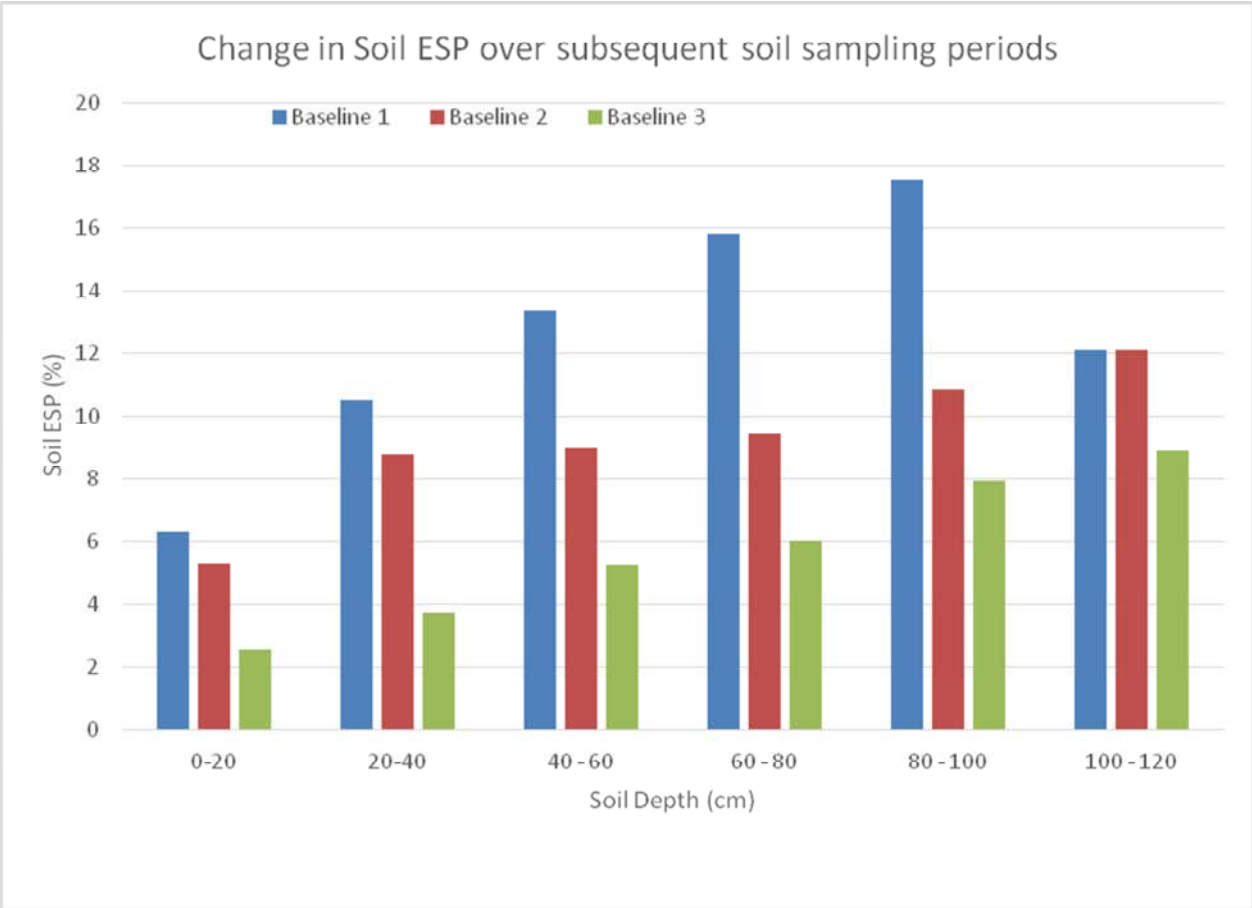


Figure 4.1. Change in Exchangeable Sodium Percentage (ESP)

Nitrate

The reduction in nitrate values reflects the take up by plant roots as they become established.

Calcium

The increase in calcium values reflects the application of lime subsequent to Baseline 2.

Calcium/Magnesium Ratio

A Calcium/Magnesium ratio of around 2 is considered to represent an optimum balance for plant growth. The calcium magnesium ratio has increased to the optimum at depth.

Cation Exchange Capacity (ECEC)

The cation exchange capacities have improved near the surface, due to the addition of lime after Baseline 2. This favours healthy plant growth.

5. Performance of soils on the Stage 1B irrigation area

5.1. Trial location

The area selected for the Stage 1B trial area has no previous history of cropping or substantial soil improvement, although improved pasture was briefly irrigated in 2009 when small amounts of produced water were irrigated under an earlier REF approval (details provided in AGL, 2010). Some soil sampling and monitoring was completed as part of this earlier irrigation trial program.

The Stage 1B area is approximately 4.1 hectares in area and is located to the south of the Stage 1A trial area. See Attachment 2.

5.2. Baseline 1 (Parent soil)

Soil samples were taken from a transect across the Stage 1B area to a depth of 100mm. Samples were mixed and aggregated to form a representative sample for testing.

The results are shown in Attachment 5.

5.3. Baseline 2 - Soil improvement

AGL engaged an agronomist to provide recommendations as to shallow soil improvements to enable the growing of improved pasture and improve the capacity of the soil to take in irrigation water.

As a result the following soil adjustments were carried out for the comparative pasture trial area:

- Lime – 4 tonnes/ha
- Sow crops with Di Ammonium Phosphate (DAP) fertiliser

No substantial sub-surface soil improvements were carried out across this area except for aeration, liming, and 50% of the area having a trace mineral soil conditioner applied. See Attachment 5.

5.4. Key findings - Baseline 2 (irrigated) vs Baseline 1

Key observations for the parent soils in Stage 1B are:

Salinity (EC)

Remains at a low to moderate level.

Soil pH

The soil remains relatively acidic.

Organic Carbon (OC)

Organic carbon levels remain just above the desired level of 2.5%

Calcium

Calcium levels increased as a result of the addition of lime.

Cation Exchange Capacity (ECEC)

ECEC values remained well below the desirable level of 25.

Sodicity (Exchangeable Sodium Percentage)

ESP values reduced from 16.9% to 8.6%.

5.5. Perched water piezometers

Paired piezometers (SP9a, SP9b, SP10a, and SP10b) were installed in the Stage 1B area (see Attachment 2) to monitor the potential for perched water to develop inside and immediately outside (ie downgradient) of the irrigated pasture area. The piezometers were installed to a depth of 500mm inside the area to be irrigated and 700mm outside the area to be irrigated.

Table 5.1 shows the surface elevation of the piezometers and the perched water elevations for June 2013 which indicates how close the water was to the surface.

Table 5.1: Elevation of piezometer sites and perched water levels (June 2013)

Piezometer	Ground Elevation (mAHD)	Perched Water Table Elevation (mAHD)
SP9A	118.25	No water present
SP9B	117.30	No water present
SP10A	114.99	114.19
SP10B	113.81	No water present

6. Sedimentation, runoff and erosion control

A number of environmental protection measures were installed across the Stage 1A irrigation trial area to ensure that bare soils were not eroded during rainfall events and to ensure that soil and sediment was retained within the irrigation plot areas.

6.1. Protection measures

The following sedimentation, runoff and erosion control protection measures were installed for the Stage 1A trial irrigation area. They are shown in Attachments 3 and 6:

- Trial plot bunding and drainage to catch dams;
- Diversion banks to catch all runoff from the trial plots and divert it to the catch dams;
- Two catch dams with pumps and recycling pipework to collect any runoff from the trial area and recycle it back to the storage dam;
- Modern overhead spray irrigation system;
- Diversion drains to prevent the possibility of any overland runoff entering the trial area; and
- Spraygrassing of all structures.

Prior to the construction phase an extensive system of silt fences was installed to intercept any runoff during this period. These fences have now been removed.

These siteworks were supplemented by the following monitoring locations which are in place to minimise sediment runoff and subsurface water migration:

- 10 soil moisture monitoring positions;
- 8 paired piezometers;
- 6 rain gauges; and
- An automatic weather station.

6.2. Summary of weather and irrigation applied

The key information relevant to the performance of the sedimentation, runoff and erosion control measures during the reporting period is shown in Table 6.1

6.2.1. Rainfall

Rainfall for the reporting period totalled 205.8 mm, as recorded by the AGL weather station on Tiedmans. This compares with a total of 176.8mm recorded at the Bureau of Meteorology (BOM) site at Gloucester Post Office (site no 60015). April rainfall was 33% less than the mean, while May rainfall was close to the mean. The June rainfall total (92.2mm) was 35% higher than the mean (68.4mm).

6.2.2. Rain days

Out of the 91 days in the reporting period, 49 days (54%) were wet. A wet day occurred when 0.2mm (or more) of rainfall was registered in the Tiedmans weather station rain gauge.

6.2.3. Rainfall intensity

All of the rain events that occurred during the period were below the threshold level of 24.9mm/hour which defines a 1 in 1 year rainfall event at Tiedmans. See FK (2012) *Soil Quality Monitoring and Management Program – Tiedman irrigation trial*. The highest hourly rainfall intensity rate was 5.2mm/hour, which occurred on the 24/05/2013.

6.2.4. Blended water irrigation

Blended water application commenced in late April and a total of 8mm was applied. A further 31mm was applied in May and none was applied in June due to the low levels of evapotranspiration, combined with a large number of wet days.

Table 6.1 - Key weather and irrigation information

Key information	April	May	June	Total for the period
Rainfall				
AGL weather stn	52.0mm	61.6mm	92.2mm	**205.8mm**
Bureau of Meteorology Gloucester Post Office	61.6mm	55.8mm	59.4mm	**176.8mm**
Mean monthly rainfall at Gloucester Post Office	77.3mm	68.0mm	68.4mm	**213.60mm**
Number of rain days (≥ 0.2mm recorded)	14	16	19	**49**
Percentage rain days	47%	52%	63%	**54%**
Highest rainfall days	25.2mm (21/04/2013)	30.4mm (24/05/2013)	19.8mm (27/06/2013)	**Not Applicable**
Highest hourly rainfall rate (mm/hr)	4.4mm/hr (21/04/2013)	5.2mm/hr (24/05/2013)	4.4mm/hr (29/06/2013)	**Not Applicable**
Blended water irrigation application	8.0mm	31.0mm	0.0mm	**39.0mm**
Total applied water (rainfall plus blended water)	60mm	92.6mm	92.2mm	**244.8mm**
Blended water salinity	1380µS/cm	1380µS/cm	Not Applicable	

6.3. Performance under rainfall and irrigation

The combined application of rainfall and blended water irrigation totalled 244.8mm, which is approximately 15% higher than the mean rainfall for Gloucester.

6.3.1. Trial plot bunding and drainage to catch dams

Due to the installation of the plot bunds no erosion was encountered in the period between installation of the plots and establishment of the trial crops. The trial crops established quickly, due to the favourable weather after planting and the improved soil quality. All plot bunds performed to design requirement during the period. Some small non-draining low lying areas occurred at the inside corners of some of the northern plots but the area affected was not considered to be significant enough to warrant the need for any remedial measures.

6.3.2. Diversion banks to catch runoff from the trial plots and divert it to the catch dams.

Two additional diversion banks were installed to divert overland flow from natural runoff from entering Catch Dam 2. Catch Dam 1 did not require any changes.

6.3.3. Two catch dams with pumps and recycling pipework

Both Catch Dam 1 and Catch Dam 2 operated to design requirements and runoff from the trial plot area was collected and pumped back to the Blended (Southern) Water Dam on Tiedmans.

6.3.4. Overhead spray system

The irrigation system was managed in accordance with the operating procedures and blended water was applied when there was sufficient deficit available in the soil. During June no irrigation took place due to the wetter than normal conditions and insufficient soil moisture deficit.

6.3.5. Diversion drains

All diversion drains operated satisfactorily during the period and erosion had not occurred due to grassing of the drains and installation of silt traps at regular intervals.

6.3.6. Spraygrassing of all structures

All bund walls, diversion banks and diversion drains have a well established grass cover and are mowed to ensure that there are no flow blockages.

The grassed aprons in front of the catch dams, in conjunction with geofabric netting, have prevented any erosion from occurring as well as preventing any siltation of the dams.

Plate 1. Catch Dam 2. Salinity meter floating in the middle.

Plate 2. Catch Dam 2 Recycle Pump

Plate 3. View west along southern boundary of trial plots. Diversion drain (along fenceline) and additional diversion bank (in middle distance)

7. Stage 1A critical control point monitoring and response plan

7.1. Critical Control Points

The critical control points were nominated in the soil quality monitoring and management plan. Full details are provided in Fodder King (2012) *Soil Quality Monitoring and Management Program – Tiedman irrigation trial*, Report for AGL Upstream Investments Pty Ltd.

Table 7.1: Stage 1A Trial Irrigation Area Critical control points

Critical Control Point	Hazard	Trigger	Response	Mitigation	Risk
CSG Dam and Mixing Dam	Brackish overflow to landscape	Excessive rainfall	Record and report lost volume from storages	Continual monitoring of dam depth and salinity with maintenance of adequate freeboard	Low
Catch Dams	Brackish overflow to landscape	Excessive rainfall or irrigation	Keep dams empty at all times. Record and report lost volume from storages + halt irrigation	Continual monitoring of dam depth and salinity	Low
Soil moisture monitoring system	System failure	Sensor fault	Halt irrigation	Replace defective sensors	Low
Shallow piezometer water level	Perched water tables	Excessive rainfall and/or over-irrigation	Adjust irrigation rates	Review irrigation schedule	Low
Ameliorated soil in the irrigation area (1)	Increasing salinity	Soil salinity increase of more than 50% above the average value of the new baseline for the ameliorated soils	Review with agencies and if necessary: • Increase dilution of CSG water. • Adjust irrigation rates. • Install collection and recycling system.	6 monthly soil sampling	Low
Non -ameliorated parent soil (2)	Increasing salinity	Soil salinity increase of more than 50% above the average value of 0.12 dS/m (1:5) in the root zone to 1m depth	Review with agencies and if necessary: • Compare against external control site • Increase dilution of CSG water. • Adjust irrigation rates.	6 monthly soil sampling	Very Low

Key (1) – across the 16 ameliorated soil sampling sites.
(2) – across 5 proposed parent soil locations (four internal sites within each of the 4 soil treatment types plus one external control site)

None of the Critical Control Point hazards have occurred during the reporting period. Whilst the amelioration of the soil resulted in higher salinity the causal source of this was not blended water but from the choice of ameliorants and the mixing of ameliorant in a deeper soil layer which had naturally derived elevated salinity. The elevated levels have since receded and it is expected that these values will be lower in Baseline 4.

Due to the limited amount of blended water applied during the period (winter) it was determined that testing of non-ameliorated parent soil was not warranted.

8. References

AGL (2010) *Irrigation monitoring report for Stratford Pilot – Tiedman Property 2009.* AGL Upstream Gas.

AGL (2012) *Water Management Plan for the Tiedman Irrigation Program – Gloucester,* AGL Upstream Gas.

DECC (2004) *Environmental Guidelines: Use of Effluent by Irrigation*, NSW Department of Environment and Conservation, ISBN 1 74137 076 0.

Fodder King (2010) *Technical Assessment of land in the Gloucester Basin for irrigation of CSG water,* Report for AGL Upstream Investments Pty Ltd.

Fodder King (2011) *Preliminary Investigations and Design of an Irrigation Trial on land in the Gloucester Basin for irrigation of CSG water*, Report for AGL Upstream Investments Pty Ltd.

Fodder King (2012) *Soil Quality Monitoring and Management Program – Tiedman irrigation trial*, Report for AGL Upstream Investments Pty Ltd.

Fodder King (2013) *Soil quality monitoring and management, Report 1- Pre irrigation (Activities to 31 March 2013),* Report for AGL Upstream Investments Pty Ltd.

Lucas S.A (2009) Sodium flux in Woodlot Soils Irrigated with Treated Effluent: The Implications for Sustainable Irrigation and Soil Management, Lambert Academic Publishing, Saarbrucken, p195

Henderson L (2000) Soil Landscapes of the Dungog 1:100000 Sheet. Map and Report. Department of Land and Water Conservation

Parsons Brinckerhoff (2011) *Gloucester Exploration Program - Irrigation Proposal Review of Environmental Factors*, Report PR_5506 for AGL Energy Limited.

Parsons Brinckerhoff (2012) *2012 Gloucester Groundwater and Surface Water Monitoring – Annual Status Report*, Report PR_1243 for AGL Upstream Investments Pty Ltd.

Parsons Brinckerhoff (2013) *Gloucester Gas Project – Tiedman Irrigation Trial Baseline Water Monitoring Program*, Report PR_6306 for AGL Upstream Investments Pty Ltd.

Attachments

Attachment 1 – Stage 1A trial plot layout

Attachment 2 – Stage 1B trial plot layout

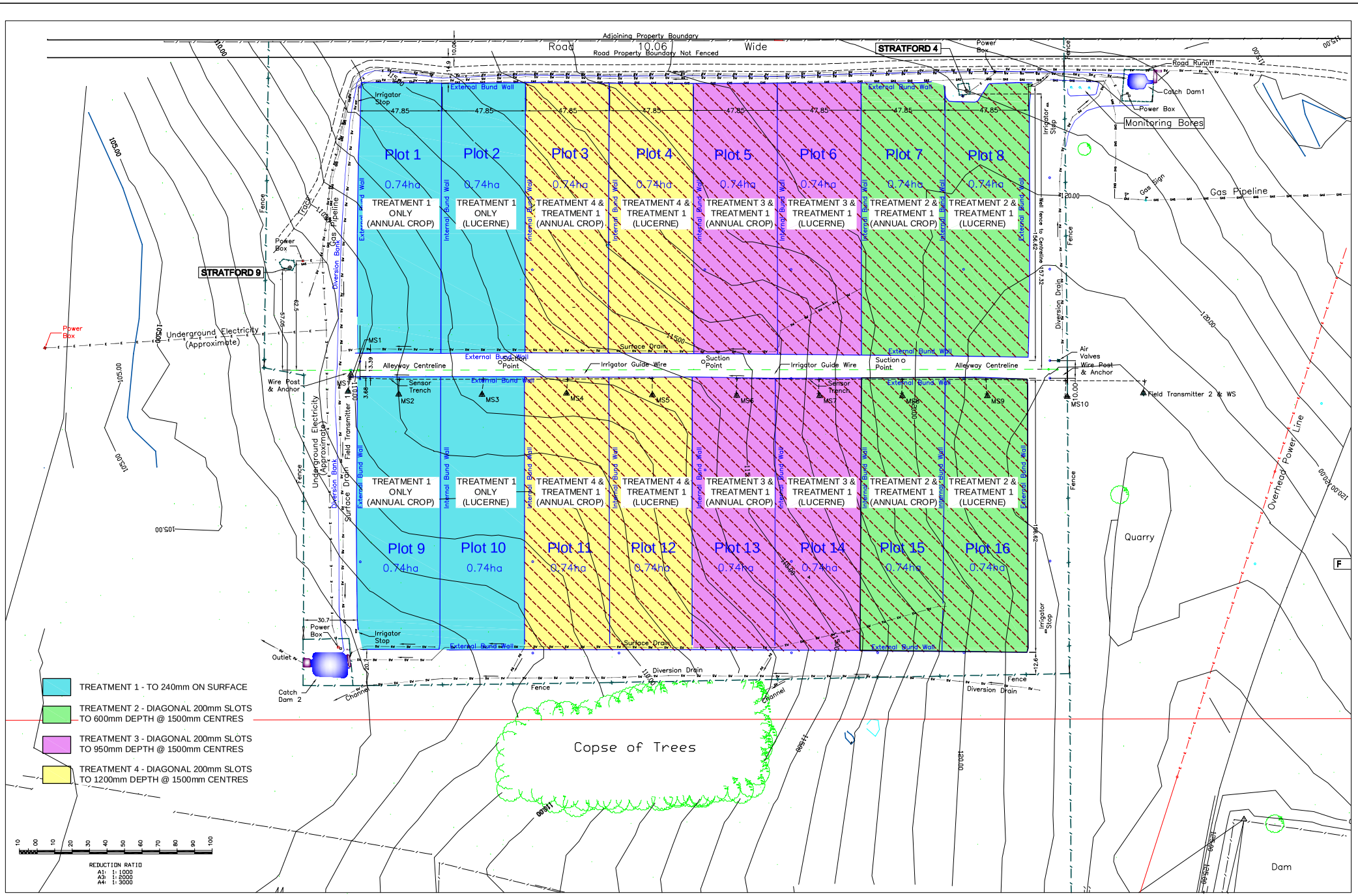
Attachment 3 – Stage 1A Baseline 3 soil test results

Attachment 4 – Stage 1A – Baseline 3 vs Baseline 2 comparisons

Attachment 5 – Stage 1B soil test results

Attachment 1.

Stage 1A trial plot layout



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D	6-May-13	FINAL WAE (BY FODDER KING AND AGL)	FK	FK
C	24-Apr-13	SPLIT SHEET 01	FK	FK
B	5-Apr-13	PLOT AREA TEXT	FK	FK
A	7-Feb-13	INITIAL ISSUE	MH	MH

SURVEY: M Hanlon
DESIGN: M Hanlon
DRAWN: M Hanlon
CHECKED: M Hanlon
SURVEY FILE: J:\12161 Fetterplace Civil, AGL site, Gloucester\ccad7\12161V02 WAE Survey 2012-12-20.ccx

A1
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ORIGIN PM35266 RL 124.736
CONTOUR INTERVAL: 0.25m
APPROVED: PROJ.MAN

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Natural Resources
Planning
Surveying
Civil Engineering
Environmental Engineering

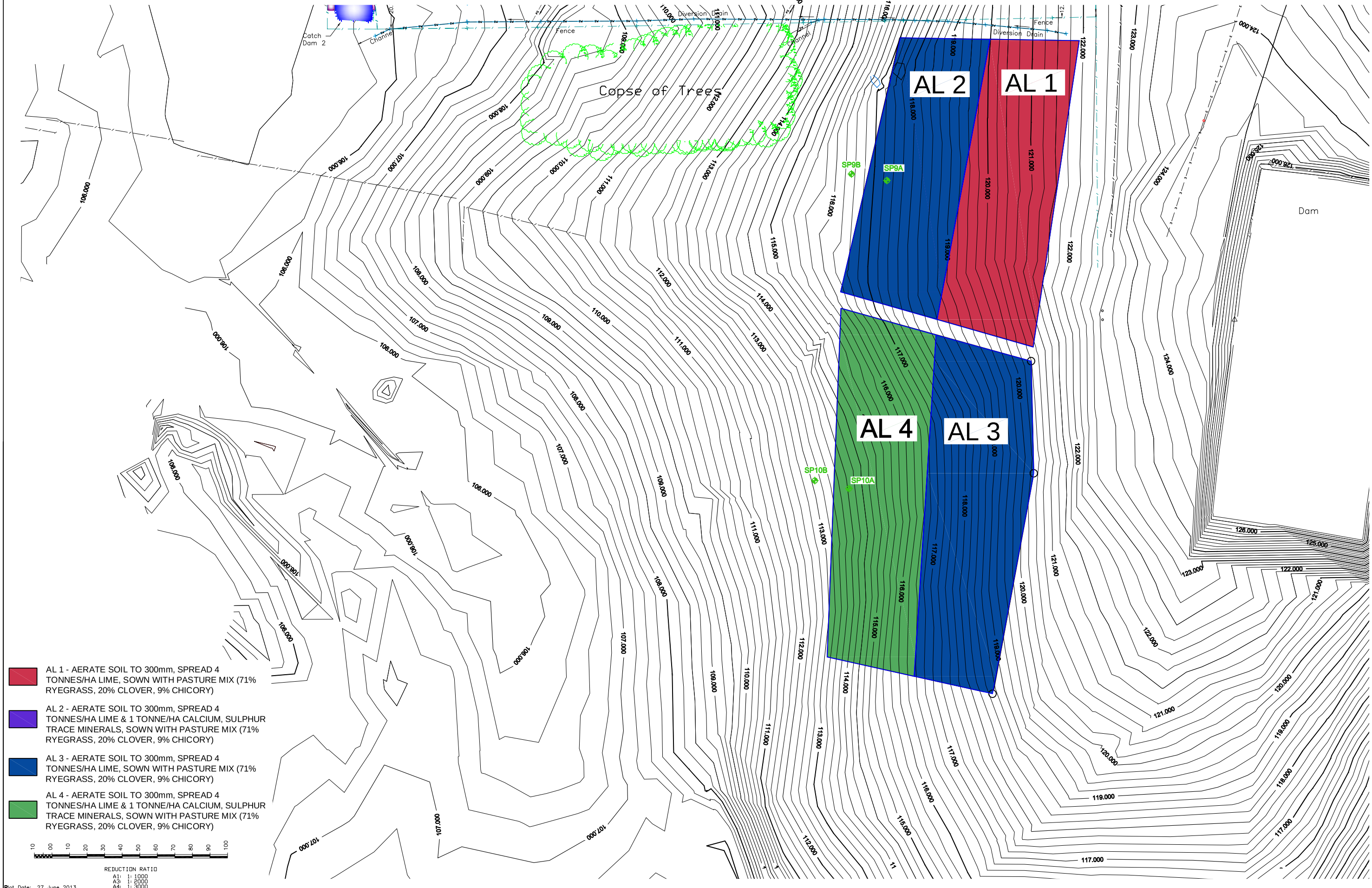
ISO9001:2008 FS559272

CLIENT: FODDER KING & FETTERPLACE CIVIL
PROJECT: AGL - GLOUCESTER - IRRIGATION TEST PLOT
TIEDMANS IRRIGATION TRIAL
STAGE 1A TRIAL PLOT LAYOUT
WORKS AS EXECUTED

DATE: 7 February 2013
DRAWING No.:
SHEET 01A
GLO-ENG-DWG-G-401
Rv. D

Attachment 2.

Stage 1 B trial plot layout



AL 1 - AERATE SOIL TO 300mm, SPREAD 4 TONNES/HA LIME, SOWN WITH PASTURE MIX (71% RYEGRASS, 20% CLOVER, 9% CHICORY)

AL 2 - AERATE SOIL TO 300mm, SPREAD 4 TONNES/HA LIME & 1 TONNE/HA CALCIUM, SULPHUR TRACE MINERALS, SOWN WITH PASTURE MIX (71% RYEGRASS, 20% CLOVER, 9% CHICORY)

AL 3 - AERATE SOIL TO 300mm, SPREAD 4 TONNES/HA LIME, SOWN WITH PASTURE MIX (71% RYEGRASS, 20% CLOVER, 9% CHICORY)

AL 4 - AERATE SOIL TO 300mm, SPREAD 4 TONNES/HA LIME & 1 TONNE/HA CALCIUM, SULPHUR TRACE MINERALS, SOWN WITH PASTURE MIX (71% RYEGRASS, 20% CLOVER, 9% CHICORY)

10 00 10 20 30 40 50 60 70 80 90 100

REDUCTION RATIO
A1: 1:1000
A3: 1:2000
A4: 1:3000

Plot Date: 27 June 2013
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Rv	DATE	REVISIONS	REC.	APPR.
B	27-Jun-13	AMENDMENTS AS PER EMAIL RECEIVED ON 27/6/13		
A	26-Jun-13	ADDITIONAL SHEETS AS PER EMAIL RECEIVED ON 24/6/13		

SURVEY: M Hanlon
DESIGN: M Hanlon
DRAWN: M Hanlon
CHECKED: M Hanlon
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A1

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ORIGIN:PM55266 RL:124.736
CONTOUR INTERVAL: 0.25m

APPROVED: PROJ.MAN

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ISO9001:2008 FS555072

CLIENT: FODDER KING

PROJECT: AGL - GLOUCESTER - IRRIGATION TEST PLOT

TIEDMANS IRRIGATION TRIAL
STAGE 1B TRIAL PLOT LAYOUT

DATE: 7 February 2013
Rv. B
DRAWING No.:
SHEET 05

Attachment 3.

Stage 1A Baseline 3 soil tests

STAGE 1A BASELINE 3 SOIL TEST RESULTS

AVERAGE	Depth	EC (1:5)	pH	NO3	Org-C	K	Ca	Mg	Na	Al	K	Ca	Mg	Na	Al	K	Ca	Mg	Na	Al	ECEC	Ca/Mg	ESP
N =	cm	dS/m	CaCl2	mg/kg	%	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	%	%	%	%	meq/100g	ratio	%
16	0-20	0.32	6.64	44	3.1	0.961	14.875	5.661	0.558	0.005	376	2981	688	128	0.4	4.1	67.6	25.8	2.5	0.0	22.1	2.8	2.5
12	20-40	0.30	6.02	29	2.1	0.688	10.448	6.588	0.665	0.098	269	2094	801	153	8.8	3.6	55.6	36.4	3.8	0.6	18.5	1.8	3.8
12	40 - 60	0.25	5.31	24	1.7	0.549	6.913	7.275	0.788	0.383	215	1385	884	181	34.4	3.4	41.7	46.6	5.2	3.1	15.9	1.0	5.2
8	60 - 80	0.20	4.80	18	1.2	0.435	5.363	8.495	0.955	1.151	170	1075	1033	220	103.5	2.8	30.9	52.3	6.0	8.1	16.4	0.7	6.0
4	80 - 100	0.14	4.24	8	0.6	0.270	2.210	10.520	1.295	1.905	106	443	1279	298	171.3	1.7	13.9	64.4	7.9	12.1	16.2	0.2	7.9
3	100 - 120	0.25	4.29	6	0.4	0.235	1.845	9.730	1.340	1.835	92	370	1183	308	165.0	1.6	12.2	64.4	8.9	12.9	15.0	0.2	8.9

Maximum	Depth	EC (1:5)	pH	NO3	Org-C	K	Ca	Mg	Na	Al	K	Ca	Mg	Na	Al	K	Ca	Mg	Na	Al	ECEC	Ca/Mg	ESP
N =	cm	dS/m	CaCl2	mg/kg	%	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	%	%	%	%	meq/100g	ratio	%
16	0-20	0.59	7.04	88	5.21	2.36	23.00	10.50	0.90	0.02	923	4609	1276	207	2	8	77	36	4	0	33.6	5.13	3.6
12	20-40	0.57	6.98	79	4.07	1.55	18.60	10.00	0.97	1.06	606	3727	1216	223	95	6	72	55	6	6	31.1	3.48	5.8
12	40 - 60	0.52	6.92	62	3.18	1.38	15.60	11.40	1.08	1.52	540	3126	1386	248	137	6	58	63	8	9	27.1	2.03	7.9
8	60 - 80	0.28	6.95	45	1.88	0.64	13.90	12.50	1.40	4.24	250	2786	1519	322	381	5	55	73	9	25	25.1	1.44	8.5
4	80 - 100	0.14	4.43	12	0.70	0.28	2.35	12.50	1.50	2.31	109	471	1519	345	208	2	16	70	8	16	17.8	0.28	8.4
3	100 - 120	0.36	4.44	11	0.46	0.25	2.20	11.50	1.51	2.49	98	441	1398	347	224	2	13	69	9	19	16.6	0.19	9.1

Minimum	Depth	EC (1:5)	pH	NO3	Org-C	K	Ca	Mg	Na	Al	K	Ca	Mg	Na	Al	K	Ca	Mg	Na	Al	ECEC	Ca/Mg	ESP
N =	cm	dS/m	CaCl2	mg/kg	%	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	%	%	%	%	meq/100g	ratio	%
16	0-20	0.17	6.13	17.4	1.97	0.4	10.3	3.14	0.32	0	156	2064	382	74	0	2	57	15	1	0	14.3	1.59	1.3
12	20-40	0.13	4.42	8.4	1.02	0.23	5.04	3.12	0.35	0	90	1010	379	80	0	2	30	21	2	0	9.4	0.55	2.3
12	40 - 60	0.11	4.33	2.8	0.62	0.19	2.36	2.28	0.34	0	74	473	277	78	0	2	23	28	4	0	7.9	0.37	3.7
8	60 - 80	0.13	4.05	2.3	0.46	0.23	1.79	3.13	0.45	0	90	359	380	103	0	2	14	37	4	0	8.5	0.19	3.6
4	80 - 100	0.13	4.05	2.9	0.5	0.26	2.07	8.54	1.09	1.5	102	415	1038	251	135	1	12	59	7	8	14.6	0.17	7.5
3	100 - 120	0.14	4.14	2	0.39	0.22	1.49	7.96	1.17	1.18	86	299	968	269	106	2	11	60	9	7	13.3	0.19	8.8

Standard Deviation	Depth	EC (1:5)	pH	NO3	Org-C	K	Ca	Mg	Na	Al	K	Ca	Mg	Na	Al	K	Ca	Mg	Na	Al	ECEC	Ca/Mg	ESP
N =	cm	dS/m	CaCl2	mg/kg	%	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	%	%	%	%	meq/100g	ratio	%
16	0-20	0.13	0.26	21.2	0.87	0.57	3.92	1.94	0.18	0.01	222	786	236	42	1	1	6	6	1	0	5.54	0.97	0.6
12	20-40	0.13	0.86	22.2	1.05	0.35	4.41	2.41	0.19	0.30	138	885	293	44	27	1	12	11	1	2	5.87	0.94	1.1
12	40 - 60	0.12	1.02	18.0	0.81	0.34	4.26	2.79	0.25	0.53	132	854	339	57	47	1	13	13	2	4	6.21	0.58	1.6
8	60 - 80	0.05	0.98	15.4	0.51	0.14	3.93	2.74	0.28	1.47	56	789	334	64	132	1	14	14	2	9	4.81	0.43	1.7
4	80 - 100	0.01	0.27	6.5	0.14	0.01	0.20	2.80	0.29	0.57	6	40	340	67	52	0	3	8	1	5	2.31	0.08	0.7
3	100 - 120	0.16	0.21	6.3	0.05	0.02	0.50	2.50	0.24	0.93	8	101	304	55	83	0	1	7	0	8	2.34	0.00	0.2

Attachment 4.

Stage 1A – Baseline 3 vs Baseline 2 comparisons

Differences in average values between Baseline 3 (irrigated) and Baseline 2 (ameliorated)

Depth cm	EC (1:5) dS/m	pH CaCl2	NO3 mg/kg	Org-C %	K meq/100g	Ca meq/100g	Mg meq/100g	Na meq/100g	Al meq/100g	K mg/kg	Ca mg/kg	Mg mg/kg	Na mg/kg	Al mg/kg	K %	Ca %	Mg %	Na %	Al %	ECEC meq/100g	Ca/Mg ratio
0-20	-0.55	0.51	-117	0.40	-0.05	3.08	0.00	-0.48	0.00	-20	617	0	-111	-0.2	-1.0	7.5	-3.7	-2.7	0.0	2.55	0.71
20-40	-0.28	0.69	-23	0.62	0.06	3.19	-1.86	-0.89	-0.14	23	638	-226	-203	-12.3	0.4	17.5	-11.9	-5.0	-0.9	0.36	0.87
40 - 60	-0.19	0.01	-21	0.36	0.04	0.71	-1.66	-0.78	0.03	17	142	-201	-180	2.5	0.5	6.8	-4.1	-3.8	0.6	-1.66	0.23
60 - 80	-0.18	-0.46	-12	0.08	0.00	-0.07	-0.94	-0.71	0.70	0	-14	-114	-163	62.7	0.2	-0.7	-1.2	-3.4	5.1	-1.02	0.00
80 - 100	-0.25	-0.95	-26	-0.32	-0.14	-2.50	1.31	-0.56	1.35	-55	-500	159	-129	121.6	-0.9	-13.7	9.9	-2.9	7.6	-0.54	-0.37
100 - 120	-0.15	-1.28	-5	-0.34	-0.14	-2.66	-1.18	-0.84	1.70	-54	-533	-143	-193	152.7	-0.5	-11.8	3.3	-3.2	12.1	-3.12	-0.23

Denotes an increase in Baseline 3 soil test values compared to Baseline 2 soil test values

Differences in average values between Baseline 3 (irrigated) and Baseline 1 (parent soil)

Depth cm	EC (1:5) dS/m	pH CaCl2	NO3 mg/kg	Org-C %	K meq/100g	Ca meq/100g	Mg meq/100g	Na meq/100g	Al meq/100g	K mg/kg	Ca mg/kg	Mg mg/kg	Na mg/kg	Al mg/kg	K %	Ca %	Mg %	Na %	Al %	ECEC meq/100g	Ca/Mg ratio
0-20	0.25	2.18	41.30	1.87	0.64	12.33	-0.99	-0.22	-0.26	250	2471	-121	-51	-23	1	43	-36	-5	-3	11.50	2.82
20-40	0.20	1.62	27.40	1.62	0.27	8.90	-5.32	-1.16	-0.36	105	1784	-647	-266	-33	1	46	-36	-8	-3	2.33	1.78
40 - 60	0.11	0.69	21.05	1.30	0.18	5.62	-5.23	-1.50	-0.09	70	1126	-635	-346	-8	1	34	-27	-8	0	-1.02	1.03
60 - 80	0.01	0.00	15.46	0.90	0.07	3.91	-3.42	-1.68	0.74	26	783	-416	-387	67	0	23	-19	-10	5	-0.39	0.68
80 - 100	-0.03	-0.66	5.14	0.35	-0.07	1.39	-1.17	-1.50	1.51	-26	278	-142	-345	136	0	9	-8	-10	9	0.17	0.22
100 - 120	0.08	-0.80	4.41	0.17	-0.05	1.11	-1.46	-1.37	-2.71	-21	223	-178	-316	-243	0	7	-4	-8	5	-4.48	0.19

Denotes an increase in Baseline 3 soil test values compared to Baseline 1 soil test values

Attachment 5.

Stage 1B soil test results

STAGE 1 B – SOIL TEST RESULTS

Nutrient	Units	Result- Baseline 1	Result – Baseline 2
Chlorides	mg/kg	140	65
Electrical Conductivity	dS/m	0.21	0.11
pH ($CaCl_2$)	pH units	4.63	4.80
NO_3- Nitrogen extract	mg/kg	53.1	15.5
Phosphorous Colwell	mg/kg	82.8	40.9
Sulphur	mg/kg	10.0	14.4
Organic Carbon	%	2.82	2.98
Copper ex	mg/kg	0.49	<0.5
Zinc ex	mg/kg	4.27	3.3
Manganese ex	mg/kg	32.9	22.0
Boron ex	mg kg	0.62	0.51
Potassium ex	mg/kg	145	224
Potassium ex	meq/100g	0.37	0.57
Calcium ex	mg/kg	429	820
Calcium ex	meq/100g	2.15	4.10
Magnesium ex	mg/kg	305	384
Magnesium ex	meq/100g	2.54	3.20
Sodium ex	mg/kg	245	163
Sodium ex	meq/100g	1.07	0.71
Aluminium ex	mg/kg	16.5	6.30
Aluminium ex	meq/100g	0.18	0.07
Ex Potassium	%	5.89	6.69
Ex Calcium	%	34.0	47.8
Ex Magnesium	%	40.3	37.3
Ex Sodium	%	16.9	8.26
Ex Aluminium	%	2.91	0.82
ECEC	Meq/100g	6.3	8.58