
**LOWER MURRAY RECLAIMED
IRRIGATION AREA ENVIRONMENTAL
MONITORING REPORT
PHASE 1**

JULY 2008

**Lower Murray Reclaimed Irrigation Area
environmental monitoring report**

Phase 1

Lower Murray Reclaimed Irrigation Area environmental monitoring report Phase 1

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SUMMARY

The Commonwealth and South Australian state government is funding (\$22 million) and facilitating a major rehabilitation and restructuring program in the Lower Murray Reclaimed Irrigation Area (LMRIA) in cooperation with irrigators to reduce irrigation water use and pollutant loads returned to the River Murray. Water quality and environmental values (eg recreation, drinking water supplies) in the lower region of the river have been shown to be impacted by pollutant discharges from the LMRIA.

Key elements of the rehabilitation project are upgrading and metering of water infrastructure, and installation of drainage water re-use systems to recycle polluted water on farms.

A monitoring project was established to provide a benchmark on the environmental outcomes and effectiveness of the LMRIA rehabilitation process. The project involved measurement of irrigation and drainage volumes, water quality in the river inlet and drainage channels, farm management (eg stocking rates, fertiliser use), and soil condition at six study locations (Cowirra, Baseby, Wall Flat, Pompoota, Woods Point, and Jervois irrigation areas). A water and pollutant balance model was also developed and calibrated to estimate the sources and volumes of water and pollutants returned to the River Murray from the entire LMRIA, pre- and post-rehabilitation.

This report contains preliminary results and baseline information obtained prior and during the LMRIA rehabilitation project implementation stage (2005–07). The key outcomes of the study to date are as follows:

Water use—Water use per hectare was monitored from 10 different sites with different degrees of rehabilitation completion. The average water use per watering of 0.6 ML/ha for the fully rehabilitated site at Woods Point was one third of the average water use per watering (1.8 ML/ha) for the non-rehabilitated sites. A large proportion of the reduction in water use is achieved by new water delivery infrastructure and lasering of paddocks, but significant additional efficiency gains are achieved following construction of re-use systems. The water balance modelling indicates that full completion of rehabilitation in the LMRIA should result in an estimated 50 GL less water extracted from the river per year.

Drainage and river inlet water quality—*Escheria Coli* (*E Coli*) bacteria, total nitrogen (TN), total phosphorus (TP), and total organic carbon (TOC) concentrations were consistently much higher in the drainage water than the river inflow water, as a result of runoff and drainage from cattle faecal material, fertilisers, and soil constituents. These drainage water constituents show peaks in concentration during the irrigation season. Salt concentrations were also much higher in drainage water, but increased after the end of the irrigation season, as groundwater salt concentrations were not diluted by the less saline irrigation water during this time.

Pollutant loads—Pollutant loads (TP, TN, TOC) were closely linked to flood irrigation events and peaked during the irrigation season. Periodic large rainfall events occasionally make a contribution to sediment loads. Salt (TDS) loads were more constant due to regional saline groundwater inputs. Substantial average reductions in drainage volumes (68% or 40 GL) and pollutant loads (eg TN 70%, TP 79%, *E Coli* 77%) returned to the river from the LMRIA are estimated following completion of rehabilitation. These reductions will result from the improvements in water efficiency lowering drainage volumes and construction of re-use systems to intercept and recycle surface runoff water on farm. Further ongoing monitoring is required to verify these predictions.

Links between pollutant loads, on-farm activities and rainfall events—There was a weak linkage demonstrated between paddock-level farm management activities and drainage water

quality. The dilution and processing of pollutants in the main drainage channels are believed to make the interpretation of paddock level activities complex.

Soil condition—Baseline monitoring of soil condition found current satisfactory levels of key parameters (eg N, P, salinity, and pH) with increases in concentrations of some constituents towards the drain end of irrigation bays.

River Murray water quality—River Murray water quality was analysed from 2002–06 at Mannum, Murray Bridge and Taillem Bend. *E Coli*, NO_x and FRP increase downstream of Mannum and this is likely to be due to discharge from the LMRIA drainage channels and in-river processing of pollutants. Decreases in concentrations of some parameters (TKN, TP, FRP) have been observed in recent years. However, given the current low river flow conditions, we cannot be confident that these trends result from reduced pollutant discharges from the LMRIA.

Environmental costs and benefits—A basic environmental cost–benefit analysis was undertaken to estimate the costs and benefits of the LMRIA rehabilitation project. The net estimated benefits outweighed the costs by greater than a factor of two to three times. The greatest benefit derives from more efficient water use. It should be noted that this is a preliminary and limited analysis and actual social costs could be higher with some irrigators leaving the industry via a government exit package.

Irrigator education—A goal of the study was to increase irrigators' understanding of how farm management can affect water quality. Information on the monitoring study and its results were regularly put in the LMRIA newsletter which goes to all irrigators. The irrigators in the study were also visited by a farm management consultant who discussed their specific results in detail.

The preliminary (Phase 1) results are extremely encouraging for the LMRIA rehabilitation project's goal of improving the quality and quantity of water in the River Murray. The monitoring study is being continued until mid–2009 (Phase 2) to attempt to fully assess the benefits of the LMRIA rehabilitation programme. However, the current drought situation, low river flows and restricted irrigation water allocations makes evaluating monitoring data and the programme's outcomes difficult.

INTRODUCTION

Background

There is approximately 5,200 ha of land on the former floodplain of the River Murray between Mannum and Wellington. This is known collectively as the Lower Murray Reclaimed Irrigation Area (LMRIA). Most of this land was drained and developed for agriculture between 1880 and 1940 with levee banks constructed along the river's edge to control flooding. Since completion of the barrages at the mouth of the Murray in 1940, the reclaimed areas have been 1.0–1.5 m below the river level. There are 27 separate irrigation areas on the LMRIA with irrigation currently used to grow pasture on 24 areas and three are no longer commercially irrigated. Dairy farming is the predominant land use with a smaller area used for beef cattle, fodder production and lifestyle farming.

Flood-irrigation through sluices and siphons is used to irrigate pastures in the LMRIA. The total annual water allocation from the River Murray for the LMRIA is 89.5 GL including an environmental land management allocation (RMCWMB 2004). Prior to 2005, water off-takes were not formally metered. Flood irrigation is the preferred irrigation method because of its benefits in reducing soil salinisation. The saline groundwater table on the floodplain is close (ca. 1 m below under normal river levels) to the paddock surface and can reach the soil surface through upward groundwater pressure and capillary action (DWLBC 2003). As flood irrigation uses gravity, its energy cost is low, as is its maintenance requirements and capital cost.

Historically, some of the irrigation practices in the LMRIA have been inefficient due to poor condition of the water delivery infrastructure, and, in some instances, poor management practices resulting in excess surface irrigation runoff. As a result large volumes of drainage water containing pollutants such as nutrients and pathogens have been pumped back to the river from the LMRIA (Murray & Philcox 1995, Eco-Management Services 2003). This discharge is at a level that poses a risk to the river's environmental value eg aquatic ecosystem, recreational, and drinking water supply (EPA 2001).

The Federal and South Australian state government is funding (\$22 million) and facilitating a major rehabilitation and restructuring program, in cooperation with irrigators, of the LMRIA to reduce water use and pollutant loads returned to the River Murray. Various infrastructure and farm management improvements are currently in progress as part of the rehabilitation project including:

- **New water delivery infrastructure**—New water delivery infrastructure (siphons/sluices, meters, inlet channels) is being installed to improve the efficiency of the flood-irrigated water delivery. The Department of Water Land and Biodiversity Conservation (DWLBC) have set the requirement that all water off-takes must be metered by 30 June 2007.
- **Laser grading of paddock surfaces**—Laser grading of paddocks is being undertaken in conjunction with water delivery infrastructure upgrades. Laser-levelling results in a smoothly sloping surface that delivers water quickly and efficiently along the irrigation bay (Philcox 2002). This substantially reduces irrigation and sub-surface drainage volumes.
- **Runoff re-use system construction**—re-use systems (> 50 kL/ha capacity) are being constructed that recycle excess surface irrigation runoff water and pollutants (that were previously returned to the river) back onto the farm (EPA 2005). The LMRIA rehabilitation programme has set the requirement of no return of surface irrigation runoff to the river by 30 June 2008.
- **Rebuilding of stock laneways**—stock laneways are being resurfaced and regraded to slope away from drainage channels. This will minimise the input of cattle manure to channels during normal farm operations and large rainfall events when runoff occurs from these areas.

- **environment improvement and management program (EIMP) implementation**—EIMPs are tailored to individual farms to ensure staged improvements to overall farm environmental management. These programmes are a legislative requirement for irrigators to receive a temporary exemption from the *Environment Protection (Water Quality) Policy 2003*. An EIMP includes the major infrastructure improvements noted above and other actions such as fencing of channels and levee banks to prevent stock access to water, bridge bunding and management of fertiliser applications.

Approximately 4,200 ha of land will be rehabilitated in the LMRIA with the remaining approximately 1,000 ha retired from commercial farming. It is expected that irrigation water use and pollutant loads from the flood-irrigated pastures will be substantially reduced following this rehabilitation program.

Study objectives

The overall objective of the monitoring study was to provide a benchmark for measuring how effective the LMRIA rehabilitation project is in reducing irrigation water use and the loadings of pollutants returned to the river. The project's specific objectives were to:

- monitor changes in flood irrigation water use and loads of pollutants returned to the River Murray during rehabilitation of the LMRIA
- assess changes or variation in water quality and quantity that were due to rehabilitation activities, seasonal or climatic influences (eg rainfall), or farm management practices (eg irrigation volumes, fertiliser applications, stocking rates)
- establish a baseline of soil condition (eg salt, nutrients) to allow the assessment of the effects of rehabilitation
- increase the understanding of the irrigation community with respect to the importance of on-farm changes for protection of river water quality
- enable an initial assessment of the rehabilitation project progress and to identify any areas where the project approach could be modified and improved
- establish a baseline for future monitoring programmes in the LMRIA
- assist the Environment Protection Authority (EPA) and DWLBC in making policy decisions regarding the use, re-use and disposal of water from the LMRIA.

Six study locations were selected for the study; Cowirra, Baseby, Wall Flat, Pompoota, Woods Point, and Jervois irrigation areas (Figure 1).

The project is planned to be ongoing until 2009 when the major rehabilitation works will have been completed.

Links to strategic plans and regional initiatives

The project has linkages to the following strategic plans:

- *South Australian State Strategic Plan*—Objective 3 Obtaining sustainability
- *EPA Strategic Plan 2005–08*—Environmental Goal 2 Water quality that meets agreed environmental values and Environmental Goal 4 Sustainable land use
- South Australian Murray Darling Basin Natural Resource Management Board (SAMDB NRMB)—regional plan and investment strategy
- *Mannum to Wellington Local Action Plan*—Mannum to Wellington Local Action Planning Committee.

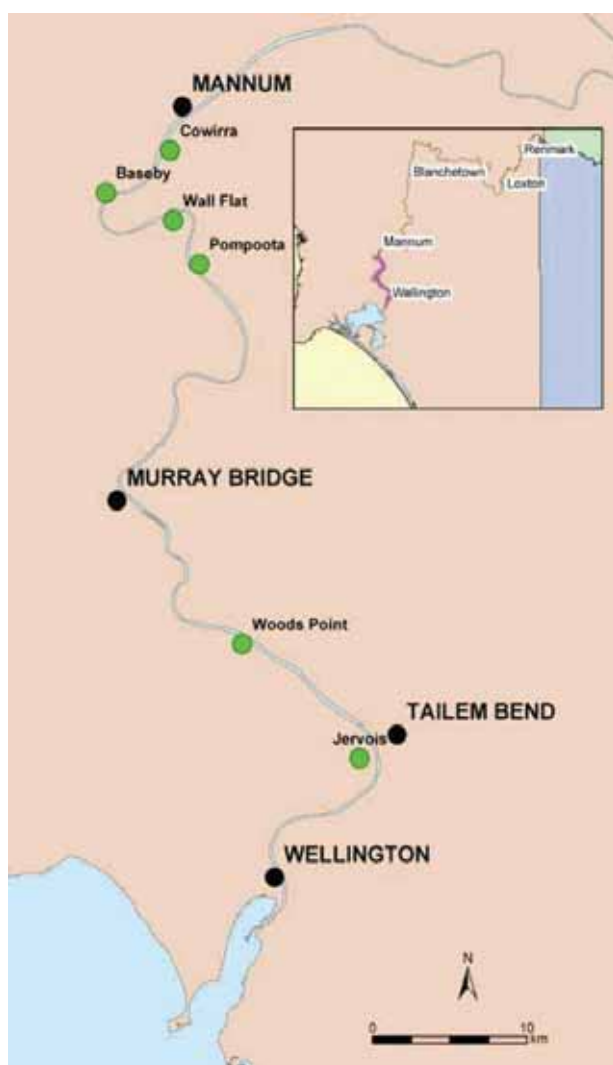


Figure 1 Study locations (green circles) and townships (black circles) on the Lower Murray River

Conceptual diagram of an irrigation area

The following conceptual diagram illustrates a typical flood irrigation area in the LMRIA (Figure 2). There are various potential sources of water and pollutants to the channel ('salt drain') that collects drainage water which is subsequently pumped into to the River Murray. Flood irrigation of pastures generates runoff and sub-surface drainage to the salt drain. The salt drains also receive regional and local irrigation groundwater inputs and occasional stormwater runoff from adjacent highland areas, including townships in some locations. Laneways and milking shed yards may be large pollutant sources during rainfall events. Birds can also be present in large numbers on the floodplain during waterings and may contribute to pollutant loads.

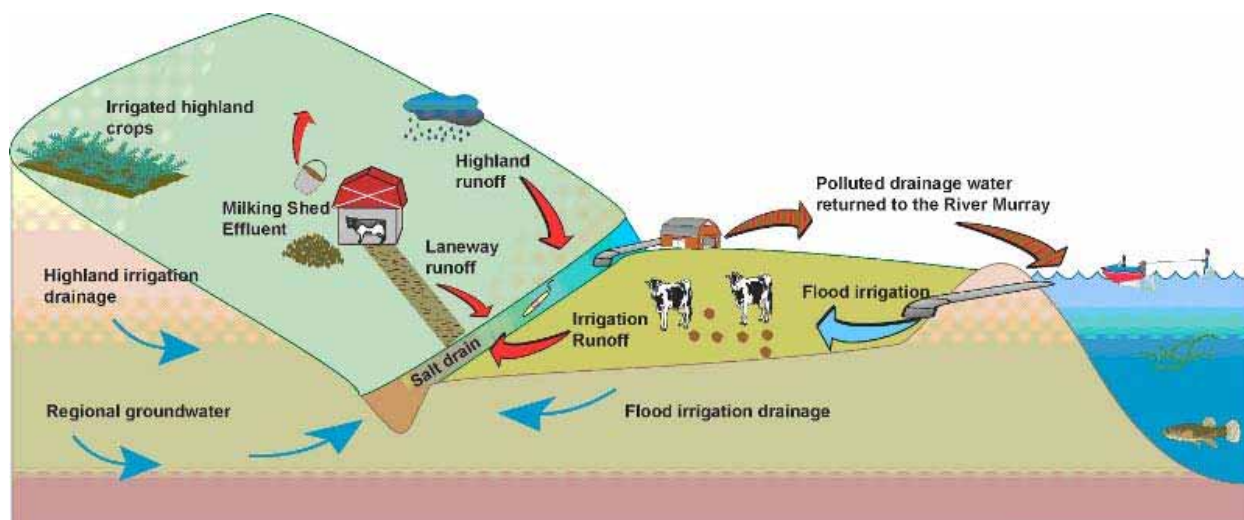


Figure 2 Conceptual diagram of the LMRIA showing pollutant sources

Monitoring setup

At each of the study locations several sampling sites were established at river inflow sluices and drainage outflow points on the salt drain (Figures 3–9).

Water flows were measured by various types of flow meters which were independently calibrated approximately every three months for the duration of the study (see Table 1). Flow data was downloaded and processed at this time. Composite auto samplers were installed at each sampling locations to collect drainage water samples. A sub-sample was taken when a particular water flow (measured by the meters at the same site, typically 0.2–0.5 ML) passed the sampling station. The sub-sample was pumped into the collection tub and mixed with previous sub-samples. The composite sample (aggregate of all sub-samples during the sampling period) is considered to give a better representation of water quality passing a particular location than discrete grab samples (only one point in time). The disadvantage is the composite sample can only be analysed for water quality constituents that can be preserved in the tub for the sampling period (typically 1–2 weeks). A telemetry system was installed to enable the drainage outflow stations to be monitored remotely and the auto sampler increment varied if necessary.

Table 1 Sampling locations and equipment

Monitoring site ID	Type of sample site	Equipment detail	Cross-sectional area (mm)
Cowirra irrigated area (within study boundary) = 152.4 ha			
CF1	Drainage outflow sampling	Unidata StarFlow & composite autosampler	600 pipe
CF2	Sluice	Propellor Meter	600*620
CF3	Sluice & river sampling	Unidata StarFlow (with LCD screen)	600*620
CF4	Sluice	Existing Tyco Irriflow Mag head	600 pipe
Baseby irrigated area (within study boundary) = 54.2 ha			
BO	Drainage outflow sampling	Mace AgriFlo & composite autosampler	256 pipe
BI1	Sluice & river sampling	Unidata StarFlow (with LCD screen)	650*700

Monitoring site ID	Type of sample site	Equipment detail	Cross-sectional area (mm)
Wall Flat irrigated area (within study boundary) = 202.3 ha			
WFO	Drainage outflow & sampling	Unidata StarFlow & composite autosampler	800 pipe
WFI	Sluice & river sampling	Unidata StarFlow (with LCD screen)	470 pipe
Pompoota irrigated area (within study boundary) = 51.1 ha			
PA1	Drainage outflow sampling	Unidata StarFlow & composite autosampler	1200*700
PA3	Sluice & river sampling	Unidata StarFlow (with LCD screen)	600*640
Woods Point irrigated area (within study boundary) = 128.4 ha			
WP2	Drainage outflow sampling	Unidata StarFlow	900 pipe
WP3	Sluice	Mace AgriFlo	600 pipe
WP4	Sluice	Unidata Propellor Meter	1205 channel
WP6	River sampling site	n/a	n/a
Jervois irrigated area (within study boundary) = 66.1 ha			
JG2	Sluice	Propellor Meter	600*650
JG3	Sluice & river sampling	Unidata StarFlow (with LCD screen)	600*650
JG5	Drainage outflow sampling	Unidata StarFlow	600 pipe



Figure 3 Clockwise from top left, monitoring station on a drainage channel, pump shed with an auto sampler and flow logging equipment, and pump discharge to the River Murray



Figure 4 Cowirra irrigation area sample sites



Figure 5 Baseby irrigation area sample sites



Figure 6 Wall Flat irrigation area sample sites



Figure 7 Pompoota irrigation area sample sites



Figure 8 Woods Point irrigation area sample sites



Figure 9 Jervois irrigation area sample sites

Water quality

Water quality samples were taken at the drainage outflow sampling site and a representative river sluice inlet channel site at each of the six sampling locations (see Table 1). Samples were collected approximately weekly during the irrigation season (September–April) and fortnightly during the non-irrigation season (May–August).

Table 2 summarises the analyses and sampling methods that were undertaken at the monitoring sites. Water quality parameters measured were: *Escherichia coli* (*E Coli*), total nitrogen (TN), ammonia (NH₄), oxidised nitrogen (NO_x), total phosphorus (TP), filtered reactive phosphorus (FRP), total organic carbon (TOC), total dissolved solids (TDS), chloride (Cl⁻), turbidity (TUR), and total suspended solids (TSS).

Either grab or composite samples were collected for different water quality constituents depending on whether the constituent could be preserved in the auto sampler tub between sample collections. Composite samples (for TN, TP, TDS, TSS, TOC, Cl) were taken after mixing the auto sampler tub with a clean plastic rod. Grab samples (for *E Coli*, NH₄, NO_x, FRP, turbidity) were taken by dipping a clean sampling bottle into the water. Samples were transported on ice to the laboratory. The samples were collected and analysed by a laboratory holding National Association of Testing Authorities (NATA) accreditation (to ISO 17025). Table 2 lists the sample analysis methods.

A separate inter-agency water quality monitoring program collects approximately weekly river water samples from SA Water’s potable supply off-takes at Mannum, Murray Bridge and Tailm Bend. These data were used to assess longer term trends in River Murray water quality.

Table 2 Sample analysis methods summary

Parameter	Analytical Methods (see APHA 2005)	Detection limit	Sampling method (and location)
Total Dissolved Solids	APHA 2510A & B	0.1 µS/cm	Composite (salt drain) & grab (river)
Turbidity	APHA, 2130B	0.05 NTU	Grab (salt drain & river)
Total suspended solids	APHA, 2540D	1 mg/L	Composite (salt drain)
Total Nitrogen	APHA 4500, NorgD and calculation for other N species	0.01 mg/L	Composite (salt drain) & grab (river)
Ammonia	APHA 4500-NH3 H	0.01 mg/L	Grab (salt drain)
Oxidised nitrogen	APHA 4110B	0.02 mg/L	Grab (salt drain & river)
Total phosphorus	APHA 4500P	0.01 mg/L	Composite (salt drain) & grab (river)
Filtered reactive phosphorus	APHA 4500P	0.01 mg/L	Grab (salt drain & river)
Total organic carbon	APHA 5310B	1 mg/L	Composite (salt drain) & grab (river)
<i>E Coli</i>	Australian Standard 4376:7	<1 CFU/100mL	Grab (salt drain & river)
Chloride	APHA 4110B	1 mg/L	Composite (salt drain) & grab (river)

A brief description of the various water quality parameters follows.

Salt: measured by Total Dissolved Solids(TDS), Electrical Conductivity (EC)

Total dissolved solids (TDS) is a measure of the concentration of dissolved salt (eg sodium, calcium, magnesium, chloride) in water and is usually expressed in milligrams per litre (mg/L). Electrical conductivity (EC) is another way to estimate the concentration of dissolved salts in water and is usually expressed in micro-Siemens per cm ($\mu\text{S}/\text{cm}$). High levels of salt (> 1000 EC) in water used for pasture irrigation may cause a decline in pasture quality or even the death of pasture plants.

EC can be calculated from TDS approximately by: $\text{EC} = \text{TDS} \div 0.55$

TDS can be calculated from EC approximately by: $\text{TDS} = \text{EC} \times 0.55$

The LMRIA drainage channels receive highly saline groundwater inputs (see Figure 2) from the wider regional catchment area.

Nutrients: total nitrogen (TN), ammonia (NH_4), oxidised nitrogen (NO_x , sum of nitrate and nitrite) total phosphorus (TP), filtered reactive phosphorus (FRP)

Nitrogen (N) and Phosphorus (P) are essential nutrients for plant (eg pasture, aquatic algae) growth. High levels of nutrients are often found in dairy drainage water from wash-off or leaching of animal faeces, urine and fertiliser. Pakrou and Dillion (2000) found approximately 85–90% of nitrogen ingested by dairy cows becomes excreta (urine and dung). N and P can exist in different forms in water. Total nitrogen (TN) is the sum total of all nitrogen forms present in the water. Organic nitrogen is a measure of the nitrogen within plant and other organic materials. It is not immediately available to the biota, but provides a store of nitrogen that may become available in the medium to long term following processing and subsequent release of soluble nutrients by micro-organisms. Ammonia (NH_4) is a readily bioavailable source of nitrogen for plants and algae. It can be toxic to aquatic organisms (particularly the un-ionised NH_3 form at high pH), but it is generally not persistent or cumulative in oxygenated waters. Total Kjeldahl Nitrogen (TKN) is an analytical measurement of nitrogen contained in both the reduced forms of organic nitrogen and ammonia. Nitrate (NO_3) is the most stable form of dissolved nitrogen in oxygenated waters and is readily bioavailable to algae. Oxidised nitrogen (NO_x) is the sum of nitrate, and the less stable oxidised form, nitrite (NO_2).

Soluble and particulate forms of organic and inorganic phosphorus are included in the measure of total phosphorus (TP). Dissolved or total reactive phosphate is the most bioavailable form of phosphorus, although it readily attaches to soil particles, particularly clay (Webster *et al* 2001). Runoff from LMRIA pastures that have been recently fertilised can be high in phosphorus (Fleming *et al* 2003a).

If nutrient levels become sufficiently high in receiving waters, and suitable environmental triggers are present (eg suitable temperature and flow), algal blooms can result.

Pathogens: measured by Indicator bacteria (*E Coli*)

E Coli bacteria occur in the digestive tracts of warm-blooded animals and are good indicators of the presence of more dangerous pathogens (eg hepatitis, *Cryptosporidium* and *Giardia*) which are potentially disease causing to people contacting or drinking polluted water. High levels of *E Coli* and pathogens are found in dairy farm runoff in the LMRIA (Adcock 2000, Eco-Management Services 2003). Sub-surface drainage contains lower levels due to removal during passage through the soil (EPA 2005). Birds and other animals can also contribute *E Coli* to drainage water.

Suspended Solid Material: measured by Turbidity (TUR) and Total Suspended Solids (TSS)

Turbidity (TUR) and Total Suspended Solids (TSS) are a measure of the amount of suspended material such as silt, clay, and other debris in water. Total suspended solids are measured from the weight of material retained on a filter while turbidity is measured by light scattering.

High levels of turbidity/suspended solids can reduce light penetration and algal photosynthesis, cause smothering of aquatic habitats, and clogging of fish gills. The River Murray in South Australia has high ambient turbidity levels resulting predominantly from upstream inputs from the Darling River.

Organic material: measured by Total Organic Carbon (TOC)

Total organic carbon (TOC) is a measure of the carbon content of dissolved and undissolved organic matter in the water. High TOC levels in water may indicate animal waste contamination. As organic carbon is food for microbes (which consume dissolved oxygen) discharges that contain high levels of organic carbon may result in oxygen depletion of receiving waters. Potable water supplies can also be affected, as organic carbon consumes chlorine, reducing the residual chlorine in treated water, increasing treatment costs and potentially producing toxic by products.

Farm management data

Farm management data (irrigation timings, stocking rates, fertiliser applications) was provided by irrigators in the study for a continuous period of approximately 12 months. Appendix 1 shows an example of a farm management information sheet that was completed each month. This information was collected to determine whether there were any water quality impacts which could be attributed to farm management activities. For example, likely water quality impacts will occur after a paddock has been fertilised and then immediately watered. In some instances where equipment damage or malfunction occurred, watering volume estimations were made from the farm management data (date of watering and area watered) and previous measured watering volumes¹.

A goal of the study was also to increase irrigators' understanding of how farm management can affect water quality. Information on the monitoring study and its results was regularly put in the LMRIA newsletter which goes to all irrigators. The irrigators within the study were also visited by a farm management consultant who discussed their specific results in detail.

Soil sampling and analysis

Soil samples were collected from the river, middle and drain ends of irrigation bays in the study. Every second bay was sampled to reduce the total number of samples and subsequent analysis cost. It was anticipated, based on previous data, that this would not significantly affect the overall results. Sampling from discrete sites within a paddock has been found to be more accurate than transect based sampling for reliable results in long term comparative sampling (Friesen and Blair 1984).

Individual soil cores were collected to a depth of 10 cm using a Hamilton Bucket Sampler. These cores were not sub-sampled. The samples were oven dried at 40°C for 24 hours prior to dispatch to a NATA-accredited laboratory. The soil samples were re-dried, ground and sieved prior to sub-sampling and analysis for: nitrate (NO₃-N), ammonium nitrogen (NH₄-N), colwell phosphorous (P), potassium (K), sulphur (S), organic carbon (Org-C), iron (Fe), salinity, and pH (in calcium chloride, CaCl₂).

¹ There is some uncertainty in this estimation as river level can greatly affect flood-irrigation flow rates.

Two of the farmers in the study (at Woods Point and Wall Flat) indicated that some fertiliser had been spread recently. In these paddocks, the top 10 mm of surface soil was removed prior to taking the sub-sample. This was done to reduce any contamination from fertiliser granules (possibly undissolved or only partially dissolved) but contamination may still have occurred in some samples. To provide benefit to farmers involved in the study, fertiliser recommendations were made based upon the results. This generally involved a maintenance application of fertiliser only, due to high ambient nutrient levels in the soil of the LMRIA.

Water Balance and Pollutant Load Model

As part of the project, a water and pollutant balance model for the entire LMRIA was developed and calibrated (Tonkins 2007). The model aimed to determine reliable estimates of the drainage components that enter the main drainage channel and are pumped into the river. Drainage volumes and pollutant loads (TP, FRP, TN, TKN, NO_x, TDS, *E Coli*) were estimated for the pre- and post-rehabilitation scenarios.

A continuous simulation model was used to estimate the frequency and magnitude of rainfall runoff being generated from different land uses (irrigated floodplain and highland areas, roads and buildings, and dry land catchments) that contribute to the total drainage for a particular irrigation area. The modelling process comprised of a number of steps (Figure 10). This included using a spreadsheet decision support model to schedule irrigation and a continuous simulation runoff model called ‘MUSIC’ developed by the Cooperative Research Centre for Catchment Hydrology to determine the runoff from each land use type.

The estimates of stormwater runoff were incorporated into a spreadsheet-based water balance and pollutant model to determine the drainage volumes and pollutant loads being generated from each irrigation area. The models were calibrated against drainage volumes estimated from recorded pump hours and calibrated pump flows (Fleming & Gepp 2002), measured salt drain salinities, and pollutant concentrations. Calculating flows from pump hours can lead to errors due to wear and tear on the pump impellers between calibrations. However, the model calibrated well against the measured salinities. Once calibrated the models were run over a 30-year period. See Tonkins (2007) for more detail.

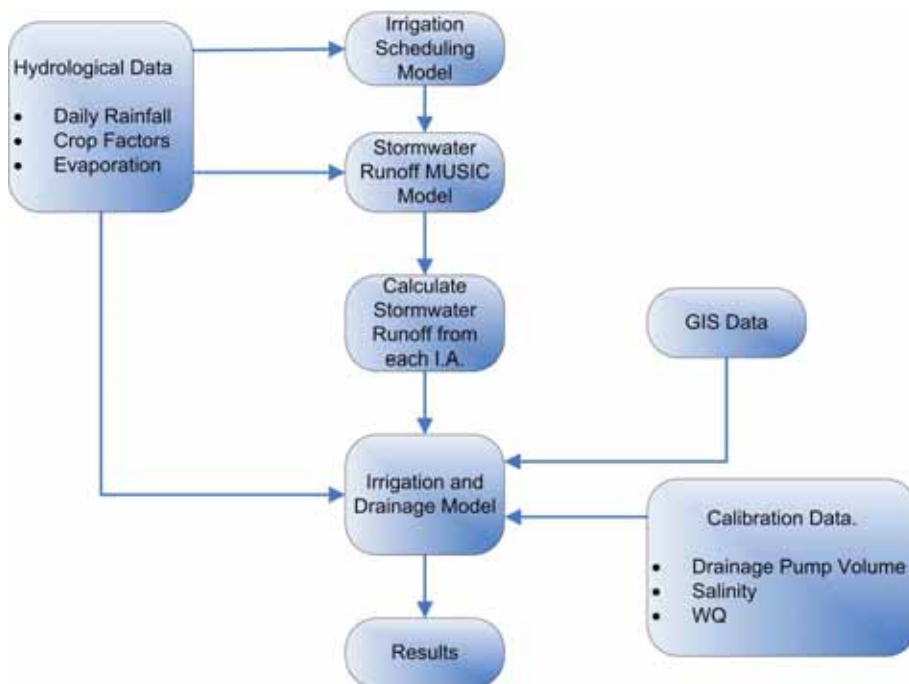


Figure 10 Modelling process flow chart

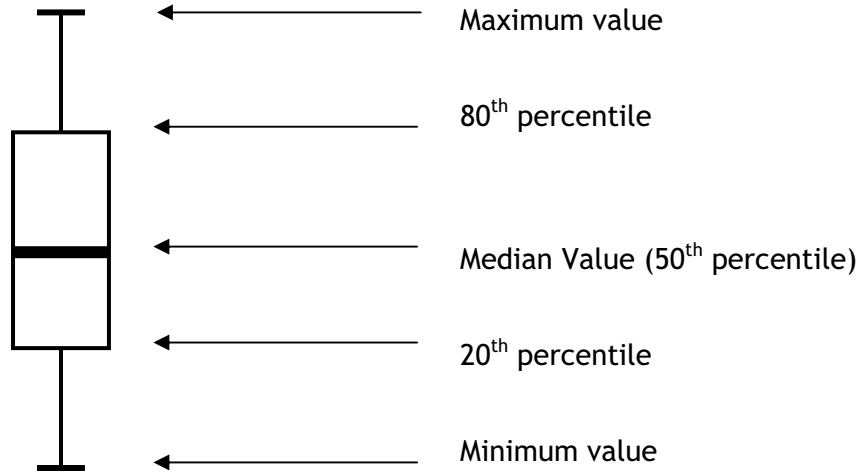
Calculations and statistical procedures

Load Calculations

Loads were calculated by multiplying the measured flow-weighted concentration of a particular parameter by the volume of water discharged during a particular time period.

Graphical display of data

Box and whisker plots are used in this report to display and summarise data. The illustration below is a guide to the various components of the box and whisker plots in the current study.



Correlation between pollutant loads, farm management factors, season and rainfall

To determine any relationships between pollutant loads and farm management activities and other events (eg irrigation, rainfall), various farm management factors were quantified as follows:

- Fertiliser was considered by calculating a factor which multiplied the rate of nutrient (nitrogen or phosphorus) by the area applied. This factor was reduced in proportion to the time elapsed between fertiliser application and irrigation of the paddock. That is, for the same rate of fertiliser, the nitrogen (N_f) or phosphorus (P_f) factor would be higher if irrigation occurred immediately after fertilising, than if several days had elapsed between these events. Ten days after fertilisation the N_f and P_f factors were scaled back to reach zero.
- At each grazing, a cow factor (C_f) was calculated by multiplying the paddock area by the number of cow days (1 cow grazing for one day = 1 cow day). This factor was then scaled back to reach zero after 14 days.
- Calculations were performed on management activities occurring only on those paddocks which were subsequently watered. Within the time period contributing to each water sample (the week or fortnight), the relevant farm management factors were summed over all of the contributing paddocks during the contributing time period. This resulted in a N_f , P_f , C_f and drainage volume for each sample period.
- The season (irrigation or non-irrigation season) and total rainfall in the antecedent period before a sample was collected was also used as a factor in subsequent statistical analyses. Rainfall data from Bureau of Meteorology sites at Mannum, Murray Bridge and Tailem Bend were used. The rainfall station closest to a particular irrigation area (see Figure 1) was used in the analyses; however there may be more localised rainfall variations which are not accounted for adequately in this approach.

The various factors were statistically tested against the measured pollutant loads using a multiple linear regression model to determine if there were demonstrable links. Pair-wise correlations among the various management factors (independent variables) and individual

pollutant loads (dependent variable) were made for each site. The quality of the model prediction was evaluated by computing the multiple coefficient of correlation (R^2). This is the coefficient of correlation between the dependent variable and the model predicted dependent variable. Partial regression coefficients were also calculated to give the amount that the dependent variable increases when one independent variable is increased by one unit. The statistical significance of each particular regression coefficient was tested using a standard F-test with the null hypothesis stating that the associated partial coefficient of correlation is zero.

Generally this type of model has the provision that the various farm management factors are not too strongly correlated among themselves for the partial regression coefficients to be meaningful. It is likely that nitrogen fertilisation (high N_f) will affect drainage water nitrogen content and phosphorus fertilisation (high P_f) will affect drainage water phosphorus content. However, a mixed N and P fertiliser would affect both nitrogen and phosphorus and their independent effects would be difficult, if not impossible, to separate. Grazing is likely to affect nitrogen, phosphorus, organic carbon and bacteria content simultaneously. However, a linear-based multiple regression model was still considered appropriate given the somewhat self-contained (in terms of defined inputs resulting in defined outputs) system. The statistical analyses were not performed for Wall Flat and Pompoota as the farm management of other irrigators outside of the study area could not be controlled or accounted for. Volume is excluded as an independent variable input in the regression analyses because it contributes directly to total loads of pollutants.

Trends in river water quality

Trends in river water quality from 2002–07 at Mannum, Murray Bridge and Tailem Bend were statistically analysed using the non-parametric Seasonal Kendall test (Helsel and Hirsch 1992). Seasonal variation must be accounted for, or removed, in order to better discern the trend in a water quality parameter over time. Most concentrations in surface waters show seasonal trends, as does river flow. Given the present drought situation and low river flows, it could also be particularly important to consider flow influences during trend analysis. The correlation of flow with water quality was examined using Locally Weighted Scatterplot Smoothing or LOWESS (see Helsel and Hirsch 1992). These analyses showed there was generally a poor correlation between flow and most water quality parameters so flow corrections were not possible. This is likely due to the regulated nature of the River Murray meaning water quality or flow outcomes are not immediately linked to catchment runoff events. Other additional causes of seasonal patterns include biological activity (eg greater uptake of nutrients by algae in spring–summer due to higher sunlight and temperature levels) or management activities (eg increased irrigation and fertilisation at certain times of year).

RESULTS AND DISCUSSION

Water quality

A summary of the water quality results for each sampling site is shown in Table 3. The water quality data separated into irrigation and non-irrigation seasons is summarised in Table 4. Water quality concentrations are within similar ranges to that found in previous studies in the LMRIA (Eco-Management Services 2003, EPA 2005).

Salt (TDS) concentrations were consistently higher in the drainage water than the river inflow water (Figure 11). This is to be expected, as the drainage channels intercept the saline groundwater arising in the local and regional catchment. Salt concentrations in the drainage water increased significantly after the end of the irrigation season, as groundwater salt concentrations were not diluted by irrigation water during this time (Figure 19 and Table 4). However, the Jervois site had a low salt concentration in the drainage channel in winter compared to the other sites. This finding is believed to be due to a leaking sluice and water pipeline continually inputting fresh river water into the drainage system.

E Coli concentrations were typically an order of magnitude higher in the drainage water than the river inflow water (Figure 12). This finding is largely due to the bacteria contained in stock faeces being washed into drainage channels during flood irrigation (EPA 2005). Note that the 'river' sample in these graphs is taken in the inlet channel and values should not be taken as reflective of ambient river concentration as there is less water circulation and flushing in this area, and other potential inputs (eg birds in riparian zone). *E Coli* levels generally decreased significantly during winter months when irrigation ceased and there was limited wash off of faecal material (Figure 20). The lower temperatures and higher salinities in the drains in winter may also inhibit bacteria reproduction. The large rainfall event at the end of June 2005 resulted in an increase in *E Coli* levels at several locations. These inputs are likely to be a result of runoff from dairy yards and laneways on the highland catchment areas. Total nitrogen (TN) concentrations were consistently much higher in the drainage water than the river inflow water, as a result of runoff and drainage of nitrogen from animal faeces and fertilisers (Figure 13). Total nitrogen (TN) concentrations decreased slightly on average during the non-irrigation season (Table 4), but the time series plot shows a great deal of variability between and within the sites (Figure 21). Ammonia (NH_4) concentrations also decreased by about 20% in the non-irrigation season (Table 4). Oxidised nitrogen (NO_x) was generally higher in the drainage water than the river inflow water (Figure 14). This could be a result of dissolution and wash off of ammonia and nitrate from the soil surface (followed by oxidation of ammonia to nitrate in the drainage channels) or increased irrigation-induced leaching of nitrate through the soil profile. The time series plot for NO_x was highly variable and showed no apparent trend with season (Figure 22). TN and NO_x increased during the large rainfall event at the end of June 2005. This finding may have been due to a wash-off from dairy yards and laneways, and flushing of nitrogen through the soil profile of the regional catchment area. The flood-irrigation bays which had not been irrigated recently could also have contributed to this increase.

NH_4 and NO_x formed only a small proportion of the TN concentration indicating that most of the nitrogen in the surface runoff was in the organic-N form (Table 3). This finding is consistent with the nitrogen sources being cattle manure and nitrogen fertilisers (typically urea) and a previous study found similar results (EPA 2005). Ammonia was the next highest nitrogen form followed by NO_x . Ammonia levels in sub-surface drainage have been found to be lower than the surface runoff in the LMRIA (EPA 2005). This finding is due to the removal of positively charged ammonium ions by soil particles while nitrate is more readily able to pass through the soil into groundwater (Tonkin Consulting 2004).

Total phosphorus (TP) and filtered reactive phosphorus (FRP) concentrations were consistently much higher in the drainage water than the river inflow water (Figures 15 and 16 respectively). This finding is a result of runoff and drainage of phosphorus from animal faeces and fertilisers. TP and FRP concentrations generally decreased in the non-irrigation season when there would be lower amounts of manure and fertiliser washed off the end of paddocks (Figures 23 and 24 respectively). The exception to this finding was for the large rainfall event at the end of June 2005 where spikes in TP were observed. In the river inlet channel, FRP formed on average 15% of the TP concentration while in the drainage water it formed 60%. This finding indicates that the drainage channels in the LMRIA supply a large bio-available load of phosphorus to the river.

Total organic carbon (TOC) concentrations were consistently higher in the drainage water than the river inflow water (Figure 17). This finding is presumably due to the runoff and sub-surface drainage including organic content originating from stock manure (EPA 2005). In general, TOC concentrations in the drainage water decreased significantly in the non-irrigation season when there were lower amounts of organic material washed off the end of paddocks or through the soil profile (Figure 25). The large rainfall event at the end of June 2005 resulted in increased output of organic carbon for several weeks from the study locations. This is likely to be due to increased groundwater inputs and/or ongoing breakdown of organic material deposited in the drain from the highland catchment (eg from dairy yard runoff).

Median turbidity levels in the drains were similar to those found in the river inlet channel (Figure 18). The large rainfall event at the end of June 2005 resulted in large turbidity spikes at several sites, indicating substantial erosion and runoff of sediment from surrounding highland catchments (Figure 26).

Appendix 2 contains the raw water quality data.

Table 3 Summary of water quality results by site

Site	Statistic	E Coli	TN	NH4	NOx	TP	FRP	TOC	TDS	Turbidity	Cl	SS								
		CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	mg/L	mg/L								
COWIRRA	median	1,360	0.70	3.95	1.05	0.05	0.28	0.09	2.15	0.01	1.5	6.0	20	230	1,333	31	26	530	46	
	20th percentile	538	0.50	2.86	0.53	0.03	0.12	0.06	1.46	0.00	0.7	5.0	13	192	1,052	22	20	414	33	
	80th percentile	4,000	0.82	5.44	2.20	0.07	0.76	0.11	3.04	0.01	2.7	7.0	26	246	2,689	45	38	1,780	69	
	n	52	76	52	74	76	52	74	52	74	52	74	52	74	52	74	52	74	53	74
	median	552	0.70	3.40	0.43	0.05	0.02	0.08	1.30	0.01	0.9	6.0	26	230	2,603	29	21	1,500	38	
BASEBY	20th percentile	170	0.48	2.50	0.10	0.03	0.01	0.06	0.80	0.01	0.5	5.0	19	200	974	20	9	430	19	
	80th percentile	2,960	0.82	4.60	1.30	0.09	0.16	0.11	1.88	0.01	1.4	7.0	31	249	7,980	45	34	4,600	65	
	n	52	76	52	72	76	52	75	52	72	52	76	52	72	52	72	52	72	53	72
	median	800	0.70	1.90	0.38	0.03	0.13	0.09	0.98	0.01	0.7	6.0	13	240	1,552	31	27	700	31	
	20th percentile	200	0.50	1.50	0.18	0.01	0.05	0.06	0.50	0.01	0.2	5.0	11	210	1,100	21	14	408	18	
POMPOOTA	80th percentile	4,000	0.80	2.50	0.66	0.05	0.33	0.11	1.50	0.02	1.0	7.0	16	265	2,600	45	38	1,200	43	
	n	52	76	53	76	77	52	76	53	77	53	76	53	76	53	76	53	76	53	76
	median	223	0.60	2.60	0.36	0.08	0.06	0.09	0.97	0.01	0.7	6.0	18	240	2,500	30	32	1,200	56	
	20th percentile	100	0.50	2.10	0.17	0.04	0.01	0.06	0.57	0.01	0.1	5.0	15	210	1,601	23	20	764	35	
	80th percentile	4,000	0.80	3.40	0.62	0.11	0.24	0.11	1.42	0.04	1.5	7.0	22	263	4,900	45	50	2,860	88	
n	51	76	52	75	76	52	76	52	75	52	76	52	75	52	75	52	75	53	75	

Site	Statistic	E Coli	TN	NH4	NOx	TP	FRP	TOC	TDS	Turbidity	Cl	SS									
		RIVER SALT RIVER SALT RIVER SALT RIVER SALT RIVER SALT RIVER SALT RIVER SALT RIVER SALT RIVER SALT RIVER SALT RIVER SALT RIVER SALT RIVER SALT	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	mg/L	mg/L									
WOODS POINT	median	885	7,500	0.70	3.80	0.46	0.09	0.18	0.11	1.50	0.02	0.8	6.0	22	263	1,300	38	40	520	71	
	20th percentile	253	880	0.52	3.00	0.22	0.06	0.06	0.08	0.74	0.02	0.2	5.0	17	224	750	26	23	380	37	
	80th percentile	4,000	57,600	0.85	5.40	0.76	0.12	0.47	0.14	2.44	0.03	1.9	7.0	30	294	2,900	45	57	1,700	99	
	n	48	74	48	74	48	74	48	74	48	74	48	74	48	74	48	74	48	74	53	74
JERVOIS	median	1,000	4,000	0.70	2.00	0.18	0.11	0.10	0.11	0.76	0.03	0.1	6.0	12	265	580	37	40	180	50	
	20th percentile	300	770	0.55	1.20	0.10	0.07	0.04	0.08	0.26	0.02	0.0	4.2	8	230	460	26	30	140	38	
	80th percentile	5,000	21,120	0.80	2.80	0.34	0.13	0.27	0.14	1.10	0.04	0.6	7.0	16	306	810	45	55	266	75	
	n	51	75	52	73	76	51	75	52	73	52	76	52	52	65	52	73	52	73	52	73
TOTAL	median	861	4,570	0.70	2.90	0.40	0.06	0.12	0.09	1.20	0.01	0.73	6.0	17	241	1,400	32	31	630	47	
	20th percentile	200	630	0.50	1.90	0.16	0.03	0.02	0.07	0.59	0.01	0.21	5	13	210	784	23	19	300	26	
	80th percentile	4,000	24,600	0.80	4.40	0.97	0.10	0.38	0.12	2.00	0.03	1.50	7	25	270	3,500	45	47	2,100	75	
	n	306	453	309	444	455	307	453	309	444	309	455	309	436	309	444	309	444	317	444	

Table 4 Summary of water quality results by irrigation season (irrigation season 1 Sep–30 April, non-irrigation season 1 May–1 Sep)

	E Coli		TN	NH4	NOx	TP	FRP	TOC	TDS	Turbidity	CI	TSS							
	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT							
	CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	mg/L	mg/L							
Irrigation season																			
median	1,000	8,000	0.70	3.00	0.45	0.06	0.10	0.10	1.30	0.01	0.85	6	18	230	1,295	37	31	510	46
Non-irrigation season																			
median	517	1,200	0.50	2.50	0.31	0.07	0.19	0.06	0.76	0.01	0.31	5	14	268	2,703	21	30	2,200	47
% change	48	85	29	17	30	-17	-90	40	42	24	63	17	22	-17	-109	43	5	-331	-2

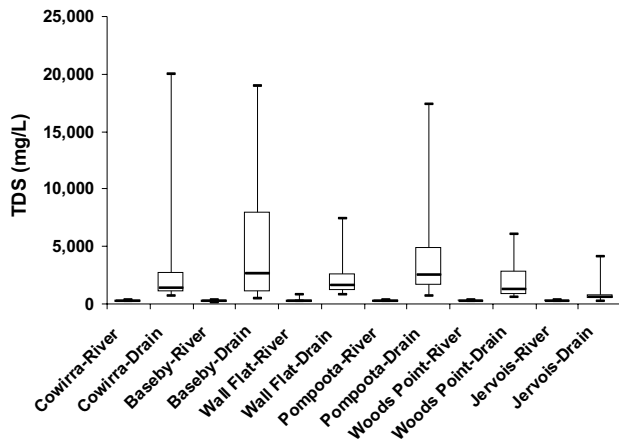


Figure 11 Total Dissolved Solids, salt drain and river concentrations

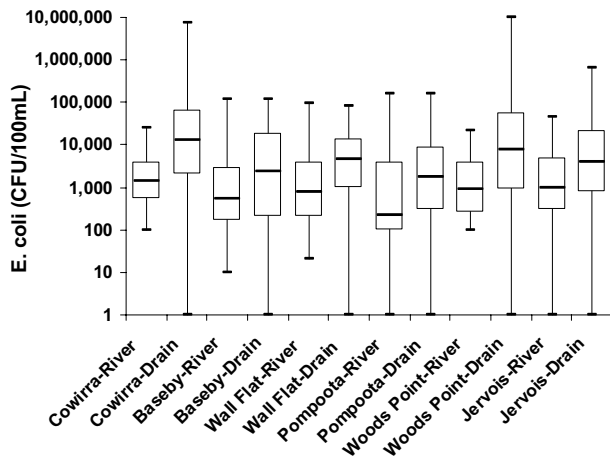


Figure 12 E Coli, salt drain and river concentrations

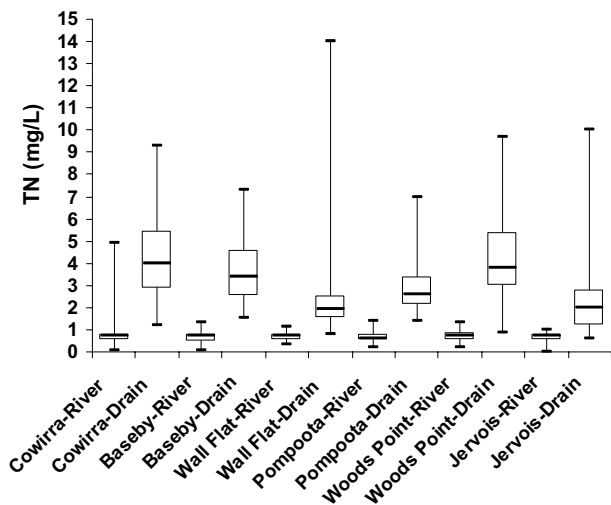


Figure 13 Total nitrogen, salt drain and river concentrations

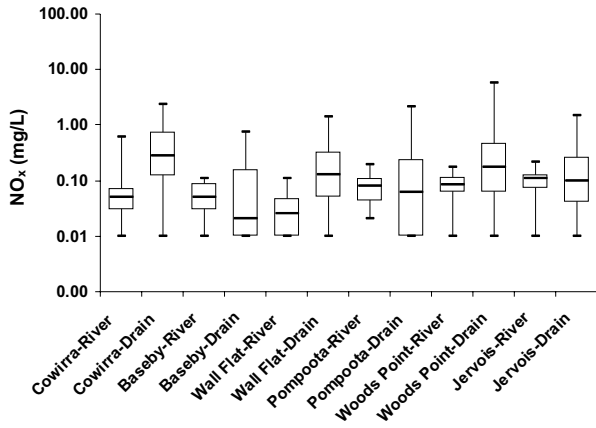


Figure 14 Oxidised nitrogen, salt drain and river concentrations (note log scale)

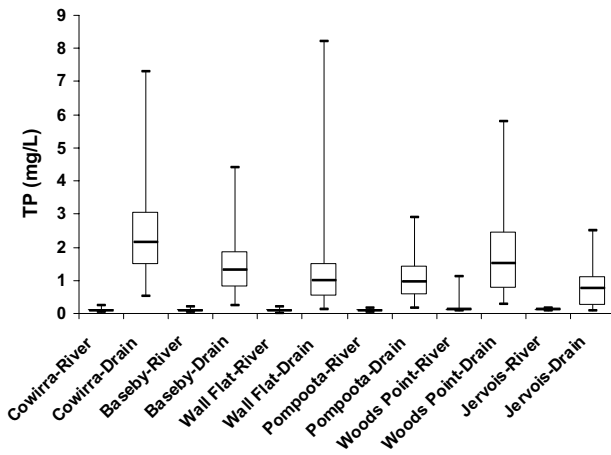


Figure 15 Total phosphorus, salt drain and river concentrations

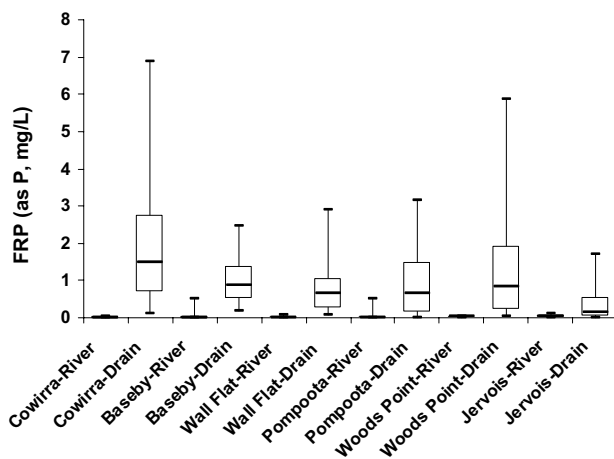


Figure 16 Filtered reactive phosphorus, salt drain and river concentrations

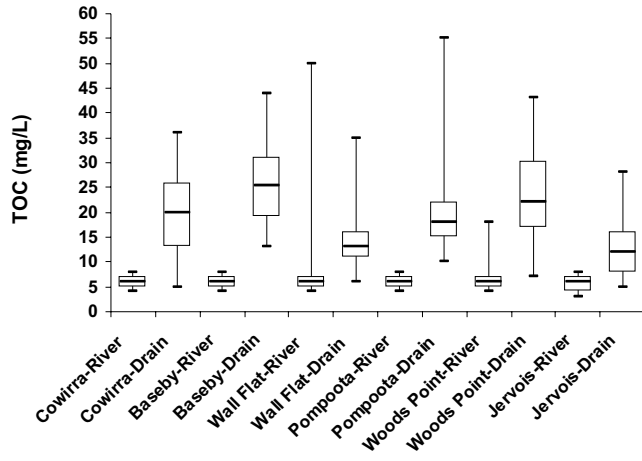


Figure 17 Total organic carbon, salt drain and river concentrations

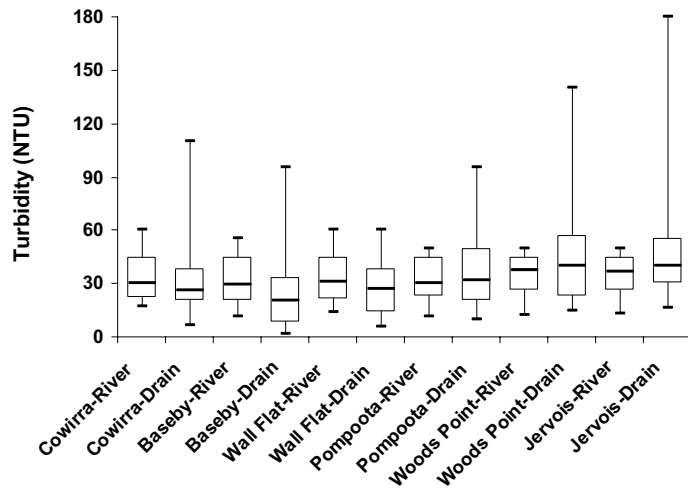


Figure 18 Turbidity, salt drain and river concentrations

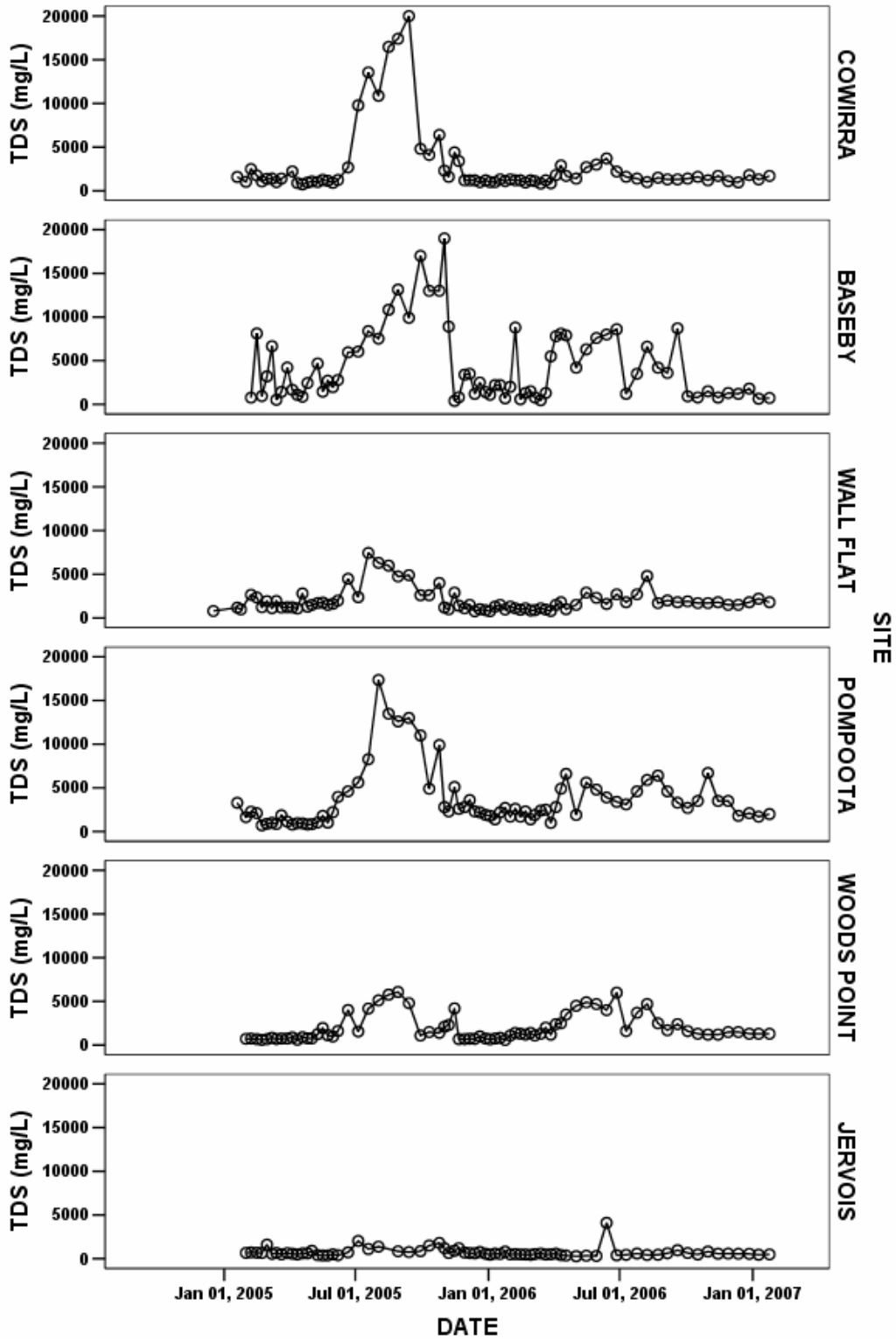


Figure 19 Total Dissolved Solids, time series of salt drain concentrations

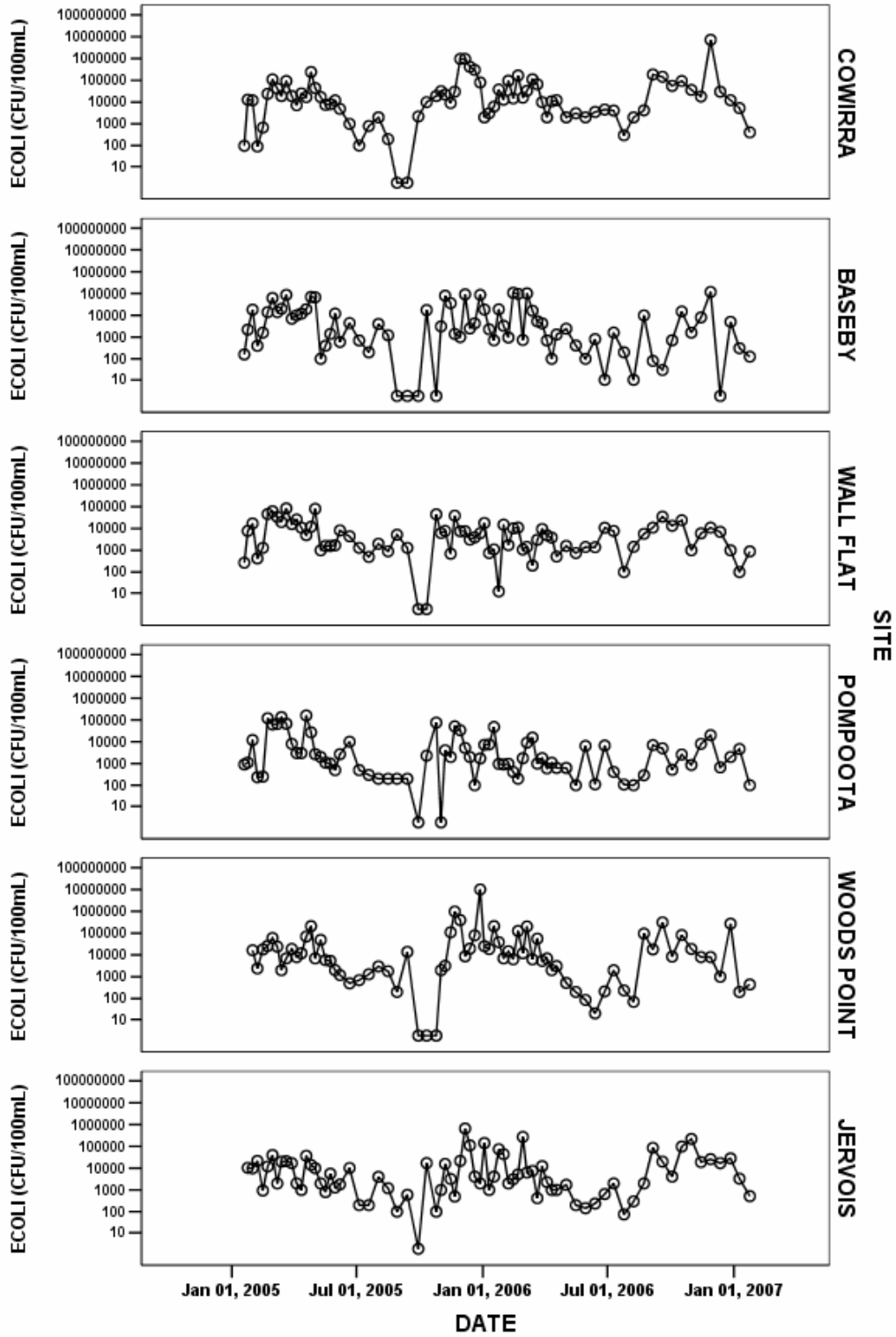


Figure 20 E Coli, time series of salt drain concentrations

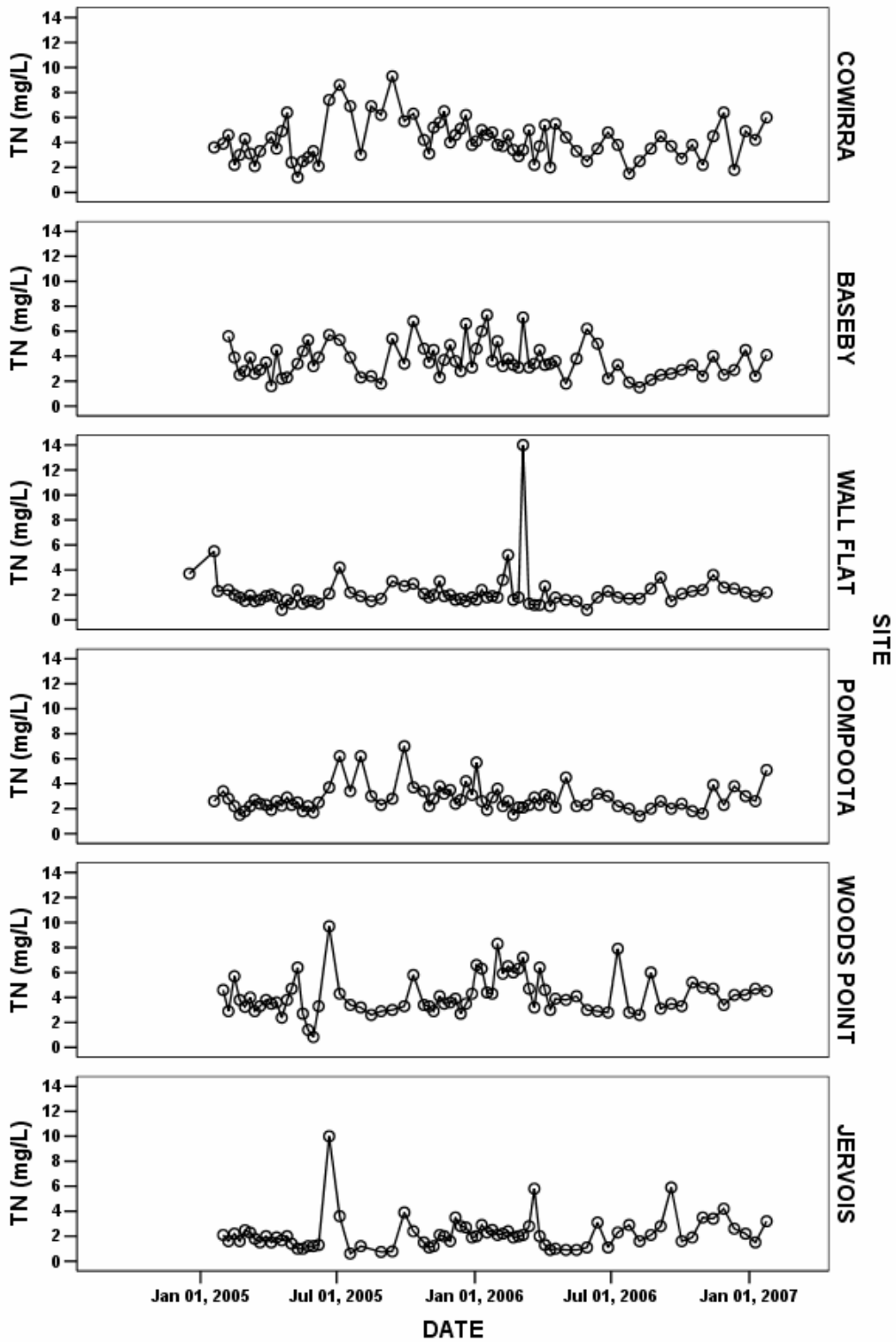


Figure 21 Total nitrogen, time series of salt drain concentrations

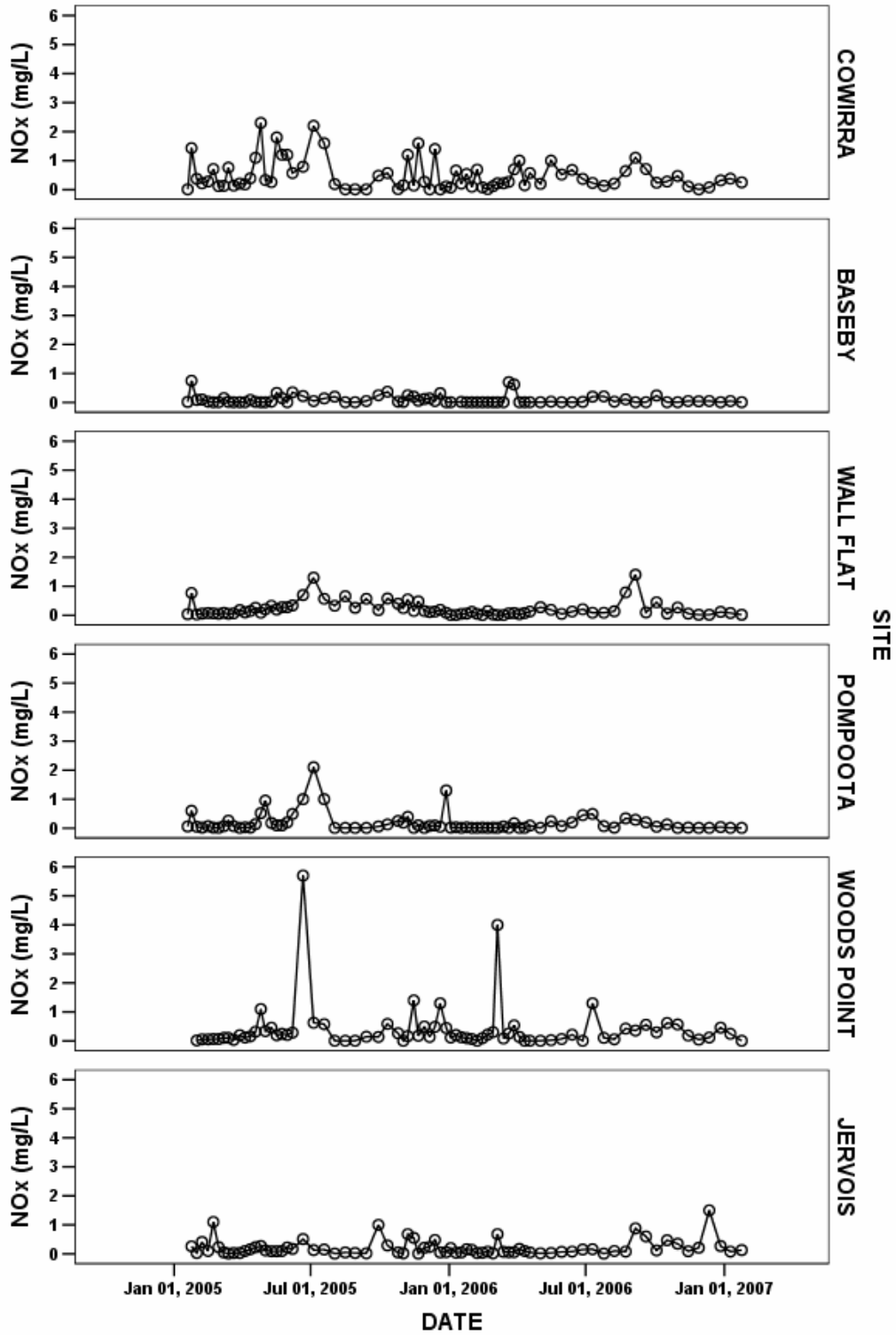


Figure 22 Oxidised nitrogen, time series of salt drain concentrations

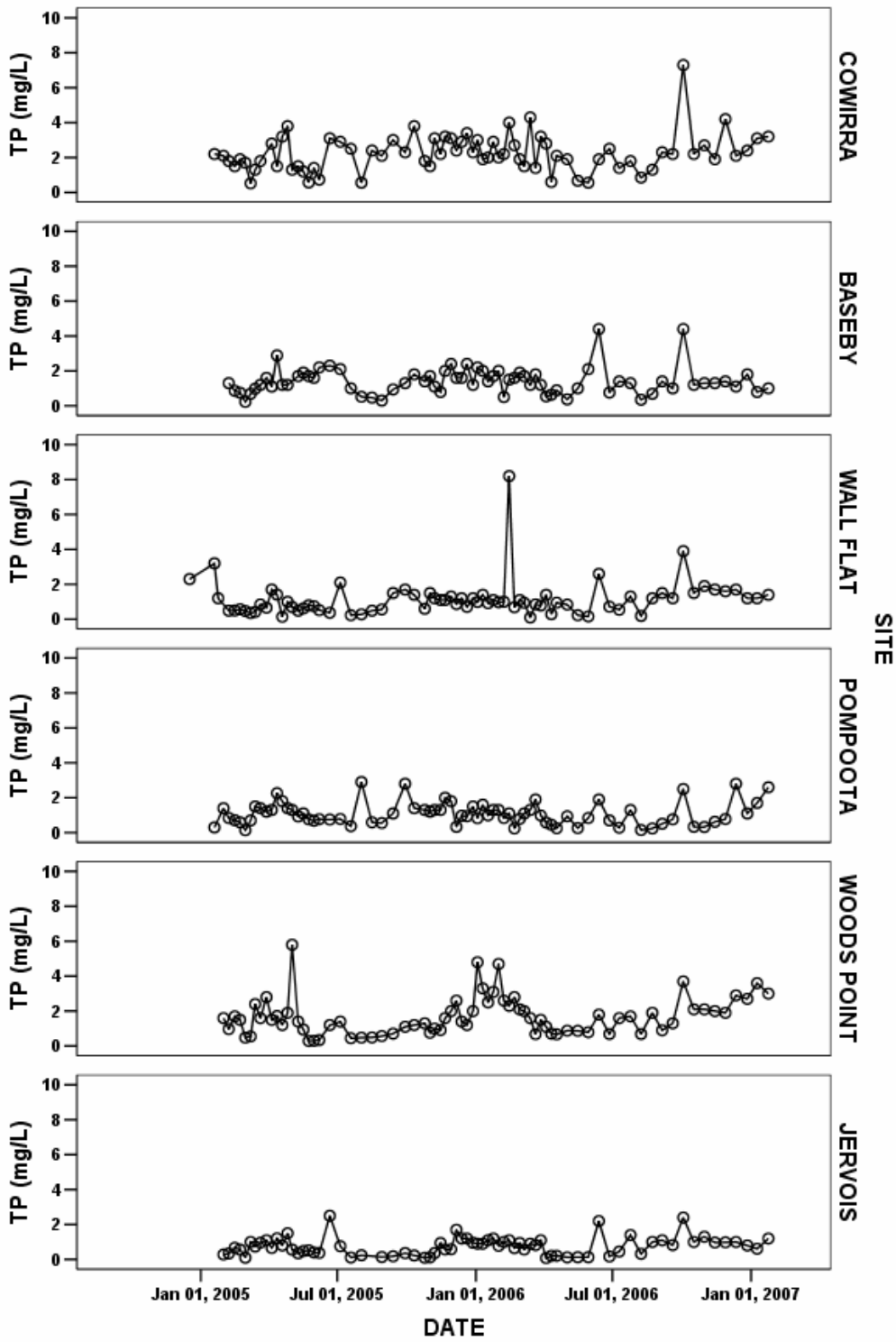


Figure 23 Total phosphorus, time series of salt drain concentrations

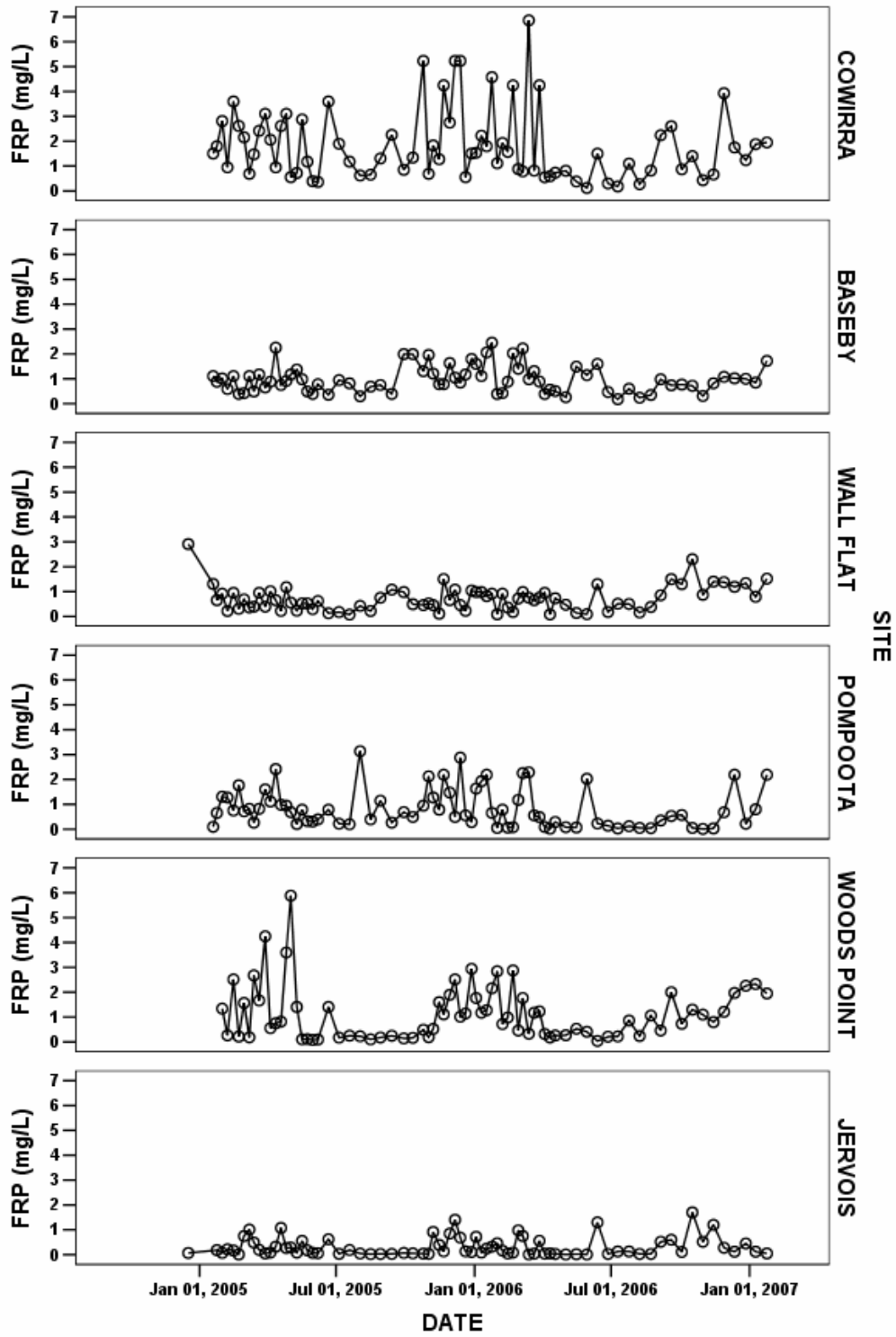


Figure 24 Filtered reactive phosphorus, time series of salt drain concentrations

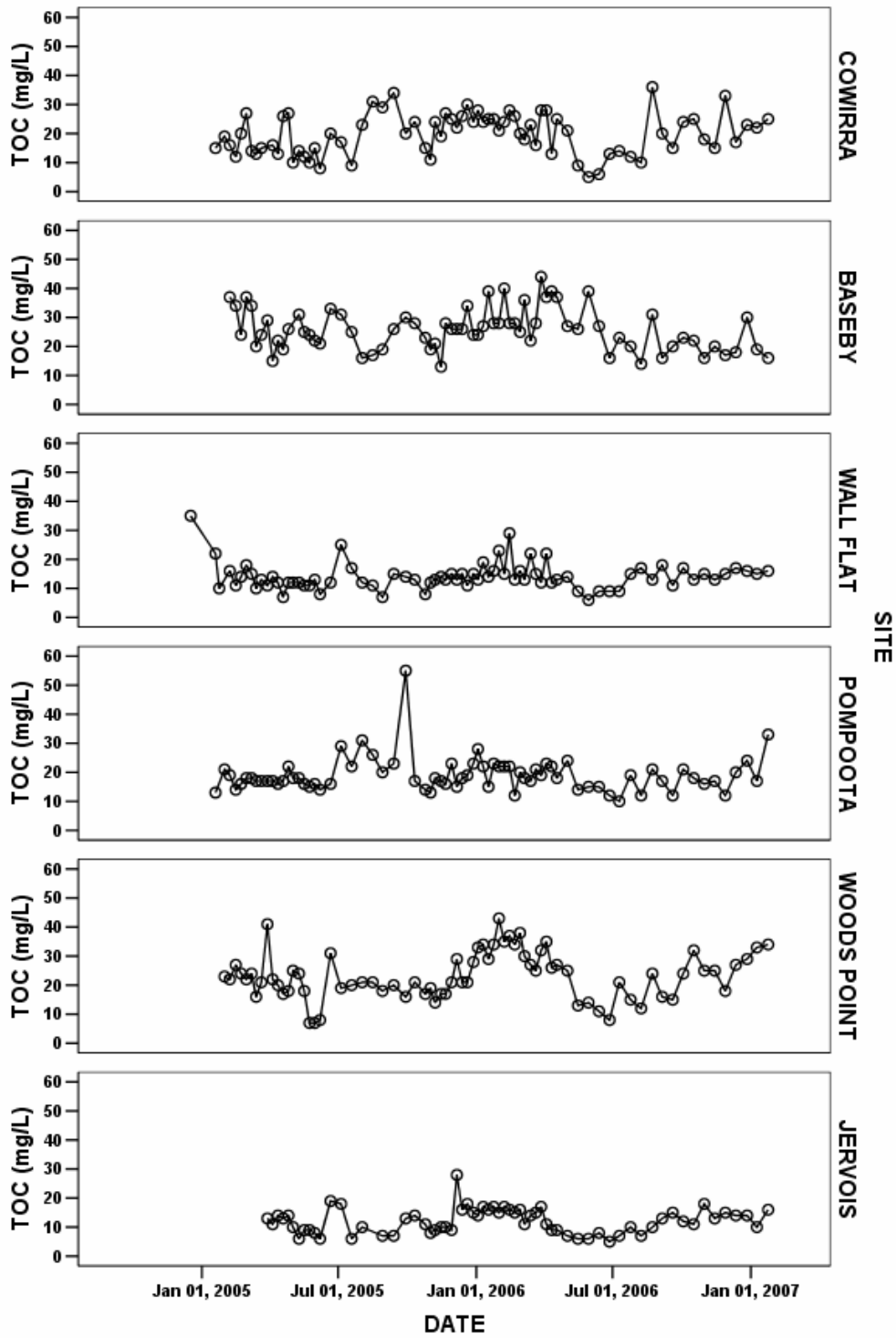


Figure 25 Total organic carbon, time series of salt drain concentrations

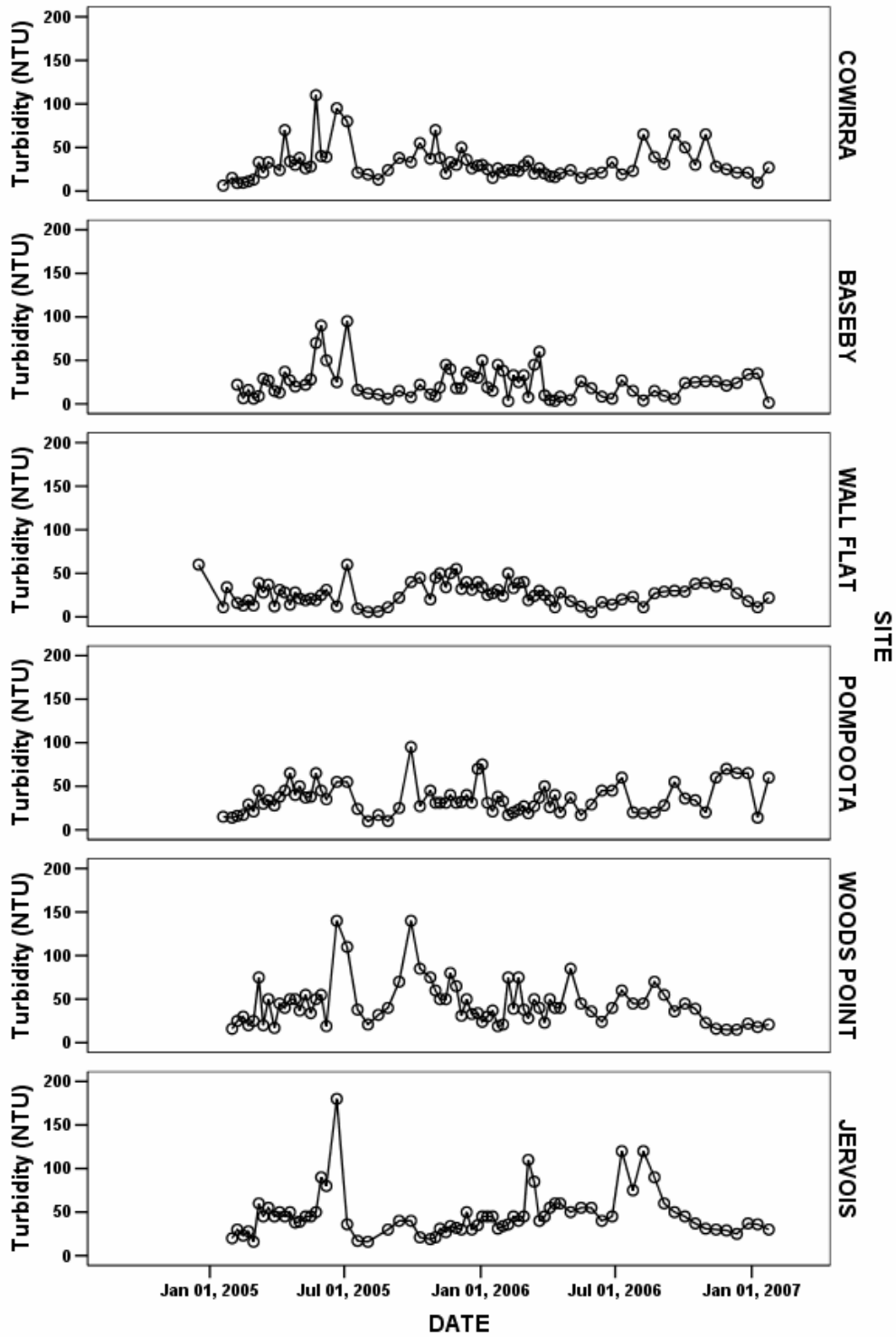


Figure 26 Turbidity, time series of salt drain concentrations

Irrigation and drainage volumes

Irrigation volumes

Flood-irrigation water volumes were measured at 10 river inlet sluices over two irrigation seasons (Table 5). The average water use per watering of 0.6 ML/ha for the fully rehabilitated site at Woods Point was one third of the average water use per watering (1.8 ML/ha) for the non-rehabilitated sites. The improvements in water efficiency following rehabilitation were attributed to a combination of improved inlet structures (new sluices and channels), metering, elimination of leaks, laser levelling of paddocks, and construction of re-use systems to recycle excess surface irrigation runoff (see Figure 27, photo of a rehabilitated site). The partially rehabilitated sites (no re-use system) had an average application rate of one ML/ha/watering (Table 5). Therefore, a large proportion of the reduction in water use was achieved by new water delivery infrastructure, metering and lasering, but significant additional efficiency gains were achieved following construction of re-use systems.

The rehabilitated area results compared well to previous data for a similar trial of a re-use system at Cowirra (0.7 ML average, EPA 2005). The partly rehabilitated (new inlet channels, lasered) and non-rehabilitated sites also compared well to previous findings (average of 0.9 and 2.4 ML/ha/watering respectively, Murray & Philcox 1995, Scown Consulting 2001, Fleming *et al* 2003b). Rehabilitation has also greatly reduced watering times and consolidated watering infrastructure, producing labour and time savings for the irrigator.

The water balance modelling results for the LMRIA estimate 51% average water use efficiency pre-rehabilitation will improve to an average of 80% post rehabilitation (Table 6). Across the whole LMRIA this translates to an estimated 50 GL/year less water extracted from the river following completion of the rehabilitation project (Table 7). These monitoring and modelling results show that pre-rehabilitation flood irrigation practises in the LMRIA were highly inefficient. The LMRIA rehabilitation project will produce large water savings and be a beneficial result for irrigators and the health of the River Murray.

All flood irrigation off-takes will be metered following rehabilitation of the LMRIA. Metering in and of itself may produce some efficiency gains due to the increased incentive to carefully manage irrigations to prevent minimise runoff of the end of the irrigation bays. The current water allocation plan (RMCWMB 2004) for the River Murray allows for an irrigation allocation of 13.92 ML/ha/year in the LMRIA², plus an Environmental Land Management Allocation (ELMA) of 3–6.5 ML/year depending on location. Based on a predicted post-rehabilitation application rate of less than 0.7 ML/ha per watering, the current irrigation allocation would allow for about 20 waterings per annum, plus ELMA waterings. Approximately 16–18 irrigations per annum are required for lasered paddocks and 12 for non-lasered paddocks, with average intervals between irrigations of 14 and 18 days respectively (Philcox 2002). Therefore, the results indicate there should be sufficient water available for irrigators to maintain full production under the current allocation.

² Note: in the 2006–07 irrigation season, irrigators have been on 60% allocation



Figure 27 Flood irrigation using rehabilitated infrastructure (water meter, siphon and inlet channels, side check banks, laser levelled paddocks)

Table 5 Irrigation volumes for individual sluices in the monitoring study

Site	Irrigation season	Area (ha) watered	Total water used (ML)	ML/ha per watering	Rehabilitation status
Cowirra					
CF2	2004-05	5.7	40.9	1.4	Non-rehabilitated
	2005-06	5.7	51.8	1.8	Non-rehabilitated
CF3	2004-05	34.5	210.9	1.2	Partly rehabilitated (lasered)
	2005-06	34.5	88.4	1.2	Partly rehabilitated (lasered)
CF4	2004-05	34.01	88.1	1.3	Partly rehabilitated (lasered)
	2005-06	34.01	97.9	1.0	Partly rehabilitated (lasered)
Baseby					
BI1	2004-05	26.1	382.2	1.8	Non rehabilitated
	2005-06	26.1	78.0	1.0	Non rehabilitated
Wall Flat					
WFI	2004-05	14.9	44.0	0.72	Partly rehabilitated (lasered)
	2005-06	14.9	30.7	0.72	Partly rehabilitated (lasered)
Pompoota					
PA3	2004-05	25.5	190.6	1.7	Non-rehabilitated
	2005-06	25.5	73.1	0.8	Partly Rehabilitated (lasered)

Site	Irrigation season	Area (ha) watered	Total water used (ML)	ML/ha per watering	Rehabilitation status
Woods Pt					
WP3	2004–05	68.1	457.1	0.9	Partly rehabilitated (lasered)
	2005–06	68.1	308.7	0.5	Rehabilitated, re-use system
WP4	2004–05	28.4	96.9	0.9	Partly rehabilitated (lasered)
	2005–06	28.4	97.5	0.7	Rehabilitated, re-use system
Jervois					
JG2	2004–05	19.7	45.1	1.5	Non rehabilitated
	2005–06	19.7	104.8	1.8	Non rehabilitated
JG3	2004–05	40.4	116.1	3.0	Non rehabilitated
	2005–06	40.4	191.5	1.9	Non rehabilitated
Average–Non rehabilitated				1.8	
Average–Partly rehabilitated (new inlet channels, meter, laser levelled)				1.0	
Average–Fully Rehabilitated (new inlet channels, meter, laser levelled, re-use system*)				0.6	

* Short irrigation bays mean that this site is likely to be comparably more efficient than other properties

Table 6 Estimated water efficiency pre- and post-rehabilitation (from Tonkins 2007)

Irrigation area	Pre-rehabilitation efficiency	Post-rehabilitation efficiency
Cowirra North	50%	82%
Cowirra	51%	80%
Baseby	57%	81%
Neeta North	56%	81%
Neeta	52%	81%
Wall Flat	43%	79%
Pompoota	46%	79%
Mypolonga North	43%	80%
Mypolonga	52%	80%
Glen Lossie	59%	84%
Toora	50%	80%
Burdett	50%	82%
Long Flat	57%	80%

Irrigation area	Pre-rehabilitation efficiency	Post-rehabilitation efficiency
Long Island	52%	79%
Yiddinga	43%	80%
River Glen	59%	78%
Monteith	43%	80%
Woods Point	48%	78%
Jervois	41%	79%
McFarlanes	59%	74%
Average	51%	80%

Note: The average annual application rate for the pre and post rehabilitation scenarios has been estimated to be 22.8 ML/ha/year and 14.4 ML/ha/year, respectively, for the LMRIA area. The average application efficiency provided in the table is a measure of the irrigation losses including seepage, runoff and evaporation, compared to the total volume that is applied for growing pasture. This calculation only considers the application efficiency of each irrigation event (ie how much is used for plant growth and how much is lost through surface and sub-surface drainage). The calculation is not strictly an estimate of irrigation efficiency compared to the available water allocation but for many irrigation areas it would provide a reasonable estimate of the overall efficiency that could be achieved. Where the number of irrigations per annum is limited (eg applying ELMA or less than full application), the actual theoretical efficiency would be higher than quoted for pasture irrigation. See Tonkins (2007) for more detail.

Table 7 Estimated annual river water extraction volumes, pre- and post-rehabilitation (from Tonkins 2007)

Irrigation Area	Pre-rehabilitation (ML/year)	Post-rehabilitation (ML/year)	Volume reduction (ML/year)	% Reduction
Cowirra North	4,448	2,553	1,895	43%
Cowirra	1,647	1,126	522	32%
Baseby	1,131	1,101	31	3%
Neeta North	957	743	214	22%
Neeta	5,417	3,956	1,461	27%
Wall Flat	6,061	3,122	2,938	48%
Pompoota	3,607	1,770	1,837	51%
Mypolonga North	6,556	2,001	4,555	69%
Mypolonga	4,966	2,819	2,147	43%
Glen Lossie	2,499	302	2,197	88%
Toora	2,841	774	2,067	73%
Burdett	552	161	391	71%
Long Flat	2,546	1,939	607	24%
Long Island	1,187	832	355	30%
Yiddinga	1,466	939	527	36%
River Glen	3,035	2,152	883	29%
Monteith	9,443	4,866	4,577	48%
Woods Point	5,372	3,794	1,578	29%
Jervois	40,097	17,667	22,430	56%
McFarlanes	1,354	1,506	-152	-11%
Total	105,183	54,124	51,059	49%

Drainage volumes

The drainage response to irrigation events was rapid, particularly in areas with a salt drain which is smaller in volume. Figure 28 shows a typical time series of irrigation and drainage volumes from Baseby. The irrigation volume is applied in a relatively short time period and the drainage response is immediate, and continues for some time after each irrigation event. The continuation of drainage flow is due to the draining of the excess soil moisture capacity and is driven by a dynamic hydraulic gradient under the paddock towards the drainage channel. As the channel water level is pumped down during normal operations, groundwater will be drawn into the drain at a faster rate.

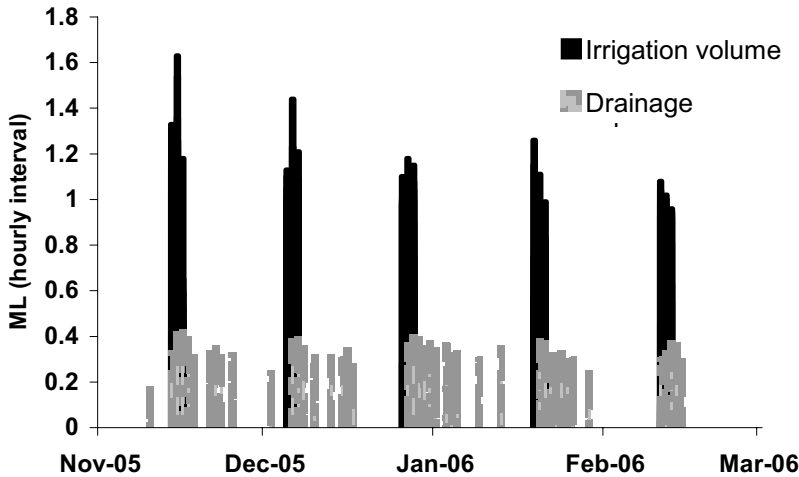


Figure 28 Snapshot timeline of Baseby drainage and irrigation volumes

The time series of drainage volumes from the different study locations is shown in Figures 29–34. As expected, drainage volumes are greatest in the irrigation season and peaks relate primarily to the timing of irrigation events as noted above. Small–moderate rainfall events do not make a significant impact on the drainage volumes compared to flood-irrigation events. Even a rainfall event of 90 mm in late June 2005 did not result in large drainage volumes returned to the river in comparison to summer irrigations.

During flood-irrigation, a water depth of about 100 mm³ is applied in a short time scale (typically 4–8 hours) with an elevated head. These flood irrigation event occurs numerous times a year while a similar sized rainfall event over a 24-hour period is estimated as a one-in-100 year occurrence for this region (Tonkins 2007). Water balance modelling estimated that flood-irrigation drainage contributes >90% of total drainage volumes (59 GL) returned to the River Murray from the LMRIA (Table 8). All other sources combined were estimated to contribute less than 10% of total drainage volumes, with stormwater typically contributing less than 5%.

However, very large rainfall events have periodically contributed large amounts of drainage water to the LMRIA, including instances of large back flooding of irrigation bays. This is due to the total highland catchment area often being much larger than the floodplain area and some irrigation areas (eg Burdett) having urban runoff contributions. Runoff is most likely to occur if an area has a high antecedent moisture level due to recent irrigation (eg if an area has been irrigated recently or there have been some smaller rainfall events to pre-wet the soil profile).

³ This calculation is based on an ‘average’ 1 ML/ha/watering efficiency (see Table 5).

Table 8 Estimated water volumes from different sources contributing to drainage from the LMRIA (from Tonkin Consulting 2007)

Irrigation Area	Stormwater			Groundwater			Flood-irrigation	Total
	Floodplain (ML/yr)	Highland irrigation (ML/yr)	Roads & buildings (ML/yr)	Dryland (ML/yr)	Regional (ML/yr)	Irrigation induced (ML/yr)	(ML/yr)	(ML/yr)
Cowirra North	29	3	4.9	41	80	23	2,066	2,248
Cowirra	10	1.4	1.2	3	42	9	631	698
Baseby	14	3.0	3.6	50	80	30	496	676
Neeta North	8	0.0	0.6	4	40	0	422	475
Neeta	36	20	8.5	40	96	130	2,624	2,955
Wall Flat	32	15	12	9	202	153	3,448	3,871
Pompoota	24	5.3	7.6	16	96	35	1,932	2,116
Mypolonga North	38	22	16	11	90	432	3,781	4,390
Mypolonga	33	6.8	14	13	94	180	2,407	2,747
Glen Lossie	25	4.5	5.4	12	171	30	1,022	1,269
Toora	20	1.8	5.4	10	69	9	1,446	1,561
Burdett	4	0.0	18	4	31	0	277	333
Long Flat	19	2.7	9.5	5	67	18	1,107	1,228
Long Island	10	2.4	68	4	23	16	570	695
Yiddinga	10	1.8	8.5	14	35	12	831	912
River Glen	21	18	4.3	11	48	57	1,242	1,400
Monteith	53	18	22	13	224	144	4,638	5,111
Woods Point	36	23	7.6	3	139	54	2,787	3,049
Jervois	212	19	42	20	447	206	21,810	22,755
McFarlanes	15	0.0	1.5	2	40	0	553	611
Total	648	168	260	282	2,113	1,538	54,092	59,102
Proportion	1.1%	0.3%	0.4%	0.5%	3.6%	2.6%	91.5%	100%

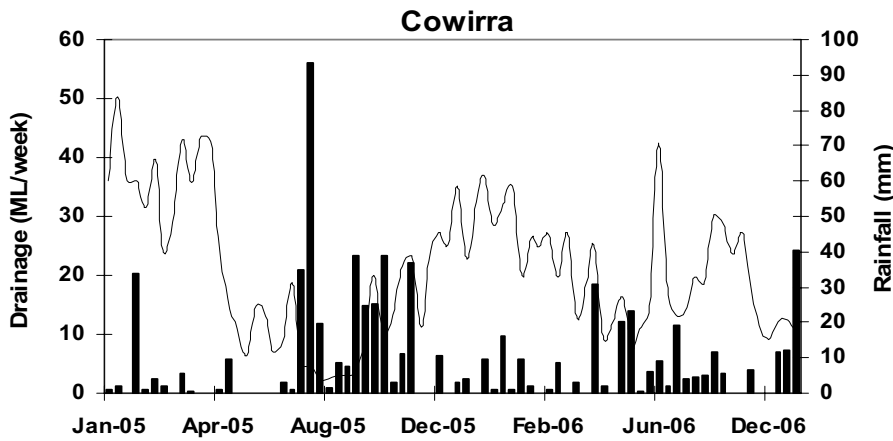


Figure 29 Cowirra drainage volumes (line) and rainfall (bars, at Mannum)

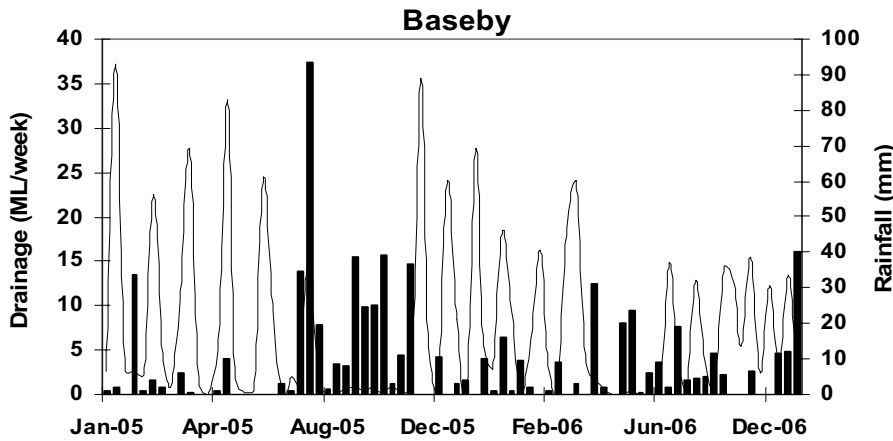


Figure 30 Baseby drainage volumes (line) and rainfall (bars, at Mannum)

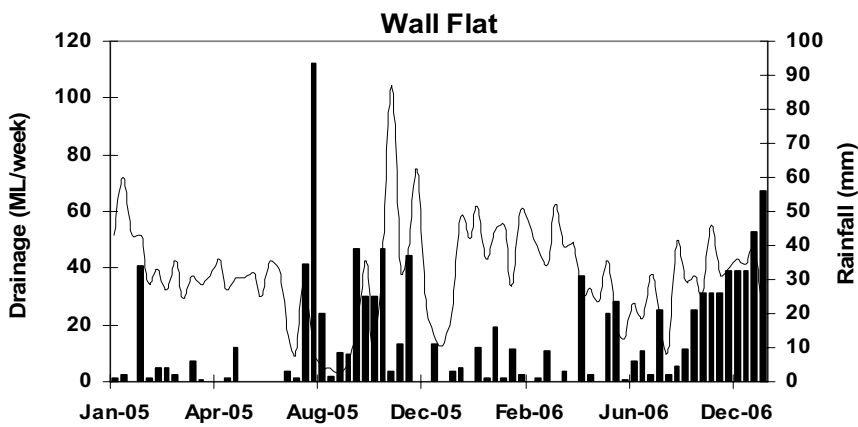


Figure 31 Wall Flat drainage volumes (line) and rainfall (bars, at Mannum)

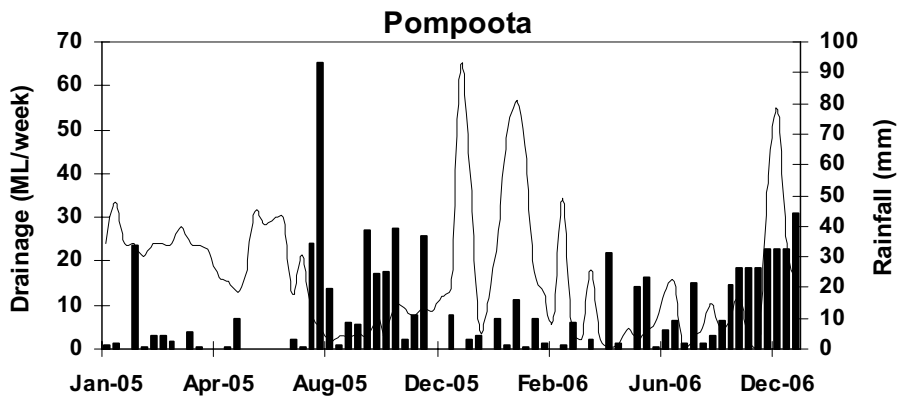


Figure 32 Pompoota drainage volumes (line) and rainfall (bars, at Mannum)

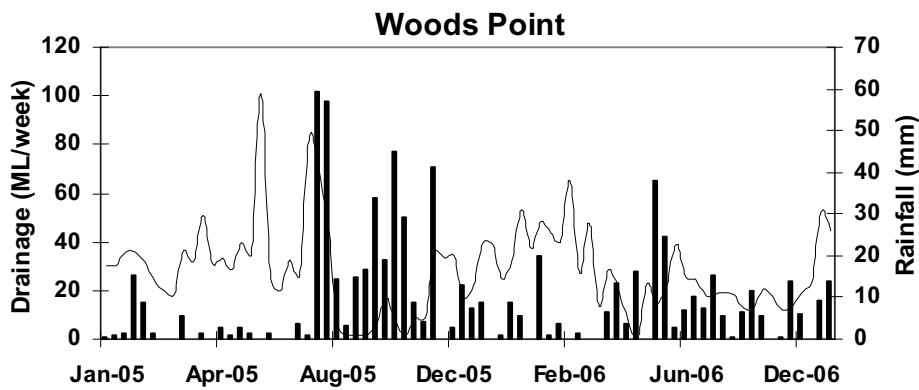


Figure 33 Woods Point drainage volumes (line) and rainfall (bars, at Murray Bridge)

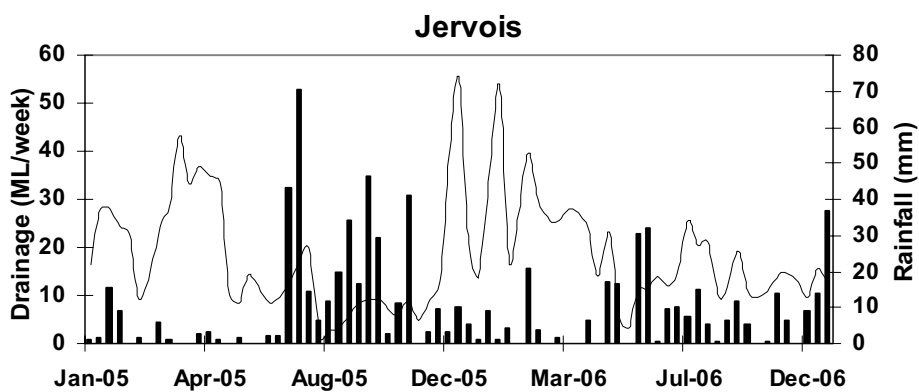


Figure 34 Jervois drainage volumes (line) and rainfall (bars, at Taillem Bend)

The annual (1 May 2005–1 May 2006) drainage volumes measured in the current study are shown in Table 9. There are differences in annual drainage volumes from different sites. If one irrigation area has a higher drainage volume than another it does not necessarily imply a lack of efficiency. There are often differences in irrigation volumes and efficiency, infrastructure leakages, rainfall variability, and regional and highland irrigation groundwater inputs which contribute to drainage. The following specific comments are made in relation to the data in Table 9:

- Woods Point area had an operational re-use system for the latter part of the study duration but surprisingly there was no decrease in drainage volumes. However a confounding factor was that Woods Point had periodic inflows from external irrigators which may have influenced the drainage results. The Starflow™ meters had difficulty picking up low (<0.05 m/s) negative flows (when neighbouring properties over watered).
- Jervois was noted to have leaking back channel infrastructure that may have contributed to high drainage volumes from that site. This is corroborated by the low salinity concentrations at Jervois (Fig 19).
- Cowirra had comparatively low drainage volumes compared to most other sites. This irrigation area has good infrastructure and is mostly lasered.
- Baseby has a relatively low-intensity watering regime compared to other areas and had low drainage volumes.
- Pompoota drainage volumes were comparatively high but were influenced from irrigators not in the trial who have not yet rehabilitated. Pompoota drainage may have been altered somewhat due to a new salt drain construction changing the hydrology in the area in the winter of 2005.
- the Wall Flat results are also influenced by the water use of other irrigators who had not yet rehabilitated.

Table 9 Drainage volumes for the study locations in 2005 and 2006

Site	Year	Contributing area (ha)	ML/year	ML/ha/year
Cowirra	2005	152.4	896	5.88
	2006	152.4	1102	7.23
Baseby	2005	54.2	211	3.90
	2006	54.2	377	6.95
Wall Flat	2005	202.3	1,486	7.34
	2006	202.3	2,097	10.37
Pompoota	2005	51.1	656	12.84
	2006	51.1	731	14.31
Woods Point	2005	128.4	1,401	10.91
	2006	128.4	1,433	11.16
Jervois	2005	66.1	805	12.18
	2006	66.1	960	14.52
Average (all years)				9.8

Rehabilitation will greatly reduce drainage volumes returned to the river, due to large water application reductions and construction of re-use systems. However further ongoing data collection will be required to demonstrate this. The ongoing drought and restricted water allocations will make interpretation of the effects of rehabilitation difficult.

Drainage flow metering is somewhat problematic in the low-flowing salt drain environment. Several flow meters failed (due to pressure sensor failure, encrustation with red worms, and some corrosion) had to be replaced. As an alternative to in-channel metering, a continuous pump-hour and EC logging system was trialled at Wall Flat, with drainage volumes calculated from pump hours and calibration of pump rates. This proved a very reliable system and correlated well to the metered results.

Pollutant loads

Median weekly loads of pollutants exported in drainage water from each sampling location were calculated for the irrigation and non-irrigation season (Table 10). The time series of pollutant loads from the various sites are shown in Figures 35–39. There were greater loads of nutrients (TP, FRP, TN, NH₄), organic carbon and suspended solids returned to the River Murray during the irrigation season. Runoff and drainage of nutrients (eg from animal faecal material and fertilisers) were found to be closely linked to irrigation events and volumes in the LMRIA (Murray and Philcox 1995, Fleming *et al.* 2003a). The results in the current study confirm these findings. The seasonal median weekly salt (TDS) loads were similar throughout the year which is consistent with regional saline groundwater inputs being relatively constant (Table 10).

The annual exported nutrient loads (Table 11) in drainage from the study locations were comparable to previous monitoring studies in the LMRIA (29.1 kg/ha/year N, 15.7 kg/ha/year P from main drainage pump, Fleming *et al.* 2003a, Murray & Philcox 1995) and other locations in South Australia (N leaching losses of 26.2–33 kg/ha/year in drainage from irrigated dairy farm paddocks, Pakrou & Dillion 2004). It was noted that Woods Point could have higher nitrogen export due to comparably high levels of fertilisation and a high (14–21 day) cattle rotation rate.

The large rainfall event that occurred in late June 2005 also resulted in some increases in suspended sediment load (Figure 39). This result suggests that there may have been additional highland runoff pollutant inputs from holding areas and laneways, and other agricultural land uses. It is possible that a flushing of pollutants on floodplain irrigation bays also occurred as the rainfall was outside the irrigation season.

As discussed earlier, further monitoring is required before the effects of rehabilitation on reducing drainage and pollutant loads can be concluded. Modelling indicates that substantial reductions are predicted for drainage volumes (68%), and loads of pollutants (eg TN reduction 70%, TP 78%, *E Coli* 77%) post-rehabilitation (Table 12). These reductions will be achieved through more efficient water application, improved management practises, and construction of runoff re-use systems. Careful management of water, particularly after fertiliser application has been shown to reduce annual nutrient loads by over 70% in Victoria (Nexhip *et al.* 1997).

The reduction in NO_x loads is lower than for other pollutants as it is mobile through the soil profile (Table 12). Salt reductions are also predicted to be modest due to regional saline groundwater inputs being the major contributor to salt loads. These salt discharges from the highland catchments to the drains are largely not affected by rehabilitation activities on the floodplain. The estimated pre-rehabilitation loads of TN (173 t/year), TP (62 t/year, and salt (TDS, 67 t/year) loads (Table 12) are reasonably comparable with previous estimates (Eco-Management Services 2003, TN 185 t/year, TP 64 t/year; Cole 1985, salt 63–71 t/year). The current model was calibrated more extensively than previous models and used a longer-term water quality dataset.

Table 10 Weekly pollutant loads in drainage outflows from the study areas

Site	Season	Median Weekly Load (kg/ha)							
		TN	NH4	NOx	TP	FRP	TOC	TSS	TDS
Cowirra	Irrigation season	0.78	0.17	0.04	0.42	0.28	3.68	6.39	243
	Non-irrigation season	0.19	0.06	0.04	0.09	0.04	0.66	3.06	175
Baseby	Irrigation season	0.24	0.03	0.00	0.08	0.05	1.77	1.86	162
	Non-irrigation season	0.02	0.00	0.00	0.01	0.01	0.23	0.26	79
Wall Flat	Irrigation season	0.40	0.08	0.02	0.22	0.16	2.88	5.82	281
	Non-irrigation season	0.19	0.02	0.03	0.06	0.03	0.98	2.61	260
Pompoota	Irrigation season	0.57	0.06	0.01	0.24	0.14	3.73	9.57	512
	Non-irrigation season	0.51	0.07	0.05	0.17	0.05	3.01	11.41	724
Woods Point	Irrigation season	0.82	0.11	0.03	0.36	0.22	5.22	10.75	281
	Non-irrigation season	0.52	0.05	0.04	0.14	0.04	2.13	12.44	260
Jervois	Irrigation season	0.61	0.05	0.03	0.23	0.06	3.73	8.37	174
	Non-irrigation season	0.22	0.03	0.02	0.05	0.01	1.43	12.72	66
Average	Irrigation season	0.55	0.07	0.02	0.24	0.13	3.38	7.50	235
	Non-irrigation season	0.22	0.04	0.03	0.08	0.03	1.32	5.05	208

Table 11 Annual pollutant loads in drainage outflows from the study areas

	Year	Annual Load (kg/ha/yr)							
		TN	NH4	NOx	TP	FRP	TOC	TSS	TDS
Cowirra	2005	24.5	8.7	3.3	12.3	12.5	108	284	13,972
	2006	28.1	8.7	2.8	18.4	11.4	147	401	10,838
Baseby	2005	19.8	5.0	0.8	8.0	4.7	141	356	13,615
	2006	23.0	5.5	0.8	11.1	6.7	165	351	10,917
Wall Flat	2005	16.3	3.4	2.3	7.8	4.3	101	269	13,789
	2006	24.3	5.8	1.8	13.8	8.8	154	324	17,807
Pompoota	2005	38.9	7.3	4.8	13.9	10.8	247	832	40,418
	2006	40.0	6.3	1.1	18.3	12.4	268	1,225	38,391
Woods Point	2005	50.4	8.1	10.8	16.0	14.6	247	990	17,914
	2006	52.9	6.0	3.3	24.7	13.0	296	797	23,397
Jervois	2005	27.0	3.0	2.6	9.6	3.6	158	650	9,561
	2006	36.0	4.8	2.9	12.5	4.5	180	1,119	8,974
Average (all years)		31.8	6.1	3.1	13.9	8.9	184	633	18,299

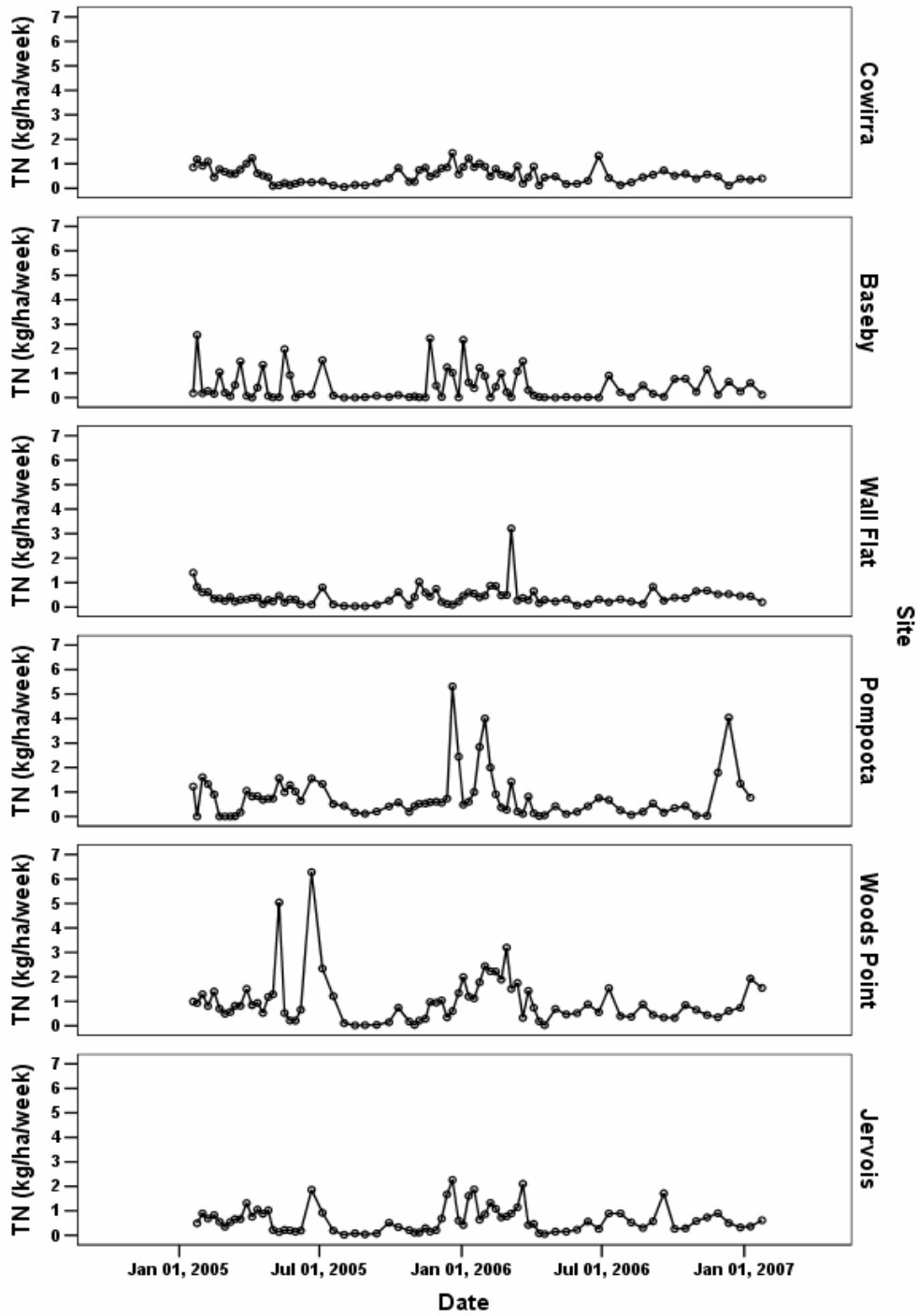


Figure 35 TN drainage loads (kg/ha/week)

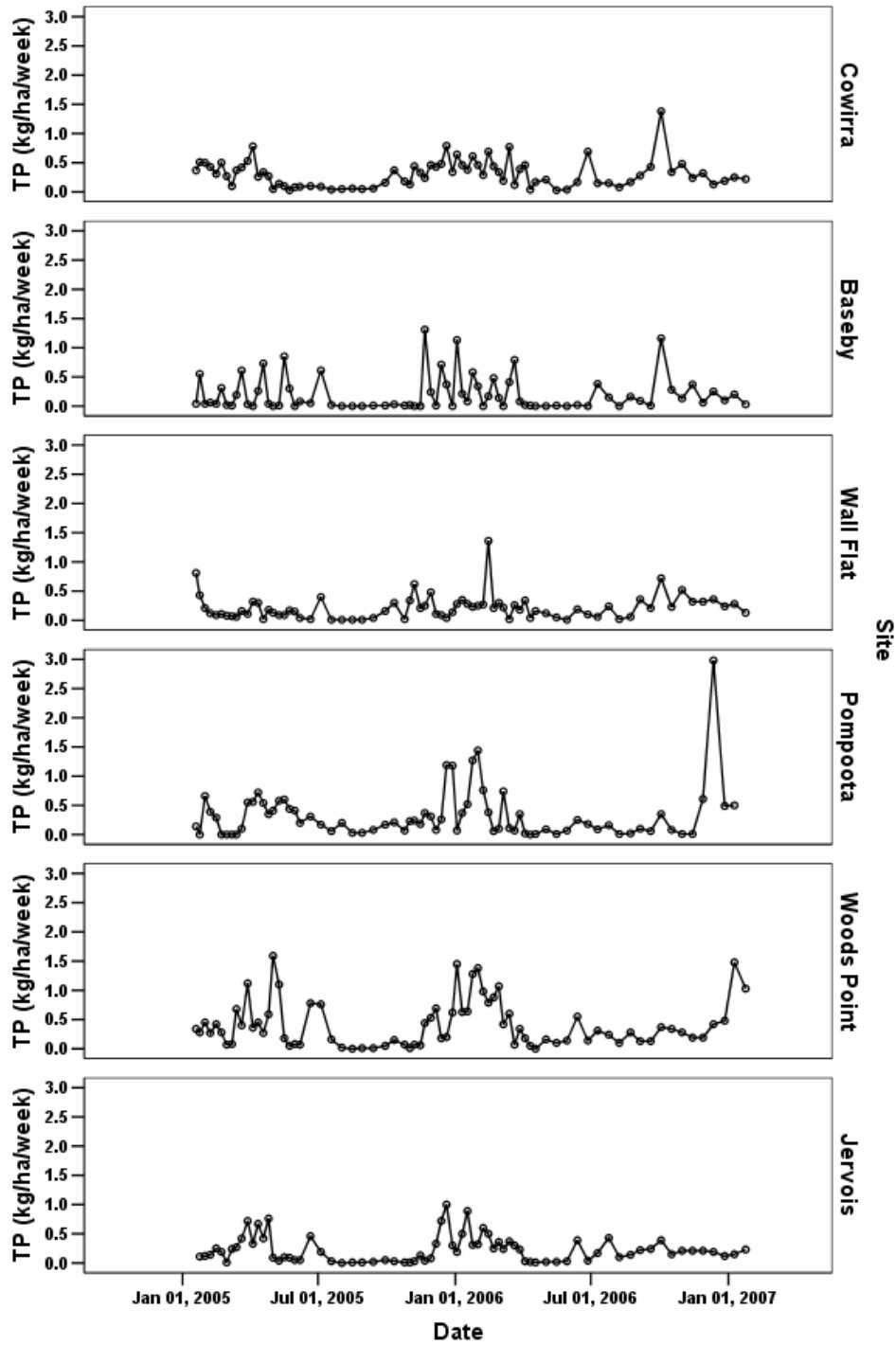


Figure 36 TP drainage loads (kg/ha/week)

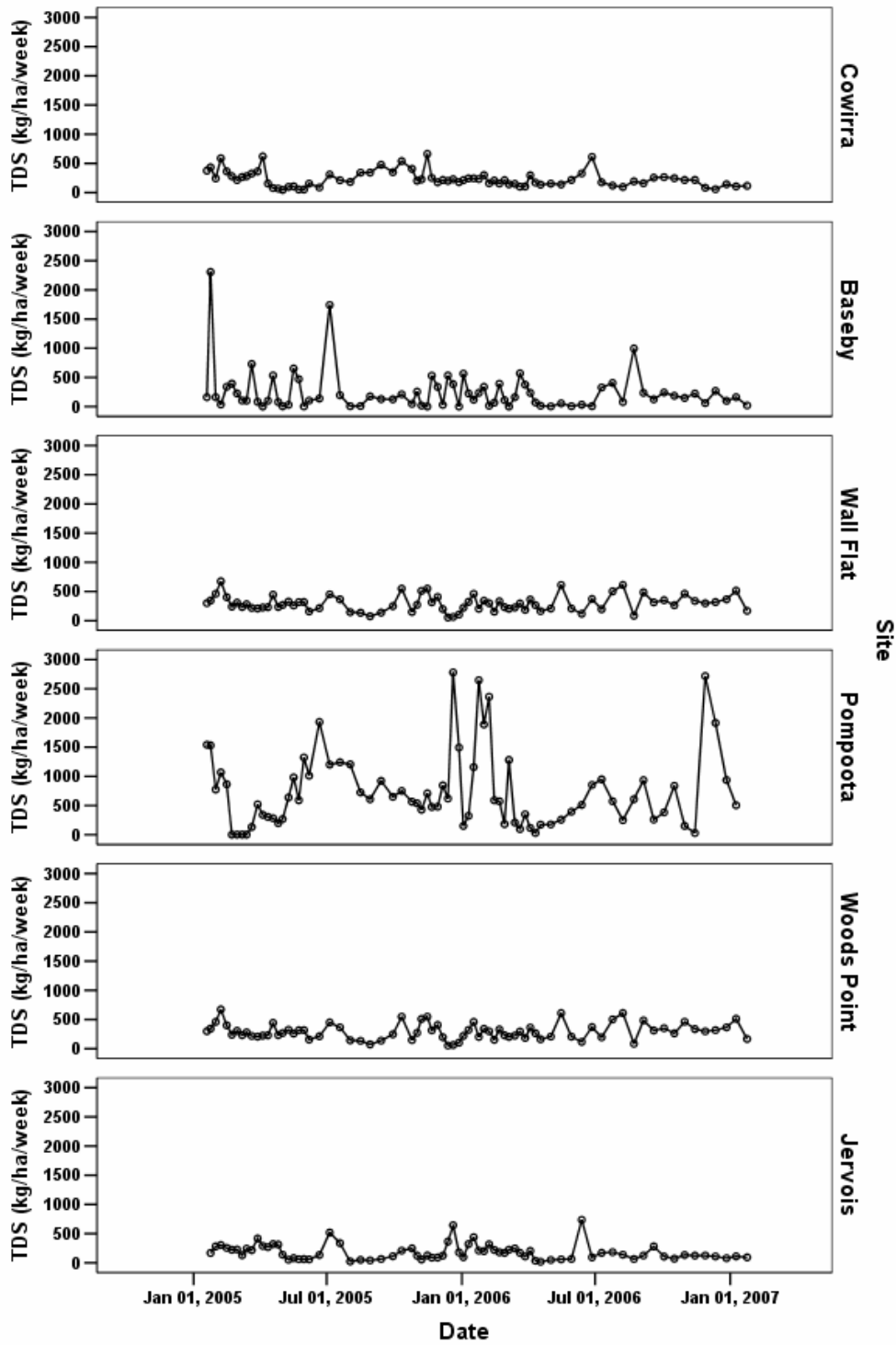


Figure 37 TDS drainage loads (kg/ha/week)

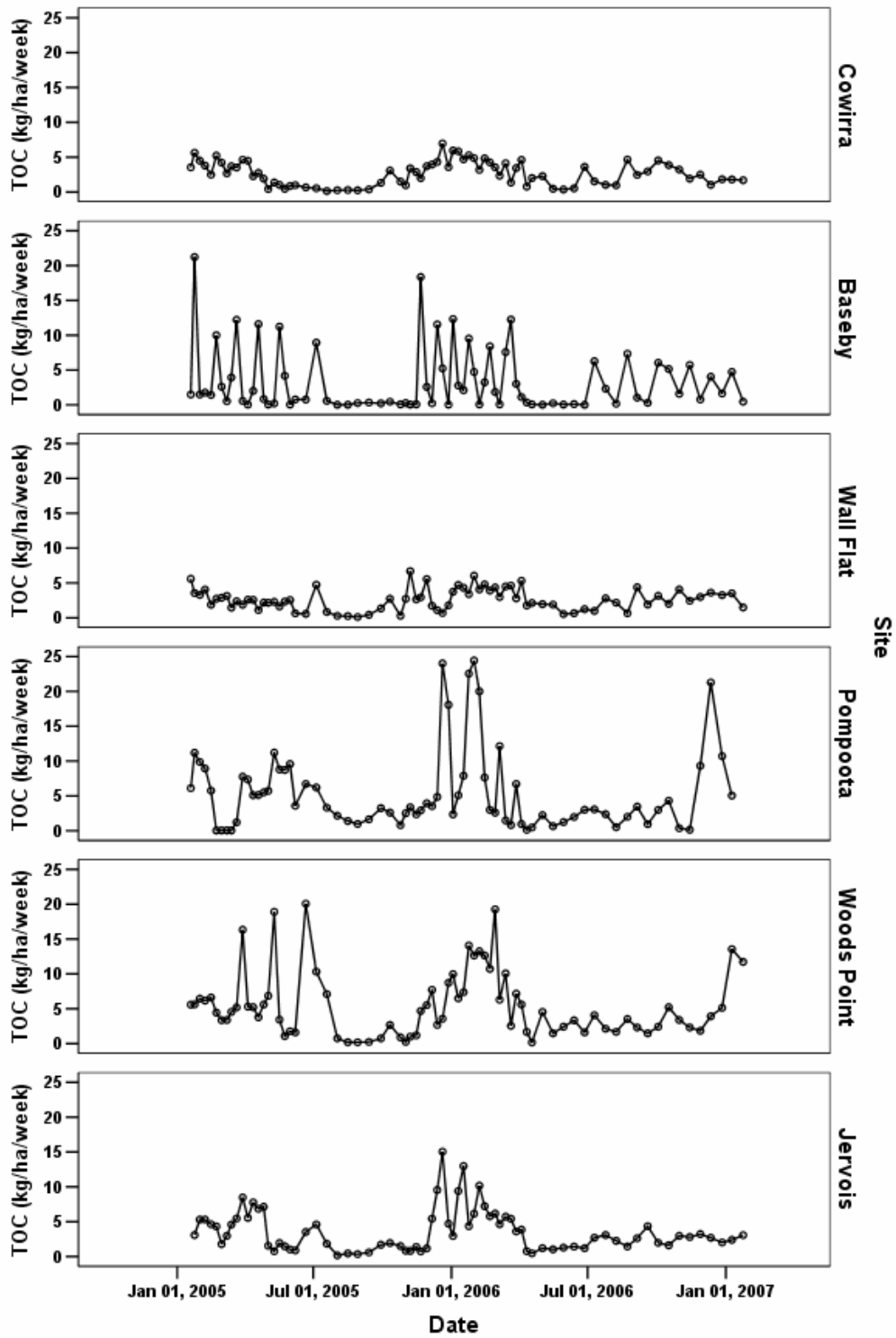


Figure 38 TOC drainage loads (kg/ha/week)

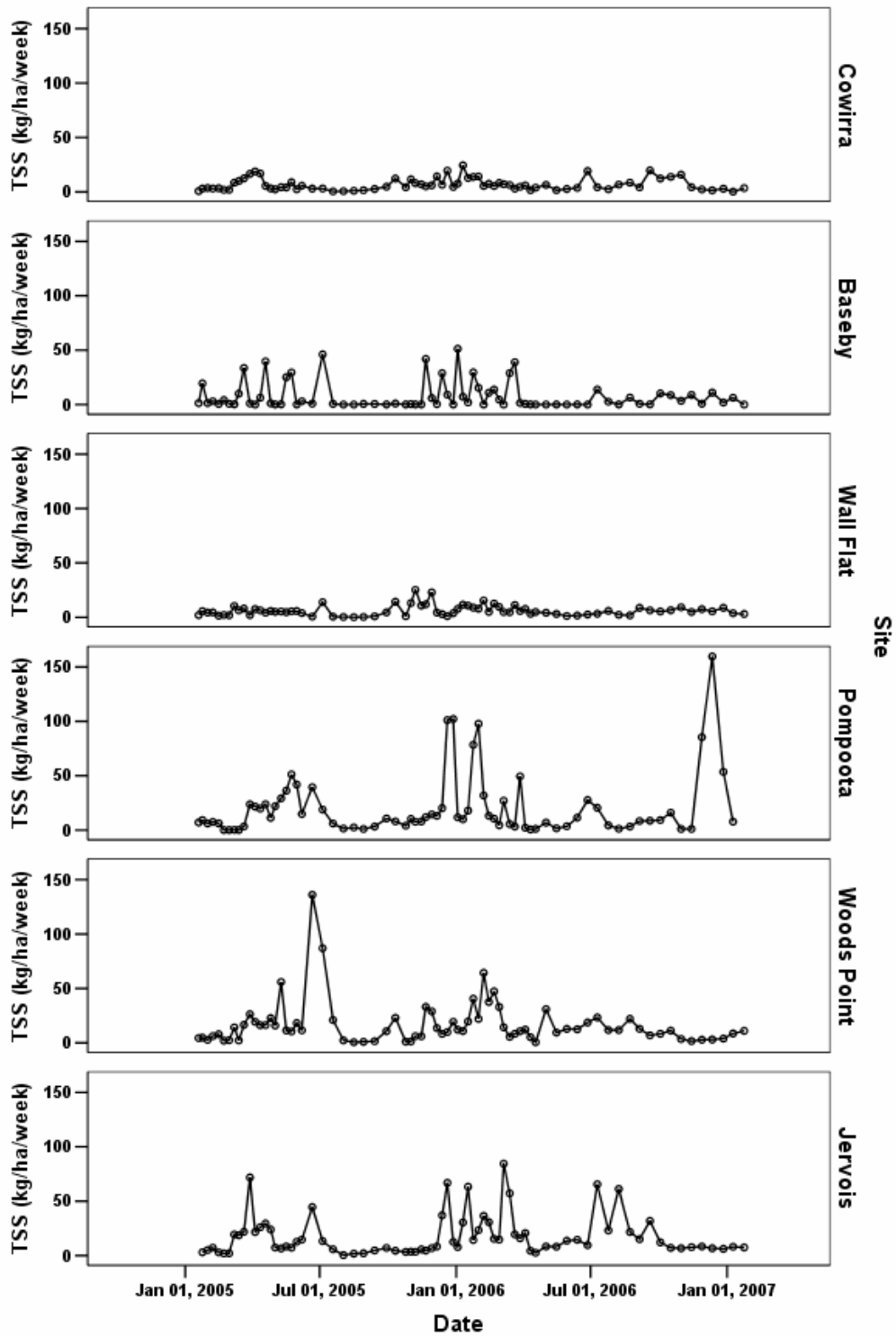


Figure 39 TSS drainage loads (kg/ha/week)

Table 12 Estimated annual pollutant loads returned to the River Murray pre- and post-rehabilitation (from Tonkin Consulting 2007)

Site	Area (ha)	Drainage (ML)	Annual pollutant load						
			FRP (kg)	TP (kg)	TKN (kg)	NO _x (kg)	TN (kg)	E Coli (CFU)	TDS (t)
Pre-rehabilitation									
Cowirra North	189	2,245	3,369	5,200	10,448	1,174	11,622	4.7x10 ¹⁵	2,745
Cowirra	70	698	1205	1,860	3,743	425	4,168	1.7x10 ¹⁵	1,170
Baseby	67	672.3	612	900	2,029	144	2,173	5.5x10 ¹⁴	2,023
Neeta North	55	475.3	252	463	1,045	122	1,168	2.4x10 ¹⁵	563
Neeta	248	2,945	1,628	2,991	6,672	728	7,400	1.5x10 ¹⁶	3,181
Wall Flat	243	3,870	2,226	3,405	8,153	634	8,787	5.9x10 ¹⁵	5,236
Pompoota	160	2,115	1,541	2,263	5,549	321	5,870	2.1x10 ¹⁵	2,267
Mypolonga North	286	4,390	4,342	5,823	15,009	1,724	16,733	2.3x10 ¹⁶	4,561
Mypolonga	271	2,747	2,680	3,598	9,411	1,193	10,604	1.4x10 ¹⁶	3,045
Glen Lossie	150	1,266	977	1,079	1,974	312	2,285	8.1x10 ¹⁴	3,256
Toora	143	1,573	224	274	1,322	140	1,462	1.5x10 ¹⁴	1,741
Burdett	42	332	131	188	521	13	534	4.4x10 ¹³	495
Long Flat	129	1,227	1,085	1,437	4,720	136	4,856	1.3x10 ¹⁵	1,709
Long Island	72	693	388	641	1,597	114	1,712	1.2x10 ¹⁵	792
Yiddinga	65	912	538	741	1,891	77	1,968	7.3x10 ¹⁴	1,054
River Glen	163	1,396	1,279	1,721	4,611	677	5,288	4.8x10 ¹⁵	1,866
Monteith	386	5,106	3,872	5,050	13,344	2,039	15,383	9.2x10 ¹⁵	6,505
Woods Point	262	3,048	3,513	4,398	11,914	1,880	13,794	4.7x10 ¹⁵	3,166
Jervois	1490	22,748	15,709	19,218	50,304	4,313	54,616	4.1x10 ¹⁶	20,067
McFarlanes	113	610	266	352	764	85	849	2.0x10 ¹³	766
Total	4,604	59,067	45,833	61,602	155,021	16,251	171,272	1.3x10¹⁷	66,211
Post-rehabilitation									
Cowirra North	158	775	889	1,244	3,165	651	3,815	1.2x10 ¹⁵	2,135
Cowirra	70	351	402	563	1,455	313	1,768	5.7x10 ¹⁴	1,007
Baseby	75	446	296	397	1,140	137	1,277	2.5x10 ¹⁴	2,015
Neeta North	55	235	95	159	461	92	553	9.0x10 ¹⁴	492

Site	Area (ha)	Drainage (ML)	Annual pollutant load						
			FRP	TP	TKN	NOx	TN	E Coli	TDS
			(kg)	(kg)	(kg)	(kg)	(kg)	(CFU)	(t)
Post-rehabilitation									
Neeta	260	1,291	508	835	2,466	492	2,958	4.9x10 ¹⁵	2,694
Wall Flat	202	1,203	432	597	1,857	276	2,133	1.1x10 ¹⁵	3,193
Pompoota	117	650	377	502	1,635	167	1,802	4.8x10 ¹⁴	1,651
Mypolonga North	150	1,120	503	608	2,138	523	2,660	3.0x10 ¹⁵	3,028
Mypolonga	203	1,081	717	872	3,012	723	3,736	4.3x10 ¹⁵	2,325
Glen Lossie	22	319	90	87	205	49	253	8.2x10 ¹³	2,512
Toora	58	325	28	31	200	41	241	2.3x10 ¹³	1,045
Burdett	18	94.5	20	26	95	4	100	7.9x10 ¹²	362
Long Flat	129	619	484	583	2,522	120	2,643	6.3x10 ¹⁴	1,506
Long Island	72	337	134	202	672	89	761	4.5x10 ¹⁴	685
Yiddinga	68	322	146	183	637	50	687	2.1x10 ¹⁴	878
River Glen	160	712	521	636	2,215	550	2,765	2.2x10 ¹⁵	1,571
Monteith	341	1,717	848	1,006	3,622	1,072	4,695	2.3x10 ¹⁵	4,964
Woods Point	270	1,197	1,033	1,185	4,323	1,300	5,622	1.6x10 ¹⁵	2,640
Jervois	1,200	5,476	2,349	2,642	9,363	1,806	11,169	7.1x10 ¹⁵	12,518
McFarlanes	141	496	251	302	810	106	917	1.6x10 ¹³	819
Total	3,769	18,764	10,123	12,659	41,993	8,561	50,554	3.1x10¹⁶	48,042
% Reduction									
Cowirra North	16%	65%	74%	76%	70%	45%	67%	74%	22%
Cowirra	0%	50%	67%	70%	61%	26%	58%	66%	14%
Baseby	-12%	34%	52%	56%	44%	5%	41%	54%	0%
Neeta North	0%	51%	62%	66%	56%	25%	53%	62%	13%
Neeta	-5%	56%	69%	72%	63%	32%	60%	68%	15%
Wall Flat	17%	69%	81%	82%	77%	56%	76%	80%	39%
Pompoota	27%	69%	76%	78%	71%	48%	69%	76%	27%
Mypolonga North	48%	74%	88%	90%	86%	70%	84%	87%	34%
Mypolonga	25%	61%	73%	76%	68%	39%	65%	70%	24%
Glen Lossie	85%	75%	91%	92%	90%	84%	89%	90%	23%

Site	Area (ha)	Drainage (ML)	Annual pollutant load						
			FRP (kg)	TP (kg)	TKN (kg)	NOx (kg)	TN (kg)	E Coli (CFU)	TDS (t)
% Reduction									
Toora	59%	79%	87%	89%	85%	71%	84%	85%	40%
Burdett	57%	72%	85%	86%	82%	66%	81%	82%	27%
Long Flat	0%	50%	55%	59%	47%	11%	46%	50%	12%
Long Island	0%	51%	65%	68%	58%	22%	56%	63%	14%
Yiddinga	0%	65%	73%	75%	66%	35%	65%	71%	17%
River Glen	2%	49%	59%	63%	52%	19%	48%	55%	16%
Monteith	12%	66%	78%	80%	73%	47%	69%	75%	24%
Woods Point	-3%	61%	71%	73%	64%	31%	59%	66%	17%
Jervois	19%	76%	85%	86%	81%	58%	80%	83%	38%
McFarlanes	-25%	19%	5%	14%	-6%	-26%	-8%	22%	-7%
Total	18%	68%	78%	79%	73%	47%	70%	77%	27%

Farm management data

Stocking rates

Table 13 shows the cow grazing days per hectare in the study locations with an annual average of about 400 cow days per hectare recorded. The average stocking rate range is between about 3.5-7 cows/ha in the LMRIA (LMIAG 1999, Scown Consulting 2001). High stocking rates are likely to increase the amount of nutrient inputs per hectare (either through increased fertiliser, dung and urine export, and purchased fodder), and subsequently increase the amount of nutrient losses to the environment (Rural Solutions SA 2006). The stocking rate information provides a baseline during the implementation phase of rehabilitation.

Table 13 Stocking rate data June 2005–06

Site	Area grazed (ha)	Cow days	Cow days/ha
Cowirra	116	47,490	409
Baseby	76	33,323	438
Wall Flat	15	7,662	511
Pompoota	51	18,664	366
Woods Pt	216	80,668	373
Jervois	66	29,710	450
Average			416

Fertiliser applications

Table 14 shows the average fertiliser applications in the study. Urea and nitrogen:phosphorus:potassium (N:P:K) fertilisers were the most commonly utilised. These fertiliser application rates compare well to previous data from the LMRIA (Fleming *et al.* 2003a).

Table 14 Fertiliser data

Site	Irrigation season	Area (ha) fertilised	N (kg/ha)	P (kg/ha)	Fertiliser type
Cowirra	2004–05	237	52	1	urea, DAP, chicken litter
	2005–06	240	36	2	urea, DAP, chicken litter
Baseby	2004–05	135	21	1	urea, NPK
	2005–06	–	–	–	–
Wall Flat	2004–05	49	29	1	urea, NPK
	2005–06	–	–	–	–
Pompoota	2004–05	4.6	37	–	urea
	2005–06	–	–	–	–
Woods Point	2004–05	653	21	1	urea, NPK
	2005–06	274	25	0.1	urea, NPK
Jervois	2004–05	88	29	2	urea, DAP
	2005–06	71	85	–	urea

Statistical analysis between farm management and pollutant drainage parameters

In general, the items used in the multivariate analyses explained comparatively little of the variance in pollutant loads (low R^2 values, Table 15), indicating that factors that were not accounted for in the model were also impacting on the pollutant loads. It is not uncommon in environmental studies to have relatively small R^2 values due to the complexity of the relations between different factors. It is possible the effects of paddock level farm management activities are masked when runoff or sub-surface drainage enters into the salt channels where the samples were taken from. In these channels there is a large volume capacity and dilution and mixing with previous water. There may also be processing and transformation of nutrients and other pollutants in the channels themselves (eg uptake of nutrients by aquatic vegetation). The proportion of surface runoff entering the drain is also important, as most of the nutrients are transported from the paddock in surface runoff (Murray and Philcox 1995). The degree of paddock runoff for each watering event was not measured in the current study.

At Cowirra the overall R^2 values of around 0.3–0.5 were more encouraging. The cow factor (C_f) was positively linked with several pollutant loads (NH_4 , TP, FRP, TOC) at Cowirra and some other sites. This finding reflects the importance of stock pollutant inputs and the timing of grazing in relation to watering events.

Seasonal effects were significant in relation to the loadings of TN, TP, FRP, and TOC at several sites. These effects were anticipated as drainage volumes and associated pollutant loads are at their highest during the irrigation season.

TN load was not significantly dependent on fertiliser nitrogen inputs (N_f) at any site, with the TP load only significant on phosphorus fertiliser inputs (P_f) at Woods Point. TN was correlated with rainfall at two sites while TP was not correlated at any site. The potential confounding factors mentioned above may be responsible for this result. Rainfall was positively correlated with TDS at several sites, indicating a possible flushing of salt out of the soils and/or increased input of regional saline groundwater.

Table 15 Regression analyses of pollutant loads versus farm management factors, season and rainfall

Load parameter	Factor	Partial regression coefficients (standard error)			
		Cowirra	Baseby	Woods Point	Jervois
TN	Season	0.325 (0.088)**		-1.39 (0.56)*	
	N_f				
	P_f				
	C_f		0.008 (0.004)*		
	Rainfall	0.006 (0.002)*			0.014 (0.006)*
	R^2	0.30	0.06	0.02	0.07
NH_4	Season				
	N_f	0.001 (0.000)*			
	P_f				
	C_f	0.003 (0.001)**	0.003 (0.001)*	0.002 (0.001)**	
	Rainfall		0.006 (0.002)**		
	R^2	0.27	0.10	0.15	
TP	Season	0.199 (0.051)**		-0.300 (0.126)**	
	N_f				
	P_f			0.022 (0.009)**	
	C_f	0.002 (0.001)*		0.002 (0.010)**	0.005 (0.002)*
	Rainfall				
	R^2	0.36		0.19	0.07

Load parameter	Factor	Partial regression coefficients (standard error)			
		Cowirra	Baseby	Woods Point	Jervois
FRP	Season	0.159 (0.074)*			
	N _f	0.002 (0.001)*			
	P _f				
	C _f	0.004 (0.001)**	0.003 (0.001)**	0.003 (0.001)**	
	Rainfall				
	R ²	0.38	0.14	0.12	
TOC	Season	1.931 (0.388)**			1.87 (0.92)*
	N _f				
	P _f				
	C _f	0.019 (0.006)**	0.055 (0.026)*		
	Rainfall				
	R ²	0.48	0.09		0.13
TDS	Season			-1010 (0.236)**	
	N _f				
	P _f				
	C _f	-1.99 (0.98)*			
	Rainfall	7.23 (1.89)**	16.7 (3.5)**		5.5 (2.2)*
	R ²	0.28	0.23	0.26	0.05
TSS	Season				
	N _f				
	P _f	1.46 (0.35)**			
	C _f		0.209 (0.083)*		
	Rainfall		0.351 (0.123)**		
	R ²	0.48	0.18		

Note: only significant findings (* P<0.05, ** P<0.01) are reported, R² values are the multiple coefficient of correlation.

Soil analyses

The soil sampling results are summarised in Table 16. There were satisfactory levels of most of the major soil constituents to maintain good pasture growth although there was a high level of variation between sites for some parameters (eg P, K). Nitrate was found to be low to marginal on many paddocks sampled while ammonium was high. This may be due to seasonal changes between nitrogen forms and is not considered to be of concern (MBP Consulting 2005).

Soils in the LMRIA are typically very heavy clays (60–70% clay), substantially modified by organic matter with a considerable degree of uniformity. They are naturally fertile soils with high levels of trace elements. Friability is variable depending on the amount of organic matter. Typical characteristics are high (210 mm/hr) hydraulic conductivity, very high (150–400 mm/m) water holding capacity, and a bulk density of 0.6–1.3 g/cm³ (MBP Consulting 2005).

Table 16 Soil analysis data summary

Location	Statistic	NO ₃ -N mg/kg	NH ₄ -N mg/kg	P mg/kg	K mg/kg	S mg/kg	Org-C %	Fe mg/kg	Salinity dS/m	pH (CaCl ₂)
Baseby	median	2	40	138	437	75	6.4	3,333	0.46	6.3
	20th percentile	1	30	82	333	36	5.3	2,556	0.26	5.8
	80th percentile	6	54	204	719	168	7.4	4,222	0.83	6.6
	n	45	45	45	45	45	45	45	45	45
Wall Flat	median	6	19	46	225	47	4.5	1,536	0.31	6.5
	20th percentile	4	15	34	168	37	4.2	1,104	0.24	6.2
	80th percentile	8	25	76	266	71	5.0	1,904	0.32	6.6
	n	12	12	12	12	12	12	12	12	12
Cowirra	median	5	68	191	542	57	7.2	2,050	0.43	6.3
	20th percentile	2	46	105	320	34	6.2	1,716	0.32	6.2
	80th percentile	18	101	380	984	145	9.2	2,504	0.71	6.6
	n	47	47	47	47	47	47	47	47	47
Pompoota	median	3	52	125	298	71	7.4	2,847	0.55	6.3
	20th percentile	2	36	92	208	58	5.8	1,904	0.49	6.2
	80th percentile	16	74	280	628	92	8.0	3,065	0.79	6.6
	n	15	15	15	15	15	15	15	15	15
Jervois	median	1	98	355	558	82	6.0	2,151	0.55	6.3
	20th percentile	1	70	193	412	61	5.4	1,547	0.48	5.9
	80th percentile	6	125	704	1095	163	6.4	2,850	1.06	6.7
	n	19	19	19	19	19	19	19	19	19

Location	Statistic	NO ₃ -N mg/kg	NH ₄ -N mg/kg	P mg/kg	K mg/kg	S mg/kg	Org-C %	Fe mg/kg	Salinity dS/m	pH (CaCl ₂)
Woods	median	9	64	192	514	153	5.8	2,533	0.96	6.7
Point	20th percentile	3	45	102	308	85	5.5	2,146	0.61	6.3
	80th percentile	22	87	283	836	334	6.0	3,260	1.82	7.0
	n	52	52	52	52	52	52	52	52	52
All areas	median	5	55	173	464	87	6.1	2,466	0.56	6.4
combined	20th percentile	1	34	89	281	47	5.4	1,820	0.34	6.1
	80th percentile	16	90	332	874	201	7.4	3,282	1.00	6.7
	n	190	190	190	190	190	190	190	190	190
Recommend- ed levels		>5		>45	>120	>5	>1.5		<2.3	5.7–7.2

Table 17 summarises the median level of different soil constituents relative to the position where the sample was taken on the flood-irrigation bay. The P, K, S, Fe, organic carbon, and salinity levels are typically higher at the drain or water-off end of paddocks compared to the river or water-on ends. These differences are likely to be due to migration of particulate material (manure and fertiliser) down the irrigation bays towards the drain as a result of flood irrigation. Higher levels of salt found at the drain end of paddocks are likely to be due to this area not being watered as regularly as the other areas (watering short is a common management practice). An additional reason could be that this is usually the main paddock access and watering point, and stock spend more time and therefore deposit more manure, in this location.

The soil data collected in the current study will provide a good baseline for future soil sampling following the completion of rehabilitation works. Salt and nutrient levels could change as a result of the requirement to begin recycling drainage water on-farm by June 2008. There could be positive effects with more nutrients recycled on-farm.

The raw soil data is listed in Appendix 3 and see MBP Consulting (2005) for additional information.

Table 17 Soil data versus location of samples on the irrigation bays

Location	Sample location	NO ₃ -N mg/kg	NH ₄ -N mg/kg	P mg/kg	K mg/kg	S mg/kg	Org-C %	Fe mg/kg	Salinity dS/m	pH (Ca Cl ₂)
Baseby	River	1	44	80	343	53	5.4	2,224	0.28	6.5
	Middle	3	45	138	437	74	6.7	3,001	0.37	6.3
	Drain	2	34	241	690	168	6.4	4,179	0.83	6.2
Wall Flat	River	6	18	42	209	46	4.3	1,196	0.29	6.6
	Drain	7	21	47	225	50	4.8	1,691	0.31	6.3

Location	Sample location	NO ₃ -N mg/kg	NH ₄ -N mg/kg	P mg/kg	K mg/kg	S mg/kg	Org-C %	Fe mg/kg	Salinity dS/m	pH (Ca Cl ₂)
Cowirra	River	2	52	97	286	53	6.3	1,752	0.41	6.3
	Middle	5	57	185	500	78	7.2	1,991	0.49	6.3
	Drain	16	94	402	1,115	83	8.2	2,521	0.57	6.4
Pompoota	River	1	37	86	203	61	6.5	1,780	0.51	6.3
	Middle	4	52	130	298	72	7.5	2,847	0.55	6.2
	Drain	10	89	302	593	85	7.9	2,986	0.65	6.3
Jervois	River	1	97	176	272	57	6.1	2,151	0.51	6.2
	Middle	1	98	265	489	73	5.6	3,133	0.52	5.9
	Drain	8	140	726	1,046	110	6.6	2,148	0.74	6.4
	Back	1	102	603	1,003	460	5.5	1,266	2.04	7.1
Woods Point	River	5	54	98	249	78	5.5	2,523	0.57	6.5
	Middle	8	81	188	421	137	5.8	2,633	0.84	6.7
	Drain	11	87	293	905	251	5.8	2,867	1.16	6.9
	Back	12	57	254	587	148	5.8	2,256	1.04	6.7
	Back-Water on-end	23	41	115	682	672	5.8	1,210	2.24	7.2
	Back-Water off-end	34	60	207	723	318	5.9	2,607	1.89	6.5
Recommended levels		>5		>45	>120	>5	>1.5		<2.3	5.7–7.2

Lower River Murray water quality

A summary of water quality at Mannum, Murray Bridge, and Tailem Bend between 2002–06 is presented in Table 18 and Figures 40–46. River flow downstream of Lock 1 is shown in Figure 47.

E Coli typically increases below Mannum with large spikes occurring during summer periods when flood irrigation drainage water returns are occurring (Table 18 and Figure 40). The 2004–05 irrigation seasons had low *E Coli* levels; however the 2006 season showed large spikes present at Murray Bridge and Tailem Bend. It is unclear what lay behind this inter-annual variability. The median *E Coli* levels at Murray Bridge and Tailem Bend exceed recommended guideline levels (100 *E Coli* per 100 mL) to minimise illnesses (eg gastrointestinal, ear and eye infections) resulting from recreational bathing in freshwaters (Wiedenmann *et al* 2006). One of the key objectives of the LMRIA rehabilitation program is to reduce this risk and large *E Coli* load reductions are predicted in the next year (77% reductions, Table 12).

TKN decrease slightly between Mannum and Tailem Bend, with seasonal trends being observed at all sites (Table 18 and Figure 41). The apparent reduction in reduced nitrogen concentrations despite large loadings from the LMRIA is interesting and suggests complex

nutrient dynamics. Since the River Murray is very slow moving in this region, it is possible that a large proportion of nutrient inputs from the LMRIA are being deposited in the sediment. The long water residence times and high organic loadings in the Lower Murray could also favour loss of gaseous nitrogen from the system via denitrification. This process can be a large exporter of nitrogen from aquatic systems (Harris 2001).

NH₄ concentrations decrease between Mannum and Tailem Bend with peaks in summer (Table 18 and Figure 42). In contrast, NO_x concentrations increase downstream of Mannum, with similar cyclical trends observed at all sites (Table 18 and Figure 43). The increase in NO_x could be due to oxidation of NH₄ and organic nitrogen originating from LMRIA drainage discharges. Drainage water discharges from the LMRIA are typically high in NH₄ and organic nitrogen compared to NO_x, and increase in volume during summer when peaks in the river are observed. NH₄ release from anoxic bottom sediments and subsequent oxidation to nitrate in the water column may also play a role in increasing NO_x levels with distance downstream.

Total phosphorus concentrations are relatively similar between Mannum and Tailem Bend, with cyclical decreasing trends in concentration being observed at all sites in recent years (Figure 44). This observed trend suggests that despite the large inputs, much of the P from the LMRIA drainage channels is ending up deposited in the sediment, either directly (eg settling of organic P) or indirectly (adsorption to particles and subsequent settling). Low flow conditions in the lower Murray would promote increased settling of particles. Filtered reactive (soluble) phosphorus median values increase substantially below Mannum, but FRP only forms about 2–4% of TP (Figure 45). In contrast in the LMRIA drainage channels, FRP typically forms >50% of TP (Table 4). This suggests rapid equilibration with particle surfaces or uptake by algae once drainage water is pumped into the turbid river (see Webster *et al* 2001 for detailed discussion on P dynamics). Dissolved organic carbon shows similar trends to TP and TKN (Figure 46).

‘Redfield ratios’ were used to examine the potential bioavailability of nutrients to algae. A Redfield ratio indicates the point at which dissolved nutrient concentrations in the water are considered in balance (not limiting) for aquatic algae (eg see Harris 2001). A Redfield ratio below 15 is indicative of N limitation, and above 15 of P limitation. The dissolved inorganic nitrogen (DIN) to FRP ratio (in atomic units) at Mannum, Murray Bridge and Tailem Bend is shown in Figure 48. At low dissolved nutrient concentrations, much of the data plots near the Redfield ratio line. However, a time series plot shows that most of the N-limited samples were taken prior to 2003 (Figure 49). There appears to have been an increase in nitrogen availability since that date, possibly due to reduced flows increasing residence time (Figure 47). During these conditions, in-stream and sediment processing of nutrients could have greater effect on ambient water nutrient levels. This may be leading to the observed increased nitrate levels. At Tailem Bend, samples were more often above the Redfield line than at the other sites, indicating nitrogen enrichment. The large increase in oxidised nitrogen (Figure 43) towards Tailem Bend is likely to be the reason for this transition.

It is noted that in this region of the river, blooms of the problematic blue-green algae, *Anabena circinalis*, in the Lower Murray are not frequent. These algae are typically limited by high turbidity in the river and absence of persistent thermal stratification in this region of the river (Bormans *et al* 1997). High temperatures, low river flows, and low winds promote thermal stratification of the water column. The current low flow conditions are increasing the potential for algal blooms to develop.

Trends in water quality from 2002–07 were statistically analysed using the Seasonal Kendall trend test (Table 18). Trends at Mannum would indicate an upstream influence on water quality while trends at the lower sites of Murray Bridge and Tailem Bend could indicate improvements in water quality due to the LMRIA rehabilitation project. A statistically significant decreasing concentration was observed for *E coli* at Tailem Bend, with the trend estimated to be declining by 60 CFU/100 mL per year. Other significantly decreasing trends

were found for TP and FRP but slopes tended to be similar at the three sites suggesting that this was not due to the LMRIA project's outcomes, and is more likely related to declines in river flows (Figure 47). Flow correction and trend testing on flow-corrected data was not able to be performed adequately (see 'trends in river water quality' section in the methods).

Rehabilitation works in the LMRIA have only been partly completed and very few re-use systems are operational. Much greater pollutant load reductions would be expected in the next 6–12 months with completion of rehabilitation works during 2008. Improving river water quality should follow these load reductions but low river flows and restricted water allocations during the current drought make statistical analysis of this difficult. Due to the likelihood of continued release of pollutants (nutrients, organic matter) present in the bottom sediments, improvements in river water quality for some parameters may take some time. However, *E Coli* levels are expected to drop immediately as the sediment source is likely to be limited.

Table 18 Median values and trends in river water quality at Mannum, Murray Bridge and Tailem Bend. The trend statistic is the Seasonal Kendall Slope Estimator, in water quality units per year.

Parameter	Sample site		
	Mannum	Murray Bridge	Tailem Bend
E Coli (CFU/100mL)			
median	50	290	240
trend	not signif.	not signif.	-60**
TKN (mg/L)			
median	0.695	0.580	0.580
trend	-0.12*	-0.09**	not signif.
NH ₄ (mg/L)			
median	0.020	0.015	0.011
trend	not signif.	not signif.	not signif.
NO _x (mg/L)			
median	0.054	0.117	0.197
trend	-0.014**	-0.020**	not signif.
TP (mg/L)			
median	0.102	0.104	0.116
trend	-0.026**	-0.021**	-0.021**
FRP (mg/L)			
median	0.012	0.019	0.035
trend	-0.016**	-0.016**	-0.016**

Parameter	Sample site		
	Mannum	Murray Bridge	Tailem Bend
DOC (mg/L)			
median	4.5	4.2	4.2
trend	not signif.	-0.5*	not signif.

Note: (*significant at $p < 0.05$ level, ** significant at $p < 0.01$ level)

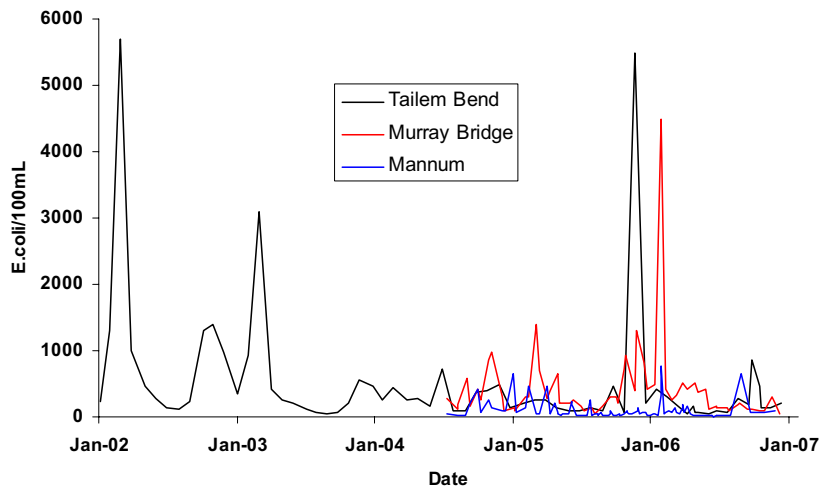


Figure 40 E Coli levels in the Lower River Murray

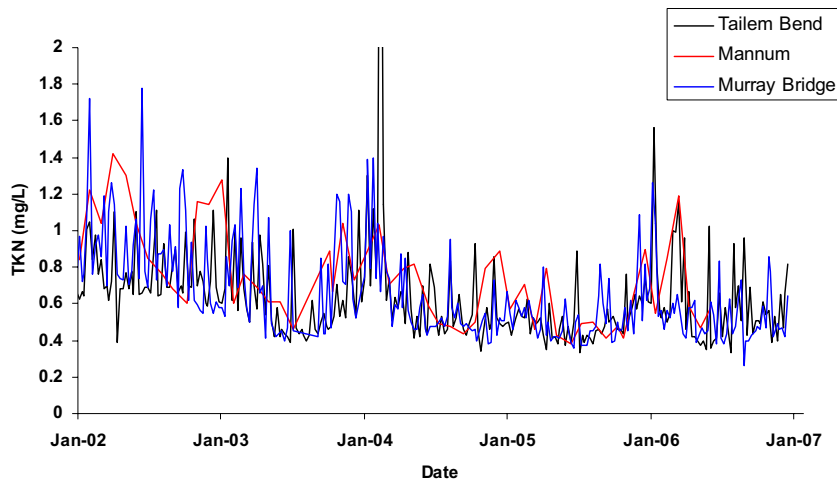


Figure 41 Total Kjeldahl Nitrogen levels in the Lower River Murray

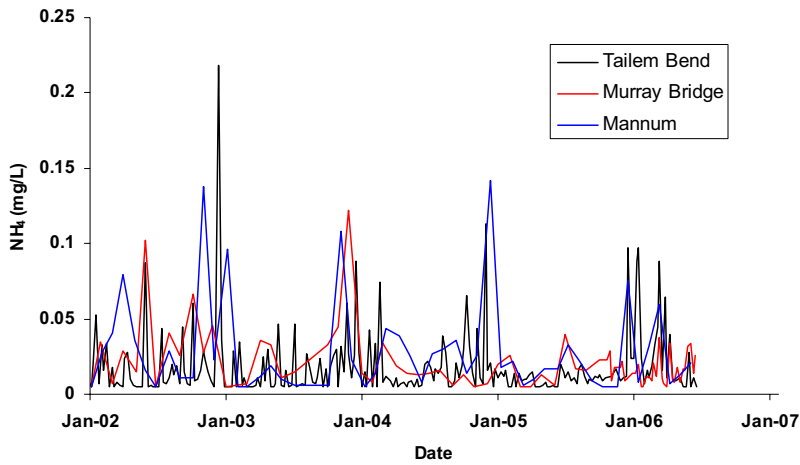


Figure 42 Ammonia levels in the Lower River Murray

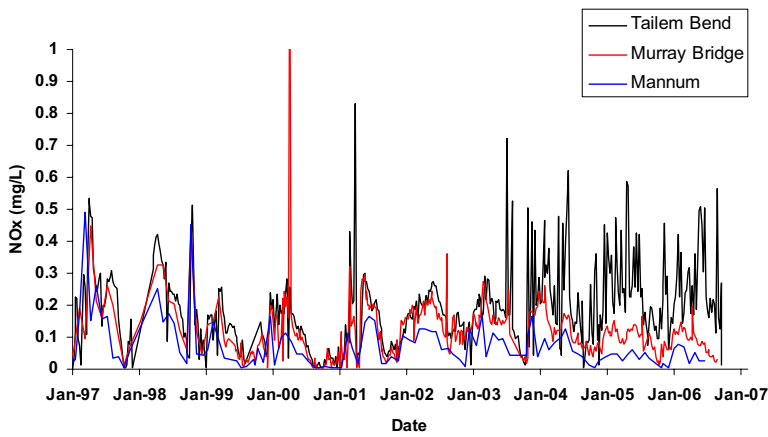


Figure 43 Oxidised nitrogen levels in the Lower River Murray

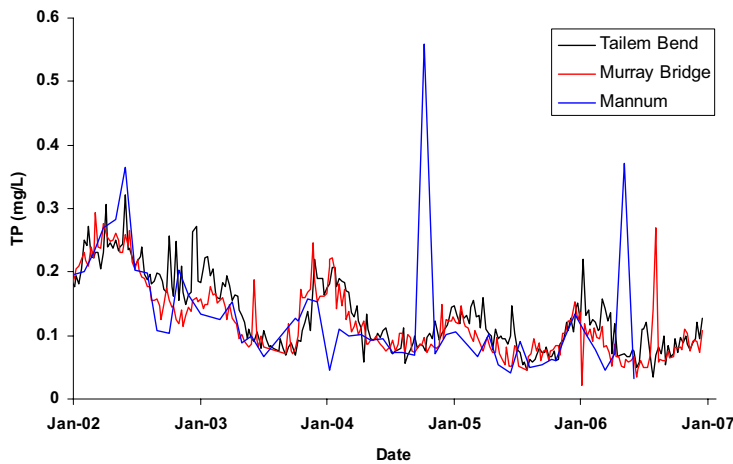


Figure 44 Total phosphorus levels in the Lower River Murray

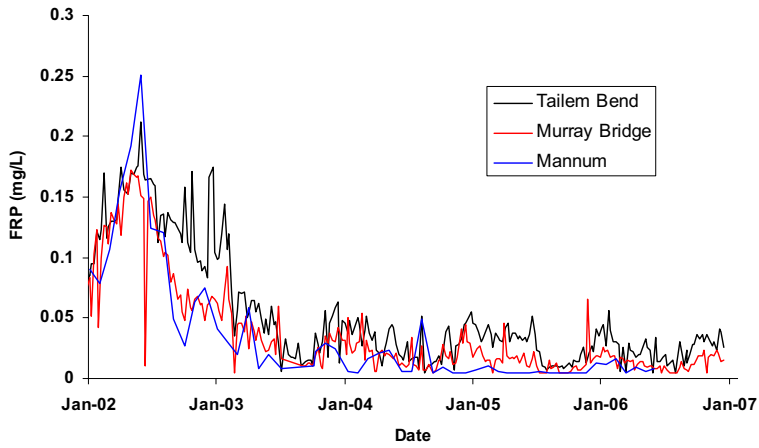


Figure 45 Filtered reactive phosphorus levels in the Lower River Murray

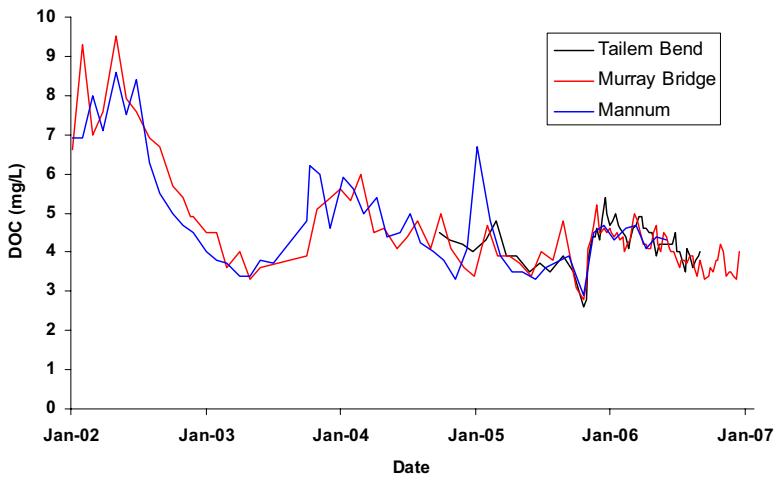


Figure 46 Dissolved organic carbon levels in the Lower River Murray

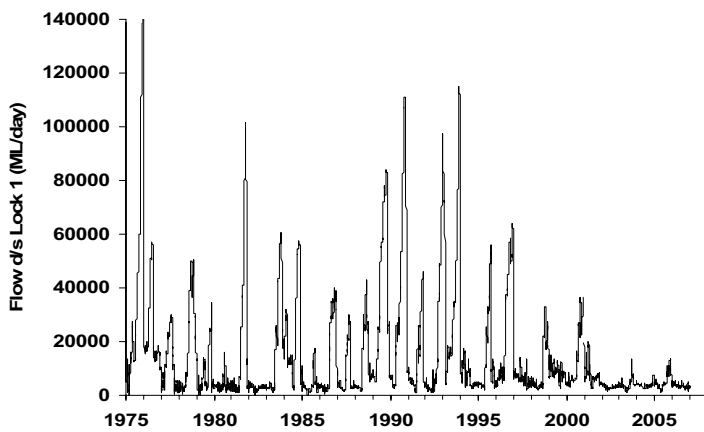


Figure 47 Flow of the River Murray downstream of Lock 1 from 1975–2007

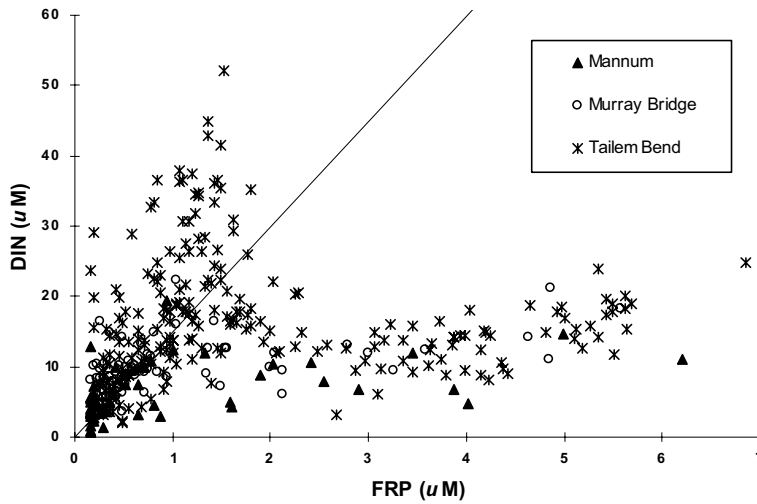


Figure 48 Dissolved inorganic nitrogen versus filtered reactive phosphorus concentration. The line indicates the Redfield ratio of 15:1.

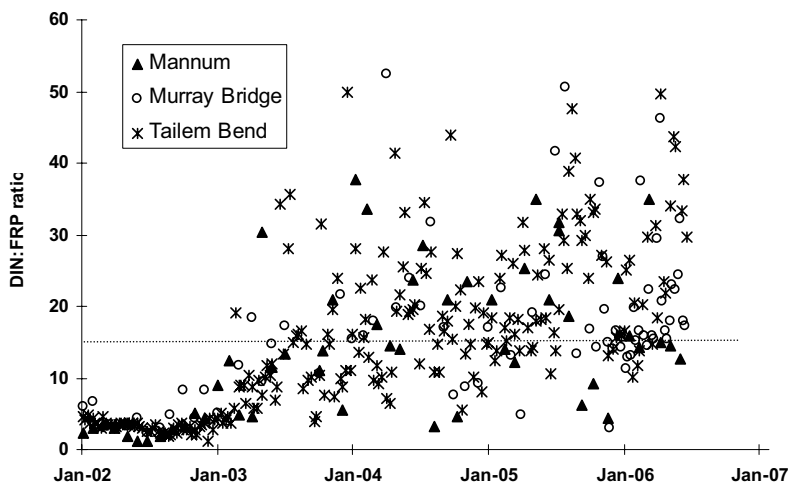


Figure 49 Time series of the dissolved inorganic nitrogen versus filtered reactive phosphorus concentration. The line indicates the Redfield ratio of 15:1.

Environmental cost-benefit analysis

A simple environmental cost-benefit approach was undertaken for the LMRIA rehabilitation project (Table 19). The project is expected to provide substantial and ongoing benefits to both irrigators and the community as the net estimated benefits outweigh the costs by greater than a factor of 2-3. The major benefit results from more efficient water use. The net benefit could be greater when the additional factors can be quantified (eg reduction in water treatment costs and costs due to illnesses from recreational bathing). There may also be recreational and tourism benefits through improving river amenity. It is noted that this is a limited analysis and actual social costs could be higher with some irrigators leaving the industry via a government exit package. The project needs to proceed further before the full costs and benefits can be quantified.

Table 19 Estimated costs and benefits of LMRIA rehabilitation project

Costs	Cost/benefit recipient	Estimate \$million
Rehabilitation—government funding contribution (\$3,135/ha, and program costs)	Government	22.0
Rehabilitation—irrigator funding contribution (\$630/ha, 4,097 ha to be rehabilitated)	Irrigator	2.6
<i>Total Estimated Costs</i>		<i>24.6</i>
Benefits		
Reduced water use*	Irrigator, community	62.3
Fertiliser savings due to less nutrient load returned to the river [†]	Irrigator	0.45
Pump electricity cost savings [^]	Irrigator	0.16
Reduced water treatment costs due to improved water quality [#]	SA Water, community	?
Health benefits due to reduced incidence of illness resulting from recreational bathing in river ^ψ	Community, government	?
<i>Total Estimated Benefits</i>		<i>62.9</i>
Estimated overall project benefit–cost ratio (≈ 2–3)		38.3

† Irrigators' funding contribution could exceed this value as additional works are undertaken above the government funding cap or the cap is not sufficient in some circumstances

* Based on 50 GL estimated reduction in irrigation volumes (Table 7) and the average water trading cost in 2005–06 year (\$1244 ML) for this region on <www.waterfind.com.au>. Note this value is currently over \$2.000 per ML due to drought conditions and restricted allocations increasing water value in the Murray–Darling Basin

[†] Estimated load of reduction 120 tonnes TN and 50 tonnes TP (see Table 9). At N:P:K fertiliser cost of \$500 per tonne (with 15% N and 5% P content w/w)

[^] Estimated on reduction in drainage volume returned to the river by a typical pump flow rating (340 L/s, Fleming & Gepp 2002) and estimated \$5 electricity cost per hour of pump operation

[#] Estimates could not be made due to a lack of data on treatment costs in relation to variable water quality and on river water quality outcomes following rehabilitation. Atech Group (1999) reported that SA Water have spent \$9.9 million in once-off costs and \$1.9 million in ongoing annual costs to deal with algal blooms across the state. Many of these blooms have been in the River Murray or in reservoirs supplied from the river. SA Water are currently spending several million dollars upgrading small township treatment plants in the Lower Murray.

^ψ Estimates could not be made due to a lack of data on bathing numbers. Wiedenmann *et al* (2006) recently conducted the first randomised control trial of microbial risks in freshwaters (study site in Germany). They found a no observable illnesses at about 100 E Coli/100mL which increased to a gastrointestinal illness rate of approximately 9% above an *E Coli* level of 1000/100 mL. Dwight *et al* (2005) estimated that the economic burden per gastrointestinal illness to be US\$36.58, US\$76.76 per acute respiratory disease, US\$37.86 per ear ailment, and US\$27.31 per eye ailment. For every one gastrointestinal illness there were 0.337 acute respiratory diseases, 0.551 ear infections, and 0.303 eye infections.

CONCLUSION

This study collected environmental monitoring information prior and during the implementation stage (2004–06) of the LMRIA rehabilitation project. Data was collected from six irrigation areas; Cowirra, Baseby, Wall Flat, Pompoota, Woods Point and Jervois. The key findings of the study to date are as follows:

Water use—Water use per hectare was monitored from 10 different intake sluices with different degrees of rehabilitation completion. The average water use per watering of 0.6 ML/ha for the fully rehabilitated site at Woods Point was one third of the average water use per watering (1.8 ML/ha) for the non-rehabilitated sites. The water balance modelling indicates that full completion of rehabilitation in the LMRIA should result in 50 GL less water extracted from the river per year.

Drainage water quality—*E Coli*, TN, TP, and TOC concentrations were consistently much higher in the drainage water than the inflow water, as a result of runoff and drainage from dairy cow faecal material, fertilisers and soil constituents. As a result, the time series of the drainage water constituents show peaks in the irrigation season. Salt (TDS) concentrations were also consistently higher in the drainage water than the river inflow water and increased significantly at the end of the irrigation season, as groundwater salt concentrations were not diluted by irrigation water during this time.

Pollutant loads—Pollutant loads (TP, TN, TOC) were closely linked to flood irrigation events and peaked during the irrigation season. Large rainfall events made a significant contribution to sediment loads. Salt (TDS) loads were more constant due to regional saline groundwater inputs. Substantial average reductions in drainage volumes (68%, 40 GL) and pollutant loads (eg TN 70%, TP 78%, *E Coli* 77%) returned to the river from the LMRIA are estimated following completion of rehabilitation. Further ongoing monitoring is required to verify these predictions.

Links between pollutant loads, on-farm activities and rainfall events—A weak linkage was demonstrated between paddock-level farm management activities and drainage water quality. The dilution and processing of pollutants in the main drainage channels are believed to add complexity to the interpretation of paddock level activities.

River Murray water quality—River Murray water quality was analysed from 2002–06 at Mannum, Murray Bridge and Tailem Bend. *E Coli*, NO_x and FRP increase downstream of Mannum and this is likely due to discharge from the LMRIA drainage channels and in-river processing of pollutants. Decreases in concentrations of some parameters (TKN, TP, FRP) have been observed in recent years. However, given the current low river flow conditions, it cannot be confidently assumed that these trends result from reduced pollutant discharges from the LMRIA.

Soil condition—Baseline monitoring of soil condition found current satisfactory levels of key parameters (eg N, P, salinity, and pH) with increases in concentrations of some constituents towards the drain end of irrigation bays.

Environmental costs and benefits—A basic environmental cost–benefit analysis was undertaken to estimate the costs and benefits of the LMRIA rehabilitation project. The net estimated benefits outweighed the costs by greater than a factor of 2–3 times. The greatest benefit derived from more efficient water use. This was a preliminary and limited analysis, actual social costs could be higher with some irrigators leaving the industry via a government exit package.

The preliminary results are extremely encouraging for the LMRIA rehabilitation project's goal of improving the quality and quantity of water in the River Murray. The monitoring study is being continued until mid-2009 (Phase 2) to attempt to fully assess the benefits of the LMRIA rehabilitation programme. However, the current drought situation, low river flows and

restricted irrigation water allocations makes evaluating monitoring data and the programme's outcomes difficult.

RECOMMENDATIONS

- The next phase (2) of the monitoring should focus on measuring pollutant loads returned to the River Murray until the end of the 2008–09 irrigation season. A continuous pump-hour and EC logging system is recommended to be installed on all main drainage pumps returning water from the LMRIA to the river with water quality sampling at the same irrigation areas as in Phase 1. Pumps should be calibrated biannually and drainage volumes and pollutant loads calculated. This will enable the effects of rehabilitation on pollutant loads from a wider study area to be estimated in a more cost-effective and low-maintenance manner.
- Irrigation efficiency should be closely monitored on a farm-by-farm basis and area level until the 2008–09 irrigation season. This information could be collected by DWLBC as part of the new LMRIA irrigator's water metering and reporting requirements. Individual farm irrigation information (volume, area watered, and watering interval) should be collected from selected sites in Phase 1 of the study.
- Farm management data should not be routinely collected in the next phase of this monitoring study. Much of this information is now collected as part of individual farm's Environmental Improvement and Management Programmes (EIMPs).
- A voluntary program that looks at management of the whole farm environmental management system (EMS) or similar tools should be supported to reduce pollutant runoff from highland areas to the LMRIA drainage channels.
- There should be continued education and transmission of environmental information to irrigators.
- Re-assessment of soil condition and stocking rates should be made post-rehabilitation and return of full water allocation post drought.
- Trends in River Murray water quality should be monitored closely over the next two years, and nutrient fluxes in the river further examined.

REFERENCES

- Adcock, P 2000, *Assessment of irrigation drainage waters from the lower River Murray reclaimed swamps for the presence of indicator bacteria and pathogens*, Australian Water Quality Centre consultancy report.
- APHA 2005, *Standard Methods for the Examination of Water and Wastewater*, 21st edition, American Public Health Association.
- Atech Group 1999, *Cost of algal blooms*, Land and Water Resources Research and Development Corporation occasional paper 26/99.
- Bormans M, Maier H, Burch M & Baker P 1997, Temperature stratification in the lower River Murray, Australia: implication for cyanobacterial bloom development, *Marine and Freshwater Research*, 48: 647–654.
- Cole, PJ 1985, *The River Murray irrigation and salinity investigation programme, results and future directions*, Department of Agriculture South Australia, technical report no. 69.
- South Australian Department of Water Land and Biodiversity Conservation 2003, *Regional salt and water balances for the Lower Murray in SA*, report 2003/27, DWLBC, Adelaide.
- Eco-Management Services 2003, *Water quality monitoring of discharges from the Lower Murray Irrigation Areas (March 2002–2003)*, Blackwood, South Australia.
- South Australian Environment Protection Authority 2001, *Ambient water quality monitoring of the River Murray 1990–1999*, EPA, Adelaide.
- 2005, *Cowirra surface irrigation re-use trial*, EPA, Adelaide.
- Fleming NK & Gepp MJ 2002, *Drainage pump monitoring—Lower Murray irrigation area*, South Australian Research and Development Institute, Adelaide.
- Fleming NK, Cox JC, Hutson JL, & Gepp MJ 2003a, *Reduced Nutrient Loads to the Lower Murray in South Australia*, milestone report no. 17—Final Report Year 2, South Australian Research and Development Institute, Adelaide.
- Fleming NK, Gepp MJ, Cox JC, & Hutson JL 2003b, *Reduced Nutrient Loads to the Lower Murray in South Australia*, Milestone Report No. 7—watering volumes and runoff 2001/3, South Australian Research and Development Institute, Adelaide.
- Friesen, DK & Blair, GJ 1984, A comparison of soil sampling procedures used to monitor soil fertility in permanent pastures, *Australian Journal of Soil Research*, 22, 81–90.
- Harris GP 2001, *A nutrient dynamics model for Australian waterways: Land use, catchment biogeochemistry and water quality in Australian Rivers, Lakes and Estuaries*, Australian State of the Environment Second Technical Paper Series (Inland Waters), Department of Environment and Heritage, Canberra.
- Helsel DR & Hirsch RM 1992, *Statistical methods in water resources*, Elsevier Science Publishing Company, New York.
- Lower Murray Irrigation Action Group 1999, *Draft Land and Water Management Plan*, LMIAG.
- MBP Consulting (2005), *Farm nutrient status—irrigation runoff trials*, Report to the Environment Protection Authority, Adelaide.
- Murray MB & Philcox 1995, *An assessment of irrigation runoff from flood irrigated dairy pastures of the Lower Murray*, Primary Industries and Resources South Australia, Adelaide.
- Nexhip KJ, Mundy GN, Collins MD & Austin NR 1997, *Development of nutrient water quality targets for irrigated pasture sub-catchments*, Final Report Project I5037, Institute of Sustainable Irrigated Agriculture, Australia.
- Pakrou N & Dillion PJ 2000, Key processes of the nitrogen cycle in an irrigated and non-irrigated grazed pasture, *Plant and Soil*, 224, 231–50.

Pakrou N & Dillion PJ 2004, Leaching losses of N under grazed irrigated and non-irrigated pastures, *Journal of Agricultural Science*, 142, 503 –16.

Philcox MB 2002, *Laser Levelling on the Lower Murray: a collection of articles and papers on laser levelling from research undertaken on the reclaimed swamps*, Primary Industries and Resources South Australia, Adelaide.

River Murray Catchment Water Management Board 2004, *Water allocation plan for the River Murray prescribed watercourse*, RMCWMB, Adelaide.

Rural Solutions SA 2006, *Discussion paper: Nutrient management on dairy farms in the South East & Murraylands of South Australia*, Agricultural Development Partnership Project, Rural Solutions SA, Primary Industries and Resources South Australia, Adelaide

Scown Consulting 2001, *Monitoring water use efficiency on 10 irrigated dairy farms in the Lower Murray region of South Australia*, final report October 2001, Strathalbyn, South Australia.

Tonkin Consulting 2004, *Sources of nutrients in South Australia*, Tonkin Consulting, Adelaide.

Tonkin Consulting 2007, *Sources and volumes of water and pollutants entering the LMRIA drainage channels*, Tonkin Consulting, Adelaide.

Webster IT, Ford PW & Hancock G, 2001, Phosphorus dynamics in Australian lowland rivers, *Marine and Freshwater Research*, 52, 127–37.

Wiedenmann A, Krüger P, Dietz K, López-Pila JM, Szewzyk R & Botzenhart K 2006, A Randomized Controlled Trial Assessing Infectious Disease Risks from Bathing in Fresh Recreational Waters in Relation to the Concentration of *Escherichia coli*, Intestinal Enterococci, *Clostridium perfringens*, and Somatic Coliphages, *Environmental health Perspectives*, 114, 228–36.

APPENDIX 1 FARM MANAGEMENT DATASHEET

FARM:

MONTH:

Date	Milkers	AM Paddock	PM Paddock	Other stock	Paddock	Irrigation			Fertiliser			Weather		Feeding (kg/cow)			
						Paddock	Water salinity	Comments	Paddock	Type	Rate kg/ha	Rainfall	Comments	Grain (kg)	Hay (kg)	Other (kg)	
Eg	105	8	12	23 heif	18	1, 3, 5		short	1-12	10:15:21:0	100 kg/ha	-	hot & windy	5	10	-	
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
13																	
14																	

APPENDIX 2 WATER QUALITY DATA

Cowirra

DATE	E Coli	E Coli	TN	TN	NH4	NOx	NOx	TP	TP	FRP	FRP	TOC	TOC	TDS	TDS	TUR	TUR	TSS
	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT
	CFU/100mL	CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	NTU	mg/L
19-Jan-05	700	98	1.8	3.6	1.5	0.02	0.01	0.13	2.2	0.042	1.5	5	15	256	1,587	45	6.2	3
24-Jan-05	1,000	13,000	0.9		0.12	0.1	1.43	0.25		0.036	1.8	4		248		50		
31-Jan-05	5,700	12,000	0.83	3.9	1.4	0.03	0.37	0.11	2.1	0.036	2.8	6	19	229	1,029	60	15	15
7-Feb-05	1,700	91	0.95	4.6	0.99	0.05	0.22	0.11	1.8	0.033	0.9	5	16	234	2,487	55	9.2	13
15-Feb-05	260	680	0.86	2.2	1.2	0.06	0.28	0.10	1.5	0.039	3.6	5	12	244	1,753	45	9.5	16
22-Feb-05	16,000	24,000	0.63	3	1.5	0.03	0.71	0.06	1.9	0.003	2.6	5	20	243	1,068	34	11	7
1-Mar-03	4,000	110,000	0.7	4.3	1.1	<0.01	0.12	0.09	1.7	0.003	2.2	6	27	243	1,366	32	13	12
8-Mar-05	2,000	42,000	0.73	3.1	0.87	0.03	0.13	0.10	0.52	<0.003	0.7	5	14	244	1,398	31	33	44
14-Mar-05	24,000	19,000	0.8	2.1	0.25	<0.01	0.76	0.10	1.3	<0.003	1.5	5	13	246	988	34	21	35
21-Mar-05	14,000	93,000	0.6	3.3	3.1	<0.01	0.14	0.05	1.8	<0.003	2.4	5	15	246	1,394	27	33	53
29-Mar-05	9,000	19,000	0.50		2.30	0.02	0.21	0.08		<0.003	3.1	4		235		28		
5-Apr-05	4,000	7,200	0.50	4.40	2.10	0.05	0.18	0.07	2.80	0.003	2.1	5	16	242	2,213	27	24	67
12-Apr-05	4,000	25,000	0.40	3.50	0.86	0.05	0.39	0.07	1.50	<0.003	0.9	4	13	240	886	27	70	96
19-Apr-05	7,000	17,000	0.65	4.90	1.30	0.05	1.10	0.06	3.20	0.007	2.6	5	26	244	741	30	34	52
26-Apr-05	4,000	240,000	0.78	6.40	0.89	0.08	2.30	0.08	3.80	0.003	3.1	5	27	247	944	27	30	44
2-May-05	3,000	44,000	0.47	2.40	0.46	0.07	0.33	0.06	1.30	0.013	0.6	4	10	244	1,075	25	38	54
10-May-05	1,000	17,000	0.50	1.20	0.41	0.07	0.26	0.06	1.50	0.007	0.7	4	14	247	1,009	24	26	44

DATE	E Coli	E Coli	TN	NH4	NOx	NOx	TP	TP	FRP	TOC	TDS	TDS	TUR	TUR	CI	TSS	
	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	
	CFU/100mL	CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
17-May-05	25,600	7,500	0.40	2.50	0.07	1.80	0.04	1.20	0.010	2.9	4	12	244	1,253	23	28	48
24-May-05	2,900	8,000	0.80	2.80	0.06	1.20	0.07	0.57	0.007	1.2	5	10	248	1,137	23	110	190
31-May-05	1,100	12,000	0.07	3.30	0.43	1.20	0.06	1.40	0.003	0.4	6	15	248	910	22	40	42
7-Jun-05	700	4,900	0.38	2.10	0.38	0.57	0.06	0.73	0.007	0.4	4	8	252	1,246	17	39	46
21-Jun-05	1,700	1,000	0.63	7.40	4.10	0.79	0.06	3.1	0.007	3.6	5	20	246	2,681	17	95	90
5-Jul-05	2,700	100	0.53	8.60	2.20	2.20	0.06	2.9	<0.003	1.9	6	17	270	9,784	17	80	97
19-Jul-05	3,200	800	0.55	6.90	0.80	1.60	0.06	2.5	0.007	1.2	5	9	301	13,545	21	21	7,800
2-Aug-05		2,000		3.00	0.03	0.19		0.56		0.6		23		10,874		19	5,600
16-Aug-05		200		6.90	<0.01	<0.01		2.4		0.7		31		16,468		13	9,200
29-Aug-05		<1		6.20	3.00	<0.01		2.1		1.3		29		17,400		24	10,000
13-Sep-05		<1		9.30	0.07	<0.01		3.00		2.3		34		20,000		38	12,000
29-Sep-05		2,200		5.70	0.41	0.48		2.30		0.8		20		4,800		33	2,200
11-Oct-05		9,900		6.30	2.20	0.57		3.80		1.3		24		4,100		55	1,900
25-Oct-05		19,000		4.20	7.90	0.02		1.80		5.2		15		6,400		37	3,200
1-Nov-05	1,000	32,000	0.60	3.10	0.30	0.15	0.07	1.50	0.003	0.7	5	11	200	2,300	29	70	1,000
7-Nov-05	200	22,240	0.80	5.20	0.88	1.20	0.10	3.10	0.007	1.8	6	24	200	1,600	35	38	680
15-Nov-05	2,700	9,000	0.90	5.60	0.66	0.14	0.10	2.20	0.007	1.3	6	19	190	4,400	50	20	2,000
21-Nov-05	3,000	30,000	0.07	6.50	1.80	1.60	0.10	3.20	0.007	4.2	8	27	190	3,400	40	33	1,600
29-Nov-05	6,300	960,600	0.70	4.00	1.80	0.27	0.10	3.10	0.010	2.7	8	25	200	1,200	39	30	440
6-Dec-05	1,220	960,600	0.50	4.60	3.10	<0.01	0.11	2.40	0.007	5.2	8	22	200	1,200	40	50	480

DATE	E Coli RIVER	E Coli SALT	TN RIVER	TN SALT	NH4 RIVER	NH4 SALT	NOx RIVER	NOx SALT	TP RIVER	TP SALT	FRP RIVER	FRP SALT	TOC RIVER	TOC SALT	TDS RIVER	TDS SALT	TUR RIVER	TUR SALT	TSS RIVER	TSS SALT
	CFU/100mL	CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	NTU	NTU	mg/L
13-Dec-05	100	416,000	0.70	5.10	3.10	0.03	1.4	0.11	2.90	<0.003	5.2	7	26	180	1,200	40	36	460	39	
20-Dec-05	609	298,700	0.80	6.20	1.90	<0.01	<0.01	0.12	3.40	0.010	0.6	7	30	180	990	45	26	790	84	
28-Dec-05	862	79,400	0.90	3.80	2.80	0.06	0.11	0.11	2.30	0.007	1.5	7	24	180	1,200	45	29	420	30	
3-Jan-06	565	2,000	0.70	4.10	0.72	0.03	0.07	0.11	3.00	0.01	1.54	6	28	190	1,000	45	30	370	36	
10-Jan-06	435	3,100	1.10	5.00	1.10	0.06	0.66	0.12	1.90	0.01	2.22	6	24	190	1,000	45	25	390	100	
17-Jan-06	305	6,200	0.70	4.60	3.10	0.05	0.21	0.10	2.00	0.01	1.80	7	25	190	1,300	50	15	480	68	
24-Jan-06	318	37,900	0.60	4.80	2.20	0.07	0.54	0.10	2.90	0.01	4.58	7	25	190	1,100	45	26	410	65	
31-Jan-06	1,800	13,000	0.80	3.80	0.91	0.07	0.10	0.12	2.00	0.01	1.11	7	21	190	1,300	45	21	490	61	
7-Feb-06	1,274	95,900	0.80	3.70	0.51	0.09	0.69	0.12	2.20	0.01	1.93	7	24	190	1,200	50	24	440	41	
14-Feb-06	1,043	14,800	0.90	4.60	0.28	0.05	0.08	0.12	4.00	0.01	1.57	7	28	200	1,200	40	24	430	43	
21-Feb-06	373	166,400	0.80	3.40	0.87	0.05	0.02	0.10	2.70	0.00	4.25	8	26	210	950	35	23	340	33	
28-Feb-06	1,274	16,000	4.90	2.90	1.60	0.05	0.12	0.09	1.90	0.01	0.88	8	20	210	1,200	34	29	440	46	
6-Mar-06	364	33,100	0.90	3.40	1.80	0.04	0.22	0.11	1.50	0.01	0.78	6	18	220	1,100	24	34	400	55	
14-Mar-06	620	110,600	0.60	5.00	4.50	0.6	0.22	0.10	4.30	0.02	6.86	7	23	230	830	25	20	290	35	
21-Mar-06	531	65,900	0.50	2.20	0.53	0.05	0.27	0.06	1.40	0.01	0.82	6	16	230	1,200	23	26	460	36	
28-Mar-06	1,445	9,900	0.60	3.70	1.3	0.05	0.70	0.09	3.20	0.02	4.25	6	28	230	860	21	20	300	38	
4-Apr-06	890	2,000	0.70	5.40	1.1	0.09	1.00	0.07	2.80	0.01	0.55	6	28	230	1,800	22	17	700	36	
11-Apr-06	410	10,900	0.80	2.00	1.5	0.08	0.15	0.06	0.60	<0.01	0.59	6	13	230	2,900	22	16	1,300	27	
18-Apr-06	299	12,200	0.70	5.50	0.25	0.07	0.57	0.07	2.10	<0.01	0.73	6	25	230	1,700	23	20	700	47	
2-May-06	1,455	2,000	0.60	4.40	0.71	0.03	0.20	0.07	1.90	<0.01	0.81	7	21	220	1,400	18	24	510	59	

DATE	E Coli	E Coli	TN	TN	NH4	NOx	NOx	TP	TP	FRP	FRP	TOC	TOC	TDS	TDS	TUR	TUR	CI	TSS	
	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT
	CFU/100mL	CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
16-May-06	3,441	3,100	0.50	3.30	3.00	0.04	1.00	0.05	0.67	0.01	0.38	5	9	230	2,700	21	15	1,300	30	
30-May-06	1,723	2,000	0.40	2.50	1.60	0.03	0.52	0.05	0.56	<0.01	0.12	5	5	230	3,000	18	20	1,900	36	
13-Jun-06		3,550		3.50	1.40		0.68		1.90		1.50	6	6		3,700		21	2,500	41	
27-Jun-06		4,570		4.80	0.80		0.37		2.50		0.30	13	13		2,200		33	960	69	
10-Jul-06		4,100		3.80	1.2		0.23		1.4		0.18	14	14		1,600		19	630	39	
25-Jul-06		300		1.50	0.7		0.13		1.8		1.10	12	12		1,400		23	510	28	
8-Aug-06		2,000		2.50	0.58		0.21		0.85		0.27	10	10		1,000		65	400	69	
23-Aug-06		4,200		3.50	0.54		0.64		1.30		0.82	36	36		1,500		39	590	65	
5-Sep-06		185,000		4.50	0.42		1.10		2.30		2.24	20	20		1,300		31	500	34	
19-Sep-06		145,000		3.70	1.40		0.71		2.20		2.60	15	15		1,300		65	510	100	
3-Oct-06		55,400		2.70	0.88		0.24		7.30		0.87	24	24		1,400		50	520	65	
17-Oct-06		93,000		3.80	0.95		0.28		2.20		1.40	25	25		1,600		30	630	89	
31-Oct-06		36,400		2.20	0.53		0.47		2.70		0.43	18	18		1,200		65	410	88	
14-Nov-06		18,000		4.50	1.10		0.11		1.90		0.66	15	15		1,700		28	690	33	
28-Nov-06		7,200,000		6.40	2.90		<0.01		4.20		3.93	33	33		1,100		25	390	29	
12-Dec-06		30,000		1.80	0.96		0.08		2.10		1.75	17	17		960		21	340	23	
27-Dec-06		12,200		4.90	0.98		0.32		2.40		1.24	23	23		1,800		21	730	36	
9-Jan-07		5,290		4.20	0.61		0.38		3.10		1.88	22	22		1,300		9.4	530	2	
24-Jan-07		410		6.00	2.50		0.25		3.20		1.95	25	25		1,700		27	640	51	

Baseby

DATE	E Coli	E Coli	TN	TN	NH4	NOx	NOx	NOx	TP	TP	FRP	FRP	TOC	TOC	TDS	TDS	TDS	TUR	TUR	TSS
	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT
	CFU/100mL	CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	NTU	mg/L
19-Jan-05	1,900	160	0.35	1.1	0.05	0.02	0.07	0.042	1.1	4	260	45								
24-Jan-05	15,000	2,200	0.79	0.97	0.09	0.75	0.11	0.042	0.9	4	254	50								
31-Jan-05	9,800	18,200	1.00	1.3	0.1	0.09	0.15	0.042	1.0	5	232	55								
7-Feb-05	200	400	0.79	5.6	0.31	0.10	0.11	1.30	0.033	0.6	8	37	233	770	50	22	64			
15-Feb-05	180	1,600	0.79	3.9	0.28	0.09	0.15	0.86	0.039	1.1	5	34	249	8,114	40	6.5	16			
22-Feb-05	8,000	14,000	0.86	2.50	0.10	0.06	<0.01	0.75	0.010	0.4	5	24	249	944	37	16	10			
1-Mar-03	44,000	62,000	0.93	2.80	<0.01	0.03	<0.01	0.23	<0.003	0.4	6	37	243	3,200	33	6	10			
8-Mar-05	120,000	14,000	0.82	3.90	1.20	0.02	0.15	0.69	<0.003	1.1	5	34	250	6,659	37	9	20			
14-Mar-05	4,000	20,000	0.92	2.60	0.18	0.02	0.09	0.98	0.490	0.5	5	20	249	522	27	29	51			
21-Mar-05	42,000	87,000	0.72	2.90	1.40	0.02	<0.01	1.20	0.007	1.2	5	24	251	1,432	23	27	66			
29-Mar-05	18,000	7,000	0.40	3.50	0.10	0.02	<0.01	1.60	<0.003	0.7	4	29	241	4,221	20	15	57			
5-Apr-05	1,000	10,000	0.70	1.60	<0.01	0.05	<0.01	1.10	0.003	0.9	5	15	246	1,663	25	13	22			
12-Apr-05	1,000	12,000	0.50	4.50	1.30	0.09	0.08	2.89	0.007	2.3	5	22	242	1,094	30	37	69			
19-Apr-05	20,000	19,000	0.57	2.20	0.41	0.07	0.02	1.20	0.013	0.8	5	19	246	874	28	27	65			
26-Apr-05	3,000	70,000	0.54	2.30	<0.01	0.04	<0.01	1.20	0.003	0.9	6	26	246	2,441	26	20	36			
2-May-05	5,000	67,000	0.48	0.01	0.08	<0.01	0.07	0.016	1.2	4	246	25								
10-May-05	<100	<100	0.50	3.40	0.21	0.07	0.03	1.70	0.010	1.4	4	31	252	4,675	25	22	40			
17-May-05	500	400	0.40	4.40	0.88	0.08	0.33	1.90	0.013	1.0	5	25	251	1,453	24	28	56			
24-May-05	2,800	1,400	0.60	5.30	1.10	0.06	0.15	1.70	0.007	0.5	5	24	241	2,705	22	70	170			

DATE	E Coli	E Coli	TN	TN	NH4	NOx	NOx	TP	TP	FRP	FRP	TOC	TOC	TDS	TDS	TUR	TUR	CI	TSS		
	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT
	CFU/100mL	CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	NTU	mg/L	mg/L	mg/L	mg/L
31-May-05	2,000	12,000	0.37	3.20	0.14	0.07	0.07	1.60	0.007	0.4	5	22	249	1,983	19	90					69
7-Jun-05	100	600	0.37	3.90	0.87	0.07	0.07	2.20	0.007	0.8	4	21	256	2,785	18	50					82
21-Jun-05	600	4,400	0.54	5.70	0.36	0.04	0.04	2.30	0.010	0.4	4	33	257	5,955	16	25					40
5-Jul-05	200	700	0.31	5.30	2.40	0.01	0.01	2.10	0.003	0.9	4	31	285	6,042	11	95					160
19-Jul-05	200	200	0.34	3.90	1.90	0.04	0.04	1.00	<0.003	0.8	5	25	289	8,385	16	16					30
2-Aug-05		4,000		2.30	0.42		0.20	0.52		0.3		16		7,522		12					22
16-Aug-05		1,220		2.40	0.26		<0.01	0.47		0.7		17		10,830		11					40
29-Aug-05		<1		1.80	0.06		<0.01	0.30		0.8		19		13,140		5.8					44
13-Sep-05		<1		5.40	0.07		0.05	0.94		0.4		26		9,900		15					42
29-Sep-05		<1		3.40	0.49		0.25	1.30		2.0		30		17,000		7.7					19
11-Oct-05		17,400		6.80	2.10		0.37	1.80		2.0		28		13,000		22					59
25-Oct-05		<1		4.60	0.37		0.03	1.40		1.3		23		13,000		11					25
1-Nov-05	200	3,100	0.60	3.50	1.10	<0.01	0.02	0.07	1.70	2.0	5	19	210	19,000	27	9.1					26
7-Nov-05	750	79,150	0.60	4.50	1.20	0.04	0.25	0.08	1.10	1.2	6	21	200	8,900	29	19					46
15-Nov-05	1,000	36,000	0.90	2.30	0.50	0.06	0.20	0.08	0.79	0.8	6	13	160	400	40	45					26
21-Nov-05	1,000	1,400	0.07	3.70	0.68	0.02	0.06	0.1	2.00	0.8	7	28	190	810	50	40					64
29-Nov-05	1,000	1,000	0.70	4.90	0.39	0.03	0.12	0.1	2.40	1.6	7	26	210	3,400	45	18					60
6-Dec-05	630	91,390	0.60	3.60	0.49	0.03	0.14	0.09	1.60	1.0	8	26	200	3,500	35	18					51
13-Dec-05	860	2,500	0.70	2.80	0.46	0.05	0.05	0.10	1.60	0.8	6	26	120	1,200	40	36					65
20-Dec-05	98	4,280	0.80	6.60	2.20	0.04	0.32	0.13	2.40	1.2	7	34	180	2,500	50	32					59

DATE	E Coli	E Coli	TN	TN	NH4	NOx	NOx	TP	TP	FRP	FRP	TOC	TOC	TDS	TDS	TUR	TUR	TSS
	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT
	CFU/100mL	CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	NTU	mg/L
28-Dec-05	341	87,040	0.70	3.10	1.20	0.08	<0.01	0.10	1.20	0.010	1.8	7	24	180	1400	45	30	35
3-Jan-06	158	18,470	0.80	4.60	1.90	0.07	<0.01	0.12	2.20	0.01	1.60	6	24	200	1,100	45	50	100
10-Jan-06	187	2,280	1.30	6.00	0.29	0.10	*	0.15	2.00	0.01	1.11	6	27	190	2,200	45	19	70
17-Jan-06	168	710	1.10	7.30	2.10	<0.01	0.02	0.18	1.40	0.01	2.06	7	39	190	2,200	50	15	36
24-Jan-06	75	18,800	0.60	3.60	2.50	0.08	<0.01	0.12	1.70	0.01	2.45	7	28	190	690	38	45	87
31-Jan-06	200	3,300	0.80	5.20	<0.01	0.10	<0.01	0.12	2.00	0.01	0.39	7	28	200	2,000	45	38	91
7-Feb-06	132	960	0.70	3.20	0.10	0.11	<0.01	0.11	0.50	0.02	0.43	7	40	190	8,800	45	3.3	40
14-Feb-06	132	107,600	0.90	3.80	0.48	0.10	<0.01	0.10	1.50	0.01	0.88	7	28	200	590	39	33	94
21-Feb-06	285	96,060	0.80	3.30	2.20	0.07	<0.01	0.11	1.60	0.01	2.03	7	28	210	1,300	37	25	46
28-Feb-06	10	740	0.90	3.10	0.57	0.05	0.01	0.11	1.9	0.01	1.41	8	25	220	1,500	34	33	61
6-Mar-06	1,286	101,120	1.10	7.10	3.20	<0.01	0.01	0.15	1.70	0.00	2.22	7	36	220	790	29	7.5	21
14-Mar-06	228	16,160	0.50	3.10	0.33	0.05	<0.01	0.09	1.20	0.02	0.98	7	22	230	470	26	45	84
21-Mar-06	1,370	5,310	0.80	3.40	0.53	0.05	0.70	0.07	1.80	0.01	1.31	7	28	230	1,300	24	60	89
28-Mar-06	300	4,280	0.50	4.50	1.4	0.05	0.62	0.08	1.20	0.02	0.89	6	44	230	5,500	20	9.8	21
4-Apr-06	700	700	0.60	3.30	0.17	0.09	<0.01	0.07	0.54	0.01	0.39	6	37	240	7,800	20	4.5	20
11-Apr-06	41	100	0.70	3.40	0.19	0.1	0.01	0.06	0.64	<0.01	0.56	6	39	230	8,100	20	3.5	14
18-Apr-06	480	1,320	0.70	3.60	<0.01	0.08	<0.01	0.06	0.89	<0.01	0.51	7	37	230	7,900	23	8.4	16
2-May-06	98	2,430	0.40	1.80	<0.01	0.04	0.01	0.05	0.37	<0.01	0.26	7	27	220	4,200	18	4.4	9
16-May-06	504	410	0.50	3.80	1.30	0.04	0.03	0.05	1.00	<0.01	1.49	5	26	230	6,300	18	26	7

* Value of 11 mg/L NO_x on 11 Jan 2006 considered an outlier and removed from subsequent analysis

DATE	E Coli	E Coli	TN	TN	NH4	NOx	NOx	TP	TP	FRP	FRP	TOC	TOC	TDS	TDS	TUR	TUR	CI	TSS	
	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT
	CFU/100mL	CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
30-May-06	213	100	0.40	6.20	0.43	0.03	0.01	0.04	2.10	<0.01	1.15	5	39	230	7,600	16	18	6,200	34	
13-Jun-06		810		5.00	0.70		<0.01		4.40		1.60	27		8,000		8.4		6,900	19	
27-Jun-06		<10		2.20	0.22		0.02		0.76		0.47	16		8,600		6		4,600	11	
10-Jul-06		1,610		3.30	0.33		0.20		1.4		0.18	23		1,200		27		470	51	
25-Jul-06		200		1.90	0.4		0.21		1.3		0.60	20		3,500		15		1,500	23	
8-Aug-06		<10		1.50	0.05		0.03		0.35		0.24	14		6,600		4		3,100	8	
23-Aug-06		9,900		2.10	0.29		0.11		0.69		0.35	31		4,200		15		2,100	27	
5-Sep-06		80		2.50	0.17		<0.01		1.40		0.98	16		3,600		9		1,800	11	
19-Sep-06		30		2.60	0.16		0.01		1.00		0.74	20		8,700		6		4,700	13	
3-Oct-06		717		2.90	0.81		0.24		4.40		0.77	23		920		24		340	39	
17-Oct-06		15,000		3.30	0.27		0.01		1.20		0.72	22		790		25		290	37	
31-Oct-06		1,600		2.40	<0.01		<0.01		1.30		0.31	16		1,500		26		630	35	
14-Nov-06		8,000		4.00	0.87		0.05		1.30		0.82	20		780		26		280	31	
28-Nov-06		118,000		2.50	0.90		0.04		1.40		1.08	17		1,300		21		500	19	
12-Dec-06		<1		2.90	1.70		0.05		1.10		1.02	18		1,200		24		470	49	
27-Dec-06		5,040		4.50	0.01		<0.01		1.80		1.00	30		1,800		34		690	34	
9-Jan-07		310		2.40	0.04		0.05		0.79		0.85	19		650		35		230	25	
24-Jan-07		126		4.10	1.40		<0.01		1.00		1.72	16		730		1.4		270	1	

Wall Flat

DATE	E Coli	E Coli	TN	TN	NH4	NOx	NOx	TP	FRP	TOC	TDS	TUR	TUR	CI	TSS
	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	RIVER	RIVER	SALT	SALT
	CFU/100mL	CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	NTU	mg/L	mg/L
17-Dec-04			0.3	3.7	1.6			2.3	0.069	2.9	293	35	60		68
19-Jan-05	270	270	0.73	5.50	0.20	0.03	0.04	3.20	0.049	1.3	377	55	11		8
24-Jan-05	4,100	7,700	0.68	2.30	0.56	0.08	0.77	1.20	0.036	0.7	266	55	34		16
31-Jan-05	4,900	17,000	1.10		0.38	<0.02	0.03	0.18	0.036	0.9	247	60			
7-Feb-05	1,600	426	0.92	2.40	1.20	0.02	0.06	0.11	0.036	0.2	246	60	16		18
15-Feb-05	20	1,300	0.73	2.00	0.42	0.03	0.08	0.09	0.029	0.9	251	55	13		9
22-Feb-05	3,000	46,000	1.10	1.80	0.53	0.03	0.07	0.08	0.007	0.3	265	39	19		11
1-Mar-03	13,000	62,000	0.70	1.53	0.18	<0.01	0.05	0.11	0.003	0.7	253	36	13		12
8-Mar-05	9,000	34,000	0.60	1.96	0.52	<0.01	0.09	0.15	0.003	0.4	253	45	39		50
14-Mar-05	4,000	20,000	0.80	1.50	0.23	<0.01	0.05	0.09	<0.003	0.4	255	32	28		44
21-Mar-05	7,000	84,000	0.51	1.60	0.28	0.01	0.07	0.06	<0.003	0.9	260	33	37		44
29-Mar-05	10,000	16,000	0.50	1.90	0.22	0.04	0.18	0.07	0.013	0.4	251	24	12		12
5-Apr-05	7,000	26,000	0.40	2.00	0.35	0.02	0.10	0.07	0.010	1.0	253	23	31		41
12-Apr-05	4,000	11,000	0.50	1.80	0.53	0.05	0.15	0.09	0.007	0.7	253	33	28		30
19-Apr-05	6,000	5,000	0.55	0.80	0.11	0.05	0.26	0.07	0.013	0.2	261	30	14		27
26-Apr-05	10,000	12,000	0.82	1.60	0.45	0.02	0.09	0.09	<0.003	1.2	254	31	28		32
2-May-05	92,000	80,000	0.41	1.30	0.15	0.11	0.21	0.07	0.020	0.6	265	27	21		28
10-May-05	<100	1,000	0.60	2.40	0.08	0.07	0.33	0.06	0.007	0.2	268	27	19		28
17-May-05	800	1,600	0.50	1.30	0.11	0.04	0.20	0.05	0.007	0.5	265	35	21		32

DATE	E Coli	E Coli	TN	TN	NH4	NOx	NOx	TP	TP	FRP	FRP	TOC	TOC	TDS	TDS	TUR	TUR	CI	TSS	
	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT
	CFU/100mL	CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	NTU	mg/L	mg/L	
24-May-05	1,600	1,600	0.50	1.50	0.16	0.05	0.28	0.06	0.80	0.007	0.5	5	11	250	1,503	29	19		26	
31-May-05	1,700	1,700	0.37	1.50	0.07	0.07	0.28	0.07	0.75	0.010	0.3	5	13	268	1,618	20	25		29	
7-Jun-05	700	8,200	1.04	1.30	0.25	0.04	0.34	0.05	0.52	0.007	0.6	4	8	259	1,987	18	31		49	
21-Jun-05	1,200	4,400	0.63	2.10	0.45	0.03	0.70	0.06	0.37	<0.003	0.1	5	12	269	4,481	19	12		15	
5-Jul-05	800	1,300	0.5	4.20	0.31	<0.01	1.30	0.07	2.1	0.003	0.2	5	25	304	2,376	16	60		73	
19-Jul-05	200	500	0.4	2.20	0.05	<0.01	0.57	0.05	0.23	0.003	0.1	6	17	309	7,440	14	9.5	3,700	13	
2-Aug-05		2,000		1.90	0.22		0.33		0.28		0.4		12		6,313		5.6	3,000	16	
16-Aug-05		900		1.50	0.42		0.66		0.49		0.2		11		5,988		6	2,800	9	
29-Aug-05		5,200		1.70	0.49		0.26		0.56		0.8		7		4,750		11	2,300	22	
13-Sep-05		1,300		3.10	1.10		0.57		1.50		1.1		15		4,900		22	2,300	32	
29-Sep-05		<1		2.70	0.66		0.18		1.70		1.0		14		2,600		40	1,100	48	
11-Oct-05		<1		2.90	1.30		0.58		1.40		0.5		13		2,600		45	1,100	68	
25-Oct-05		44,800		2.10	0.65		0.40		0.60		0.5		8		4,000		20	1,700	28	
1-Nov-05	1,100	6,200	0.60	1.80	0.38	0.01	0.25	0.08	1.50	0.007	0.5	5	12	230	1,200	28	45	490	58	
7-Nov-05	200	7,800	0.70	2.00	0.72	<0.01	0.55	0.16	1.20	0.026	0.5	7	13	220	990	18	50	390	49	
15-Nov-05	1,100	700	0.80	3.10	0.26	0.01	0.15	0.11	1.10	0.013	0.1	7	14	210	2,900	32	34	1200	57	
21-Nov-05	1,000	39,000	0.70	1.90	0.56	0.01	0.48	0.12	1.10	0.016	1.5	7	13	810	1,400	39	50	590	53	
29-Nov-05	2,000	7,500	0.80	2.00	0.52	<0.01	0.15	0.11	1.30	0.016	0.7	7	15	220	1,100	31	55	420	62	
6-Dec-05	1,750	7,500	0.60	1.60	0.38	0.02	0.11	0.11	0.87	0.007	1.1	8	13	210	1,500	45	32	620	33	
13-Dec-05	100	3,100	0.70	1.70	0.25	<0.01	0.13	0.13	1.20	0.026	0.5	9	15	200	760	28	40	310	40	

DATE	E Coli	E Coli	TN	TN	NH4	NOx	NOx	TP	TP	FRP	FRP	TOC	TOC	TDS	TDS	TUR	TUR	TSS
	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT
	CFU/100mL	CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	NTU	mg/L
20-Dec-05	145	3,930	0.70	1.50	0.17	<0.01	0.19	0.12	0.71	0.010	0.2	7	11	180	1,000	45	31	18
28-Dec-05	473	6,090	0.70	1.80	0.40	0.10	0.09	0.12	1.20	0.013	1.0	50	15	190	880	50	40	32
3-Jan-06	298	17,890	0.70	1.60	0.36	<0.01	<0.01	0.14	0.99	0.02	0.98	7	13	200	770	36	34	27
10-Jan-06	134	750	0.60	2.40	0.18	0.02	0.01	0.11	1.40	0.01	0.98	7	19	200	1,300	39	25	47
17-Jan-06	1,178	1,100	0.80	1.80	0.35	<0.01	0.05	0.12	0.92	0.01	0.82	7	14	200	1,500	45	27	35
24-Jan-06	359	12	0.60	1.90	0.26	0.01	0.06	0.11	1.10	0.02	0.92	8	16	200	960	28	31	42
31-Jan-06	300	15,000	0.80	1.80	1.20	0.10	0.12	0.12	0.97	0.01	0.09	7	23	210	1,300	40	24	30
7-Feb-06	717	1,730	0.70	3.20	0.27	0.04	0.05	0.11	1.00	0.02	0.92	7	15	200	1,100	45	50	57
14-Feb-06	288	10,170	0.70	5.20	<0.01	0.04	<0.01	0.11	8.20	0.01	0.36	7	29	210	930	40	33	31
21-Feb-06	1,723	11,060	0.70	1.60	0.43	0.03	0.15	0.11	0.69	<0.01	0.18	8	13	210	1,100	45	39	42
28-Feb-06	1,529	1,080	0.70	1.80	0.28	0.04	0.03	0.10	1.10	0.01	0.72	8	16	220	850	33	40	35
6-Mar-06	307	1,440	0.60	14.00	0.09	<0.01	<0.01	0.09	0.94	0.01	0.98	7	13	210	890	24	19	21
14-Mar-06	657	200	0.70	1.30	0.10	0.02	<0.01	0.02	0.10	0.02	0.75	7	22	230	1,100	24	24	23
21-Mar-06	87	3,060	0.50	1.20	0.20	0.03	0.07	0.04	0.85	0.00	0.65	7	15	230	960	31	30	37
28-Mar-06	110	9,450	0.50	1.20	0.27	0.03	0.08	0.07	0.79	0.07	0.76	7	12	230	800	16	25	25
4-Apr-06	690	4,900	0.70	2.70	1.5	0.11	0.04	0.07	1.40	<0.01	0.95	7	22	240	1,500	19	19	32
11-Apr-06	121	3,840	0.80	1.10	0.01	0.02	0.08	0.09	0.29	<0.01	0.08	6	12	240	1,800	23	11	22
18-Apr-06	121	520	0.80	1.80	0.17	0.06	0.13	0.06	0.95	<0.01	0.73	6	13	230	1,000	18	28	30
2-May-06	388	1,600	0.40	1.60	0.52	0.03	0.28	0.06	0.84	<0.01	0.47	7	14	230	1,500	16	18	30
16-May-06	530	750	0.50	1.50	0.27	0.03	0.19	0.06	0.23	<0.01	0.14	5	9	230	2,900	23	12	15

DATE	E Coli	E Coli	TN	TN	NH4	NOx	NOx	TP	TP	FRP	FRP	TOC	TOC	TDS	TDS	TUR	TUR	CI	TSS	
	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT
	CFU/100mL	CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
30-May-06	160	1,421	0.40	0.80	0.15	0.02	0.05	0.05	0.16	<0.01	0.09	5	6	230	2,300	17	5.5	1,300	14	
13-Jun-06		1390	1.80	1.80	0.49		0.13		2.60	1.30		9	9	1,600	1,600	17	17	810	23	
27-Jun-06		10,860	2.30	2.30	0.49		0.21		0.72	0.18		9	9	2,700	2,700	14	14	1,300	19	
10-Jul-06		7,710	1.80	1.80	0.45		0.09		0.54	0.51		9	9	1,800	1,800	20	20	800	30	
25-Jul-06		100	1.70	1.70	1.6		0.09		1.3	0.50		15	15	2,700	2,700	23	23	1,200	32	
8-Aug-06		1,450	1.70	1.70	0.34		0.14		0.19	0.16		17	17	4,800	4,800	11	11	2,600	18	
23-Aug-06		5,700	2.50	2.50	0.29		0.79		1.20	0.38		13	13	1,700	1,700	27	27	760	36	
5-Sep-06		11,000	3.40	3.40	0.81		1.40		1.50	0.85		18	18	2,000	2,000	29	29	930	36	
19-Sep-06		35,000	1.50	1.50	0.79		0.10		1.20	1.50		11	11	1,800	1,800	30	30	820	37	
3-Oct-06		13,400	2.10	2.10	0.49		0.45		3.90	1.30		17	17	1,900	1,900	29	29	820	29	
17-Oct-06		24,000	2.30	2.30	0.81		0.06		1.50	2.30		13	13	1,700	1,700	38	38	710	42	
31-Oct-06		1,000	2.40	2.40	0.83		0.27		1.90	0.87		15	15	1,700	1,700	39	39	700	34	
14-Nov-06		6,000	3.60	3.60	0.78		0.06		1.70	1.40		13	13	1,800	1,800	35	35	750	26	
28-Nov-06		11,000	2.60	2.60	0.80		0.02		1.60	1.38		15	15	1,500	1,500	38	38	660	38	
12-Dec-06		7,000	2.50	2.50	0.57		0.02		1.70	1.19		17	17	1,500	1,500	27	27	620	26	
27-Dec-06		1,000	2.20	2.20	0.42		0.12		1.20	1.34		16	16	1,800	1,800	18	18	1,000	43	
9-Jan-07		100	1.90	1.90	0.40		0.08		1.20	0.79		15	15	2,200	2,200	11	11	940	16	
24-Jan-07		891	2.20	2.20	1.50		0.02		1.40	1.52		16	16	1,800	1,800	22	22	760	33	

Pompoota

DATE	E Coli	E Coli	TN	TN	NH4	NOx	NOx	TP	TP	FRP	FRP	TOC	TOC	TDS	TDS	TUR	TUR	TSS	
	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT
	CFU/100mL	CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	NTU	mg/L	
19-Jan-05	920	910	1.40	2.6	0.13	0.04	0.06	0.09	0.30	0.049	0.1	5	13	277	3284	45	15	15	
24-Jan-05	1,600	1,100	1.30		0.37	0.19	0.6	0.1		0.039	0.7	4		272		50			
31-Jan-05	7,800	12,000	1.30	3.4	0.71	0.14	0.05	0.17	1.40	0.046	1.3	5	21	245	1,651	50	14	13	
7-Feb-05	56	236	0.97	2.8	0.36	0.07	0.02	0.12	0.84	0.033	1.3	5	19	241	2,273	50	16	16	
15-Feb-05	160,000	250	1.00	2.2	0.17	0.15	0.07	0.1	0.71	0.036	0.8	7	14	256	2,103	50	17	15	
22-Feb-05	7,000	120,000	0.58	1.5	0.54	0.08	0.02	0.07	0.59	0.013	1.8	5	16	264	706	39	29	6	
1-Mar-03	<100	62,000	0.82	1.8	0.29	0.02	<0.01	0.06	0.14	0.007	0.7	6	18	256	887	32	21	8	
8-Mar-05	2,000	65,000	0.86	2.2	0.55	0.06	0.07	0.11	0.70	0.007	0.8	5	18	255	995	32	45	62	
14-Mar-05	40,000	134,000	0.80	2.7	0.02	<0.10	0.26	0.08	1.50	0.007	0.3	5	17	256	854	29	30	47	
21-Mar-05	15,000	67,000	0.43	2.4	0.47	0.03	0.07	0.06	1.40	0.010	0.8	4	17	263	1,855	26	34	47	
29-Mar-05	17,000	8,000	0.50	2.30	0.84	0.02	<0.01	0.08	1.20	0.007	1.6	4	17	257	1,137	21	28	52	
5-Apr-05	4,000	3,000	0.50	1.90	0.54	0.04	0.03	0.08	1.30	0.013	1.1	4	17	247	789	24	38	50	
12-Apr-05	<100	3,000	0.60	2.60	0.88	0.10	0.02	0.09	2.26	0.010	2.4	4	16	252	958	26	45	62	
19-Apr-05	2,000	160,000	0.52	2.25	0.57	0.12	0.14	0.09	1.80	0.023	1.0	5	17	258	939	30	65	79	
26-Apr-05	2,000	27,000	0.68	2.90	0.19	0.08	0.52	0.07	1.40	0.003	0.9	5	22	245	786	26	40	45	
2-May-05	1,000	2,700	0.50	2.30	0.48	0.10	0.95	0.06	1.30	0.016	0.7	5	18	262	844	24	50	69	
10-May-05	<100	2,000	0.60	2.50	1.00	0.12	0.18	0.06	0.93	0.013	0.2	5	18	263	1,025	24	37	47	
17-May-05	200	1,100	0.40	1.80	0.65	0.13	0.10	0.05	1.10	0.020	0.8	5	16	268	1,788	24	38	66	
24-May-05	200	1,000	0.90	2.20	0.14	0.06	0.10	0.06	0.76	<0.003	0.3	6	15	262	1,019	20	65	88	

DATE	E Coli		E Coli		TN	TN	NH4	NOx	NOx	TP	TP	FRP	FRP	TOC	TOC	TDS	TDS	TUR	TUR	CI	TSS
	RIVER	CFU/100mL	SALT	CFU/100mL																	
31-May-05	600	500	0.21	1.70	0.49	0.11	0.20	0.07	0.68	0.010	0.3	5	16	269	2,211	23	45	70			
7-Jun-05	400	2,700	0.50	2.50	0.43	0.10	0.49	0.07	0.77	0.010	0.4	4	14	268	3,960	21	35	58			
21-Jun-05	7,800	10,000	0.48	3.70	0.68	0.08	1.00	0.04	0.75	0.010	0.8	4	16	272	4,603	13	55	94			
5-Jul-05	100	500	0.64	6.20	0.35	0.14	2.10	0.05	0.78	0.016	0.2	4	29	337	5,616	11	55	88			
19-Jul-05	<1	300	0.36	3.40	0.18	0.06	1.00	0.04	0.37	0.003	0.2	5	22	327	8,272	15	24	40	4,200		
2-Aug-05		200	6.20	2.80			0.01		2.90		3.1		31		17,350		9.7	10,000			20
16-Aug-05		200	3.00	0.10			<0.01		0.59		0.4		26		13,476		17	7,000			46
29-Aug-05		200	2.30	0.35			<0.01		0.55		1.1		20		12,600		10	6,800			22
13-Sep-05		200	2.80	0.01			<0.01		1.10		0.3		23		13,000		25	6,500			46
29-Sep-05		<1	7.00	0.17			0.06		2.80		0.7		55		11,000		95	5,900			180
11-Oct-05		2300	3.70	0.08			0.13		1.40		0.5		17		4,900		27	2,300			52
25-Oct-05		75200	3.40	0.51			0.25		1.30		0.9		14		9,900		45	5,000			71
1-Nov-05	10	<1	0.60	2.20	0.69	0.02	0.19	0.06	1.20	<0.003	2.1	5	13	220	2,800	25	31	1,300			53
7-Nov-05		4,080	0.50	2.80	0.31	0.04	0.39	0.06	1.30	0.010	1.3	5	18	210	2,300	28	31	1,000			41
15-Nov-05	110	2,000	0.80	3.80	0.42	0.07	<0.01	0.09	1.30	0.007	0.8	6	17	200	5,100	40	31	2,400			57
21-Nov-05	500	51,000	0.60	3.20	1.10	0.03	0.10	0.09	2.00	0.007	2.2	7	16	190	2,600	38	40	1,100			65
29-Nov-05	1,000	33,600	0.60	3.50	0.50	0.04	<0.01	0.10	1.80	0.013	1.5	6	23	210	2,800	39	31	1,200			84
6-Dec-05	62,940	5,200	0.50	2.40	1.10	0.04	0.08	0.10	0.33	0.010	0.5	8	15	210	3,600	38	32	1,300			56
13-Dec-05	8,840	2,000	0.50	2.70	0.55	0.04	0.09	0.11	0.97	0.010	2.9	6	18	190	2,300	50	40	820			75
20-Dec-05	75	100	0.70	4.20	0.40	0.07	0.05	0.12	0.94	0.010	0.6	7	19	180	2,200	45	31	790			80

DATE	E Coli RIVER	E Coli SALT	TN RIVER	TN SALT	NH4 RIVER	NH4 SALT	NOx RIVER	NOx SALT	TP RIVER	TP SALT	FRP RIVER	FRP SALT	TOC RIVER	TOC SALT	TDS RIVER	TDS SALT	TUR RIVER	TUR SALT	CI SALT	TSS SALT
	CFU/100mL	CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	NTU	mg/L	mg/L
28-Dec-05	345	1,710	0.70	3.10	1.00	0.10	1.30	0.12	1.50	0.013	0.3	7	23	190	1,900	45	70	720	130	
3-Jan-06	173	7,230	0.70	5.70	0.40	0.05	0.02	0.11	0.83	0.12	1.63	6	28	200	1,800	40	75	760	140	
10-Jan-06	63	7,540	0.70	2.60	0.25	0.12	0.03	0.10	1.60	0.12	1.93	7	22	200	1,400	40	31	530	43	
17-Jan-06	2,495	47,860	0.70	1.90	0.62	0.06	<0.01	0.15	0.99	0.50	2.19	7	15	210	2,200	36	21	740	34	
24-Jan-06	20	960	0.60	2.90	0.69	0.13	0.03	0.10	1.30	0.15	0.65	6	23	200	2,700	40	38	1,100	80	
31-Jan-06	200	900	0.80	3.60	0.09	0.15	<0.01	0.13	1.30	0.15	0.05	6	22	200	1,700	45	33	680	88	
7-Feb-06	243	970	0.80	2.20	0.28	0.11	<0.01	0.13	0.84	0.18	0.78	7	22	200	2,600	45	17	1,100	35	
14-Feb-06	63	410	0.70	2.60	<0.01	0.11	0.02	0.11	1.10	0.15	0.06	6	22	210	1,700	45	20	640	38	
21-Feb-06	169	200	0.70	1.50	0.12	0.10	0.01	0.11	0.24	0.12	0.08	7	12	210	2,300	40	23	770	42	
28-Feb-06	109	1,750	0.70	2.10	0.19	0.11	0.02	0.10	0.79	0.12	1.18	7	20	220	1,400	37	27	460	35	
6-Mar-06	121	9,090	0.60	2.10	0.34	0.05	<0.01	0.08	1.10	0.01	2.26	6	18	210	1,900	27	19	700	40	
14-Mar-06	199	15,530	0.50	2.30	0.47	0.07	0.06	0.11	1.30	0.02	2.29	7	17	230	2,400	30	27	920	64	
21-Mar-06	111	990	1.10	2.90	0.49	0.09	0.01	0.17	1.90	0.01	0.56	7	21	230	2,500	45	37	1,000	84	
28-Mar-06	137	1,780	0.50	2.30	0.32	0.08	0.17	0.08	0.98	0.02	0.49	6	19	230	990	23	50	370	140	
4-Apr-06	750	600	0.50	3.10	0.36	0.08	<0.01	0.07	0.58	0.02	0.09	6	23	240	2,800	22	26	1,100	52	
11-Apr-06	4,360	1,090	0.70	2.90	<0.01	0.1	<0.01	0.07	0.45	<0.01	0.02	6	22	250	4,900	23	40	2,600	100	
18-Apr-06	85	630	0.60	2.10	0.38	0.09	0.09	0.07	0.25	<0.01	0.29	6	18	240	6,600	24	20	3,600	43	
2-May-06	223	630	0.60	4.50	<0.01	0.06	<0.01	0.07	0.94	<0.01	0.08	7	24	230	1,900	22	37	830	74	
16-May-06	98	100	0.60	2.20	0.27	0.05	0.24	0.05	0.26	<0.01	0.07	5	14	240	5,600	20	17	2,900	34	
30-May-06	148	6,440	0.50	2.30	0.74	0.05	0.07	0.05	0.84	<0.01	2.03	5	15	240	4,800	18	29	3,200	43	

DATE	E Coli RIVER	E Coli SALT	TN RIVER	TN SALT	NH4 RIVER	NH4 SALT	NOx RIVER	NOx SALT	TP RIVER	TP SALT	FRP RIVER	FRP SALT	TOC RIVER	TOC SALT	TDS RIVER	TDS SALT	TUR RIVER	TUR SALT	CI SALT	TSS SALT
	CFU/100mL	CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	NTU	mg/L	mg/L
13-Jun-06		110	3.20	0.60	0.20	0.20	1.90	0.23	15	3,900	45	2,500	87							
27-Jun-06		6700	3.00	0.10	0.45	0.45	0.70	0.14	12	3,400	45	1,500	110							
10-Jul-06		410	2.20	0.28	0.49	0.49	0.28	0.03	10	3,100	60	1,200	67							
25-Jul-06		108	2.00	0.3	0.07	0.07	1.3	0.12	19	4,600	20	2,000	35							
8-Aug-06		100	1.40	0.26	0.02	0.02	0.15	0.05	12	5,900	19	2,800	28							
23-Aug-06		290	2.00	0.34	0.34	0.34	0.24	0.04	21	6,400	20	3,200	34							
5-Sep-06		7,000	2.60	0.19	0.29	0.29	0.51	0.35	17	4,600	28	2,300	41							
19-Sep-06		5,000	2.00	0.18	0.20	0.20	0.76	0.53	12	3,300	55	1,500	110							
3-Oct-06		520	2.40	0.24	0.05	0.05	2.50	0.57	21	2,700	36	1,100	65							
17-Oct-06		2,600	1.80	0.19	0.13	0.13	0.33	0.05	18	3,500	34	1,400	67							
31-Oct-06		860	1.60	<0.01	0.01	0.01	0.32	0.01	16	6,700	20	2,700	45							
14-Nov-06		8,000	3.90	<0.01	0.02	0.02	0.62	0.03	17	3,500	60	1,400	120							
28-Nov-06		20,000	2.30	0.51	0.01	0.01	0.78	0.68	12	3,500	70	1,300	110							
12-Dec-06		666	3.80	1.10	<0.01	<0.01	2.80	2.19	20	1,800	65	730	150							
27-Dec-06		2,000	3.00	0.16	0.04	0.04	1.10	0.22	24	2,100	65	890	120							
9-Jan-07		4,640	2.60	0.37	0.01	0.01	1.70	0.80	17	1,700	14	710	26							
24-Jan-07		100	5.10	1.20	<0.01	<0.01	2.60	2.19	33	2,000	60	830	160							

Woods Point

DATE	E Coli	E Coli	TN	NH4	NOx	NOx	TP	TP	FRP	FRP	TOC	TOC	TDS	TDS	TUR	TUR	CI	TSS
	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT
	CFU/100mL	CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	NTU	mg/L	mg/L
31-Jan-05	16,500	16,500	4.60	1.20	0.02	0.02	1.60	1.60	1.34	1.34	23	23	716	716	16	16		10
7-Feb-05	2,400	2,400	2.90	0.22	0.06	0.06	0.97	0.97	0.26	0.26	22	22	743	743	25	25		22
15-Feb-05	140	18,000	0.87	2.80	0.17	0.06	0.10	1.70	2.52	2.52	8	27	265	685	30	30		32
22-Feb-05	4,000	26,000	0.51	3.80	0.11	0.07	1.10	1.50	0.033	0.22	6	24	282	598	45	20		11
1-Mar-05	13,000	60,000	0.87	3.25	0.23	0.07	0.29	0.48	0.016	1.57	6	22	281	673	50	25		16
8-Mar-05	4,000	24,000	0.88	4.00	0.39	0.11	0.12	0.55	0.020	0.19	6	24	289	844	45	75		100
14-Mar-05	21,000	2,000	0.66	2.90	0.65	0.11	2.40	0.023	2.68	5	16	16	294	690	40	20		8
21-Mar-05	4,000	7,000	0.66	3.30	0.65	0.06	0.09	1.60	0.026	1.67	5	21	293	750	38	50		67
29-Mar-05	2,000	19,000	0.40	3.80	1.50	0.20	0.08	2.80	0.023	4.25	5.00	41	299	749	31	17		66
5-Apr-05	8,000	8,000	0.90	3.50	0.81	0.12	0.11	1.50	0.023	0.56	5.00	22	297	884	35	45		80
12-Apr-05	<100	12,000	0.50	3.60	0.34	0.11	0.08	1.72	0.026	0.75	5.00	20	287	614	28	40		62
19-Apr-05	20,000	70,000	0.55	2.38	0.61	0.15	0.09	1.20	0.029	0.82	5.00	17	292	903	30	50		73
26-Apr-05	6,000	210,000	0.61	3.80	0.68	0.11	0.11	1.90	0.033	3.59	5.00	18	294	770	27	50		73
2-May-05	21,000	7,000	0.59	4.70	2.50	0.09	0.08	5.80	0.026	5.88	5	25	284	762	32	37		58
10-May-05	1,000	49,000	0.70	6.40	1.00	0.15	0.09	1.40	0.029	1.41	5	24	294	1,252	26	55		71
17-May-05	500	5,800	0.30	2.70	0.32	0.13	0.07	0.94	0.036	0.10	18	18	297	1,947	27	34		60
24-May-05	1,000	5,400	0.20	1.40	0.24	0.15	0.09	0.29	0.023	0.11	5	7	293	1,127	26	50		67
31-May-05	200	2,000	0.27	0.83	0.21	0.07	0.11	0.30	0.023	0.08	5	7	307	976	22	55		72
7-Jun-05	300	1,200	0.56	3.30	0.28	0.06	0.11	0.34	0.016	0.10	4	8	315	1,618	22	19		57

DATE	E Coli	E Coli	TN	TN	NH4	NOx	NOx	TP	TP	FRP	FRP	TOC	TOC	TDS	TDS	TUR	TUR	CI	TSS	
	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT
	CFU/100mL	CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	NTU	mg/L	mg/L	
21-Jun-05	1,400	500	0.82	9.70	0.74	0.12	5.70	0.11	1.20	0.023	1.41	5	31	350	4,016	40	140		210	
5-Jul-05	100	700	0.79	4.30	0.23	0.09	0.63	0.11	1.4	0.023	0.17	6	19	386	1,556	20	110		160	
19-Jul-05	200	1,300	0.54	3.40	0.22	0.14	0.58	0.06	0.45	0.029	0.25	5	20	355	4,182	12	38	1,700	59	
2-Aug-05		3,000		3.20	<0.01		0.01		0.48		0.23		21		5,117		21	2,200	64	
16-Aug-05		1,800		2.60	0.07		<0.01		0.49		0.10		21		5,773		32	2,500	59	
29-Aug-05		200		2.90	0.27		<0.01		0.57		0.18		18		6,080		40	3,000	88	
13-Sep-05		13,900		3.00	0.38		0.15		0.71		0.25		20		4,800		70	2,100	130	
29-Sep-05		<1		3.30	0.20		0.14		1.10		0.14		16		1,100		140	410	230	
11-Oct-05		<1		5.80	0.58		0.59		1.20		0.16		21		1,500		85	460	180	
25-Oct-05		<1		3.40	0.44		0.27		1.30		0.49		17		1,400		75	490	21	
1-Nov-05	300	2,000	0.70	3.30	0.15	0.02	<0.01	0.06	0.76	<0.003	0.19	4	19	240	2,100	26	60	830	100	
7-Nov-05	410	3,180	0.60	2.90	0.22	<0.01	0.17	0.07	1.00	0.007	0.52	5	14	250	2,300	30	50	990	87	
15-Nov-05	9,000	110,000	0.90	4.10	0.49	0.05	1.40	0.12	0.91	0.026	1.60	6	17	280	4,200	37	50	1,700	86	
21-Nov-05	3,000	980,000	0.70	3.50	0.64	0.08	0.18	0.10	1.60	0.013	1.11	6	17	200	680	40	80	230	120	
29-Nov-05	1,000	396,800	0.80	3.60	0.70	0.06	0.50	0.11	2.00	0.016	1.90	7	21	210	690	40	65	220	110	
6-Dec-05	750	8,600	0.50	3.90	0.74	0.05	0.14	0.15	2.60	0.023	2.52	9	29	250	730	40	31	250	51	
13-Dec-05	135	19,500	0.60	2.70	0.37	0.04	0.49	0.12	1.40	0.013	1.01	6	21	220	710	40	50	250	65	
20-Dec-05	504	79,400	0.70	3.50	0.25	0.05	1.30	0.13	1.20	0.016	1.14	6	21	220	990	45	33	350	58	
28-Dec-05	1,296	10,100,000	0.70	4.30	2.10	0.08	0.45	0.15	2.00	0.026	2.94	8	28	230	750	50	34	250	62	
3-Jan-06	3,130	25,300	0.90	6.60	0.78	0.06	0.12	0.19	4.80	0.02	1.77	7	33	220	650	50	24	210	40	

DATE	E Coli	E Coli	TN	TN	NH4	NOx	NOx	TP	TP	FRP	FRP	TOC	TOC	TDS	TDS	TUR	TUR	CI	TSS	
	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT
	CFU/100mL	CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	NTU	mg/L	mg/L	
10-Jan-06	160	18,700	0.90	6.30	0.39	0.05	0.21	0.13	3.30	0.02	1.18	7	34	200	740	45	30	250	57	
17-Jan-06	171	209,800	0.90	4.40	0.49	0.06	0.13	0.12	2.50	0.02	1.28	7	29	210	840	50	37	290	77	
24-Jan-06	1,005	38,800	0.70	4.30	0.99	0.09	0.10	0.15	3.10	0.03	2.16	7	34	220	590	45	19	190	98	
31-Jan-06	200	7,000	0.70	8.30	2.90	0.10	0.07	0.16	4.70	0.03	2.84	7	43	240	1,100	45	21	380	75	
7-Feb-06	504	14,800	0.80	5.90	0.02	0.10	<0.01	0.16	2.60	0.04	0.72	7	35	220	1,400	40	75	540	170	
14-Feb-06	723	6,300	1.00	6.50	0.56	0.07	0.10	0.13	2.30	0.02	0.98	7	37	230	1,300	38	39	480	110	
21-Feb-06	4,360	125,900	0.80	6.00	1.90	0.09	0.22	0.15	2.80	0.02	2.88	7	34	220	1,200	50	75	460	150	
28-Feb-06	441	12,000	0.70	6.30	0.48	0.11	0.31	0.12	2.10	0.02	0.46	7	38	230	1,400	40	38	470	65	
6-Mar-06	2,489	203,500	0.80	7.20	0.78	0.15	4.00	0.14	2.00	0.04	1.77	7	30	230	1,100	45	28	380	68	
14-Mar-06	275	6,300	0.50	4.70	0.50	0.12	0.09	0.11	1.60	0.03	0.33	6	27	240	1,300	40	50	420	15	
21-Mar-06	885	56,000	0.70	3.20	0.34	0.09	0.26	0.08	0.68	0.02	1.18	7	25	230	2,000	34	40	780	81	
28-Mar-06	885	5,300	0.60	6.40	0.47	0.1	0.54	0.11	1.50	0.03	1.23	7	32	250	1,200	32	23	380	48	
4-Apr-06	400	7,000	0.60	4.60	0.18	0.08	0.14	0.09	1.10	0.03	0.32	7	35	280	2,400	31	50	890	76	
11-Apr-06	309	2,000	1.30	3.00	0.07	0.06	<0.01	0.08	0.71	<0.01	0.18	7	26	270	2,500	27	40	1,100	81	
18-Apr-06	1,039	3,100	0.70	3.90	<0.01	0.13	<0.01	0.08	0.67	0.01	0.26	7	27	270	3,500	28	40	1,500	87	
2-May-06	620	520	0.60	3.80	<0.01	0.09	<0.01	0.07	0.88	0.01	0.27	6	25	250	4,500	23	85	1,700	170	
16-May-06	884	200	0.50	4.10	0.15	0.10	0.03	0.06	0.87	0.01	0.53	5	13	260	4,900	22	45	2,800	83	
30-May-06	238	86	0.40	3.00	0.06	0.08	0.07	0.06	0.79	<0.01	0.41	5	14	250	4,700	21	36	3,300	74	
13-Jun-06		20		2.90	0.03		0.22		1.80		0.04		11	4,000			24	2,700	41	
27-Jun-06		213		2.80	<0.01		0.01		0.69		0.21		8	6,000		40	2,800	93		

DATE	E Coli	E Coli	TN	TN	NH4	NOx	NOx	TP	TP	FRP	FRP	TOC	TOC	TDS	TDS	TUR	TUR	CI	TSS	
	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT
	CFU/100mL	CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	NTU	mg/L	mg/L	
10-Jul-06		2,000	7.90	0.6	1.30	1.6	0.22	21	1,600	60	570	120								
25-Jul-06		235	2.80	0.48	0.11	1.7	0.86	15	3,700	45	1500	83								
8-Aug-06		70	2.60	0.48	0.06	0.69	0.24	12	4,700	45	2,200	84								
23-Aug-06		96,000	6.00	0.28	0.43	1.90	1.06	24	2,500	70	1,000	150								
5-Sep-06		18,000	3.10	0.34	0.36	0.90	0.46	16	1,700	55	580	89								
19-Sep-06		313,000	3.50	1.30	0.56	1.30	2.00	15	2,400	36	1,000	70								
3-Oct-06		8,400	3.30	0.47	0.30	3.70	0.73	24	1,600	45	530	82								
17-Oct-06		82,000	5.20	1.20	0.62	2.10	1.30	32	1,300	39	440	69								
31-Oct-06		18,900	4.80	0.85	0.57	2.10	1.10	25	1,200	23	400	26								
14-Nov-06		8,000	4.70	0.39	0.19	2.00	0.80	25	1,200	16	420	18								
28-Nov-06		8,000	3.40	0.70	0.05	1.90	1.21	18	1,500	15	520	28								
12-Dec-06		1,000	4.20	0.63	0.12	2.90	1.97	27	1,500	15	550	21								
27-Dec-06		272,300	4.20	0.45	0.46	2.70	2.26	29	1,300	22	480	22								
9-Jan-07		200	4.70	0.50	0.25	3.60	2.33	33	1,300	18	490	21								
24-Jan-07		443	4.50	0.14	<0.01	3.00	1.95	34	1,300	21	490	32								

Jervoirs

DATE	E Coli	E Coli	TN	NH4	NOx	NOx	TP	FRP	FRP	TOC	TDS	TDS	TUR	TUR	CI	TSS
	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	RIVER	RIVER	RIVER	RIVER	RIVER	SALT	SALT
	CFU/100mL	CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	NTU	mg/L	mg/L
17-Dec-04			0.60	0.04			0.1	0.062	0.07	8	367		30			
24-Jan-05	2,800	10,400	0.81	0.13	0.21	0.26	0.17	0.036	0.18	3	347		40			
31-Jan-05	9,600	9,800	1.00	2.1	0.16	0.04	0.15	0.28	0.059	4	301	663	40	20		12
7-Feb-05	6,000	21,600	0.90	1.6	0.13	<0.01	0.13	0.34	0.056	4	283	717	45	30		17
15-Feb-05	60	940	0.84	2.2	0.20	0.14	0.10	0.67	0.059	8	295	687	45	23		8
22-Feb-05	5,000	12,000	0.76	1.6	0.39	0.06	0.09	0.56	0.026	4	301	648	50	28		6
1-Mar-05	20,000	40,000	0.85	2.5	0.26	0.05	0.15	0.10	0.023	7	291	1,608	45	16		15
8-Mar-05	7,000	2,000	0.73	2.3	0.57	0.13	0.07	1.00	0.023	6	296	551	50	60		82
14-Mar-05	44,000	20,000	0.87	1.8	0.11	0.07	0.11	0.74	0.023	5	294	659	40	45		51
21-Mar-05	9,000	21,000	0.68	1.5	0.17	0.08	0.11	0.96	0.029	5	309	496	40	55		50
29-Mar-05	4,000	17,000	0.50	2.00	0.30	0.07	0.11	1.10	0.026	4	294	639	32	45		110
5-Apr-05	3,000	2,000	0.70	1.50	0.17	0.09	0.11	0.66	0.026	5	304	570	33	50		43
12-Apr-05	12,000	1,000	0.60	1.90	0.29	0.12	0.11	1.21	0.033	5	306	485	34	45		47
19-Apr-05	5,000	37,000	0.53	1.67	0.51	0.13	0.10	0.80	0.036	4	299	608	30	50		56
26-Apr-05	15,000	14,000	0.72	2.00	0.28	0.12	0.10	1.50	0.026	5	306	613	26	38		47
2-May-05	11,000	10,000	0.63	1.40	0.23	0.13	0.09	0.56	0.046	5	307	901	29	39		48
10-May-05	1,000	2,000	0.50	1.00	0.08	0.13	0.08	0.35	0.036	5	302	407	26	45		51
17-May-05	300	800	0.40	1.00	0.27	0.14	0.07	0.48	0.039	5	306	370	25	45		39
24-May-05	1,300	5,600	0.80	1.20	0.18	0.14	0.09	0.52	0.023	5	306	378	26	50		44

DATE	E Coli	E Coli	TN	TN	NH4	NOx	NOx	TP	TP	FRP	FRP	TOC	TOC	TDS	TDS	TUR	TUR	CI	TSS
	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT
	CFU/100mL	CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	NTU	mg/L	mg/L
31-May-05	1,500	1,300	0.13	1.20	0.27	0.13	0.22	0.09	0.40	0.026	0.08	5	8	310	495	27	90		100
7-Jun-05	200	1,800	0.46	1.30	0.18	0.16	0.17	0.11	0.37	0.026	0.06	4	6	307	396	27	80		100
21-Jun-05	1,800	10,200	0.65	10.00	1.10	0.15	0.51	0.08	2.50	0.023	0.62	4	19	330	723	27	180		240
5-Jul-05	200	200	0.54	3.60	0.11	0.14	0.13	0.09	0.76	0.039	0.04	5	18	371	2,027	17	36		52
19-Jul-05	1	200	0.42	0.61	0.12	0.12	0.15	0.07	0.11	0.026	0.19	4	6	365	1,105	13	17	390	19
2-Aug-05		4,000		1.20	0.03		0.01	0.24		0.05		10		1,377		16	490		26
16-Aug-05		1,200			0.10		0.05			0.03									
29-Aug-05		100		0.74	0.10		0.03		0.14	0.03		7	7	840		30	290		42
13-Sep-05		600		0.78	0.03		0.02		0.18	0.03		7	7	760		40	250		55
29-Sep-05		<1		3.90	0.34		1.00		0.36	0.07		13	13	860		40	270		54
11-Oct-05		17,100		2.40	0.22		0.29		0.23	0.06		14	14	1,500		21	440		32
25-Oct-05		100		1.50	0.10		0.05		0.10	0.04		11	11	1,800		19	530		25
1-Nov-05	800	1,000	0.50	1.10	0.06	0.01	0.02	0.07	0.12	0.007	0.03	4	8	250	1,200	25	21	350	35
7-Nov-05	1,730	15,650	0.60	1.20	0.23	<0.01	0.68	0.09	0.36	0.101	0.92	5	9	250	650	34	31	93	39
15-Nov-05	290	3,200	0.80	2.10	0.13	0.07	0.55	0.08	0.94	0.007	0.39	4	10	230	910	32	27	250	41
21-Nov-05	1,100	500	0.60	2.00	0.11	0.08	<0.01	0.09	0.57	0.016	0.13	6	10	210	1,200	39	34	370	63
29-Nov-05	1,000	21,600	0.70	1.60	0.43	0.08	0.21	0.12	0.58	0.020	0.85	7	9	210	700	45	32	210	53
6-Dec-05	1,850	658,600	0.80	3.50	0.76	0.06	0.24	0.13	1.70	0.020	1.41	8	28	220	640	45	30	200	43
13-Dec-05	6,200	111,200	0.70	2.80	0.17	0.10	0.48	0.12	1.20	0.016	0.69	6	16	230	610	45	50	190	62
20-Dec-05	310	4,100	0.70	2.70	0.15	0.02	0.05	0.14	1.20	0.020	0.13	7	18	230	770	45	30	240	80

DATE	E Coli	E Coli	TN	TN	NH4	NOx	NOx	TP	TP	FRP	FRP	TOC	TOC	TDS	TDS	TUR	TUR	CI	TSS	
	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT	RIVER	SALT
	CFU/100mL	CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	NTU	mg/L	mg/L	
28-Dec-05	1,350	2,000	0.70	1.90	0.17	0.07	0.06	0.13	0.95	0.020	0.11	7	15	220	570	45	35	190	40	
3-Jan-06	520	142,100	0.70	2.00	0.61	0.09	0.20	0.15	0.90	0.03	0.72	6	14	210	460	45	45	140	37	
10-Jan-06	200	1,000	0.90	2.90	0.06	0.10	0.04	0.14	0.90	0.03	0.09	7	17	210	580	40	45	180	55	
17-Jan-06	630	4,100	0.60	2.30	0.27	0.05	0.05	0.13	1.10	0.04	0.25	7	16	210	540	40	45	170	78	
24-Jan-06	1,440	74,300	0.60	2.50	0.19	0.09	0.16	0.14	1.20	0.04	0.33	7	17	220	810	40	31	280	56	
31-Jan-06	400	44,000	0.70	2.10	0.24	0.12	0.14	0.17	0.78	0.03	0.46	7	15	240	490	45	34	150	57	
7-Feb-06	750	2,000	0.70	2.20	0.06	0.12	0.03	0.15	1.00	0.04	0.16	7	17	240	530	45	36	170	61	
14-Feb-06	740	3,100	0.90	2.40	0.14	0.12	0.04	0.14	1.10	0.03	0.05	7	16	230	490	40	45	160	68	
21-Feb-06	850	5,200	0.80	1.90	0.18	0.11	0.08	0.13	0.65	0.03	0.09	7	15	230	470	45	40	150	40	
28-Feb-06	630	272,300	0.70	2.00	0.38	0.14	0.02	0.13	0.94	0.03	0.98	7	16	230	440	45	45	140	38	
6-Mar-06	1,460	6,300	0.70	2.10	0.05	0.06	0.68	0.12	0.57	0.03	0.75	6	11	240	530	34	110	170	200	
14-Mar-06	300	7,500	0.50	2.80	0.13	0.13	0.07	0.14	0.90	0.04	0.01	6	14	240	600	45	85	200	140	
21-Mar-06	420	420	1.00	5.80	0.13	0.13	0.06	0.09	0.82	0.03	0.04	6	15	240	470	40	40	150	54	
28-Mar-06	750	12,400	0.60	2.00	0.22	0.11	0.06	0.12	1.10	0.04	0.56	6	17	250	510	34	45	160	75	
4-Apr-06	230	2,300	0.60	1.30	0.05	0.12	0.17	0.10	0.08	0.04	0.04	7	11	260	580	28	55	190	59	
11-Apr-06	1,100	1,000	0.60	0.90	0.05	0.11	0.10	0.09	0.21	0.02	0.05	7	9	270	410	27	60	140	51	
18-Apr-06	520	1,000	0.60	1.00	0.05	0.13	0.05	0.08	0.21	0.02	0.03	7	9	270	360	26	60	120	50	
2-May-06	310	1,725	0.70	0.90	0.01	0.12	0.02	0.07	0.12	0.01	0.01	6	7	240	280	22	50	93	49	
16-May-06	120	200	0.60	0.90	0.03	0.13	0.03	0.07	0.13	0.01	0.02	5	6	260	340	23	55	110	48	
30-May-06	272	145	<0.01	1.10	0.09	0.07	0.07	0.06	0.13	0.01	0.01	5	6	250	310	20	55	100	64	

DATE	E Coli RIVER	E Coli SALT	TN RIVER	TN SALT	NH4 RIVER	NH4 SALT	NOx RIVER	NOx SALT	TP RIVER	TP SALT	FRP RIVER	FRP SALT	TOC RIVER	TOC SALT	TDS RIVER	TDS SALT	TUR RIVER	TUR SALT	CI SALT	TSS SALT
	CFU/100mL	CFU/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	NTU	mg/L	mg/L
13-Jun-06		238	3.10	0.29	0.08	2.20	1.30	8	4100	40	2,700	81								
27-Jun-06		650	1.10	0.30	0.15	0.17	0.03	5	390	45	120	40								
10-Jul-06		2,000	2.30	1.00	0.16	0.45	0.13	7	440	120	130	170								
25-Jul-06		75	2.90	0.60	<0.01	1.4	0.13	10	590	75	190	75								
8-Aug-06		300	1.60	0.20	0.10	0.32	0.03	7	430	120	130	190								
23-Aug-06		2,000	2.10	0.14	0.08	1.00	0.03	10	450	90	140	150								
5-Sep-06		86,000	2.80	0.13	0.88	1.10	0.52	13	620	60	210	75								
19-Sep-06		20,000	5.90	0.85	0.60	0.82	0.60	15	970	50	310	110								
3-Oct-06		4,100	1.60	0.15	0.12	2.40	0.11	12	650	45	200	74								
17-Oct-06		98,000	1.90	1.20	0.47	1.00	1.70	11	480	37	160	48								
31-Oct-06		218,700	3.50	0.34	0.35	1.30	0.52	18	810	31	230	41								
14-Nov-06		19,000	3.40	0.91	0.09	0.97	1.20	13	570	30	180	36								
28-Nov-06		26,000	4.20	0.70	0.21	0.98	0.28	15	580	29	180	39								
12-Dec-06		17,000	2.60	0.22	1.50	1.00	0.12	14	560	25	180	35								
27-Dec-06		28,200	2.20	0.18	0.27	0.80	0.45	14	550	37	180	43								
9-Jan-07		3,310	1.50	0.68	0.08	0.61	0.12	10	460	36	160	34								
24-Jan-07		520	3.20	0.08	0.13	1.20	0.05	16	490	30	160	39								

APPENDIX 3 SOIL DATA

Sample Number ¹	Location Paddock ²	Position ³	NO ₃ -N mg/kg	NH ₄ -N mg/kg	P mg/kg	K mg/kg	S mg/kg	Org-C %	Fe mg/kg	Cond. dS/m	pH (CaCl ₂)	pH (H ₂ O)
Baseby												
1	1	D	17	39	344	1,034	374	5.13	3,471	1.535	7.1	7.5
2		M	16	47	173	719	30.7	5.32	2,867	0.233	6.3	7.1
3		R	6	44	89	377	29.5	4.08	2,191	0.19	6.6	7.6
4	3	D	4	24	295	902	424	5.36	3,679	1.081	6.4	6.8
5		M	2	24	140	556	36.3	3.91	2,891	0.232	6.5	7.3
6		R	1	18	117	343	31.8	4.59	2,656	0.224	6.6	7.4
7	5	D	16	27	270	987	215	6.29	4,642	0.813	6.2	6.7
8		M	6	20	101	641	39.5	4.7	2,577	0.295	6.8	7.4
9		R	3	16	67	394	25.9	4.38	1,680	0.254	6.9	7.9
10	7	D	19	31	243	621	168	5.92	4,192	0.869	6.5	7
11		M	4	31	138	401	28	5.97	2,800	0.231	6.4	7.2
12		R	3	27	80	304	28.3	5.15	1,995	0.261	6.6	7.5
13	9	D	4	38	241	690	250	6.3	4,462	0.85	6.4	6.9
14		M	3	37	150	437	96	6.3	3,185	0.487	6.5	7.2
15		R	6	75	86	302	30.7	5.34	2,182	0.276	6.6	7.4
86	11	D	1	45	256	719	170	6.42	3,250	0.69	6.4	6.8
87		M	2	54	278	1,019	922	6.78	3,001	2.367	6.6	6.9
88		R	1	49	68	333	107	5.4	2,224	0.455	6.5	7.2
89	13	D	1	90	425	673	167	7.44	3,280	0.825	6.9	7.4
90		M	1	62	121	473	335	7.06	2,945	0.856	6.4	6.7
91		R	1	56	124	426	97	6.68	2,220	0.631	6.2	6.6
92	15	D	1	45	175	555	94.2	5.99	3,870	0.605	6.2	6.7
93		M	3	59	142	358	95.8	6.27	2,996	0.605	6.2	6.8
94		R	1	53	56	375	55.7	4.59	1,672	0.365	6.6	7.2
16	17	D	15	74	162	684	47.8	6.1	4,343	0.34	6.2	6.8
95		M	2	57	106	287	75.2	5.44	2,880	0.647	6.3	6.9
96		R	2	45	90	450	130	4.09	2,208	0.725	6.6	7
17	19	D	1	40	322	1,318	247	7.5	4,179	0.885	6	6.5
18		M	1	62	195	744	152	8.9	3,333	0.626	5.8	6.5
19		R	5	57	173	435	86.7	8.3	4,495	0.37	5.7	6.3
20	20	D	1	34	156	743	154	7.2	4,103	0.599	5.6	6.2
21		M	4	38	99	356	73.4	7.7	3,813	0.348	5.7	6.2
22		R	1	39	85	324	52.9	6.4	7,119	0.257	5.6	6.3
23	22	D	5	30	172	945	215	7.5	4,979	0.828	5.8	6.2

Sample Number ¹	Location Paddock ²	Position ³	NO ₃ -N mg/kg	NH ₄ -N mg/kg	P mg/kg	K mg/kg	S mg/kg	Org-C %	Fe mg/kg	Cond. dS/m	pH (CaCl ₂)	pH (H ₂ O)
24		M	7	50	99	372	69.6	7.3	4,074	0.332	5.9	6.2
25		R	1	29	69	276	35.6	8.2	4,533	0.276	5.6	6.3
26	24	D	1	34	165	554	64.8	7.7	4,352	0.439	5.7	6.2
27		M	2	35	82	289	46	7.4	4,129	0.285	6	6.2
28		R	1	42	80	316	33.7	8.7	3,885	0.221	5.8	6.3
29	26	D	1	30	55	331	47.6	6.6	2,883	0.258	5.9	6.2
30		M	12	41	178	699	130	6.8	4,100	0.727	6.7	7.4
31		R	10	44	54	350	73.3	6.6	3,729	0.456	6	6.4
32	28	D	2	34	180	536	121	7.4	5,344	1.003	5.7	6.4
33		M	22	45	89	425	73.5	6.72	3,758	0.374	6	6.3
34		R	1	25	56	282	70.1	6.5	2,472	0.266	5.7	6.3
Wall Flat												
35	1	D	6	33	120	253	105	6.1	1,638	0.126	5.6	6.3
36		R	7	26	73	182	87	4.72	918	0.438	6.6	7
37	3	D	1	23	83	199	54.6	4.4	1,363	0.307	6.6	7.2
38		R	6	20	77	313	74	4.44	1,043	0.362	6.9	7.4
39	5	D	24	34	38	111	59.1	4.58	1,532	0.307	6.3	6.9
40		R	4	19	48	279	47.2	4.02	845	0.265	6.4	6.9
41	7	D	4	15	44	269	36.2	4.96	1,743	0.278	6.3	6.9
42		R	1	8	22	89	25.8	4.1	1,348	0.211	6.2	6.8
43	9	D	31	19	50	230	46	4.47	2,145	0.326	6.5	6.9
44		R	6	12	21	164	27.2	3.39	1,539	0.233	6.5	7.4
45	11	D	8	16	34	220	38.3	5.01	2,552	0.316	6.2	6.9
46		R	8	16	35	236	45.3	5.5	1,944	0.317	6.8	7.5
Cowirra (Schmidt)												
47	1	D	7	124	291	1,062	40.4	9.24	2,459	0.348	6.1	6.6
48		M	2	104	105	466	46.7	6.38	1,827	0.39	6.4	7.1
49		R	1	96	105	278	54.9	7.44	1,637	0.348	6.6	7.1
97	3	D	2	133	498	1,596	293	9.39	2,910	1.442	6.8	7.3
98		M	1	108	170	402	141	9.63	1,986	0.741	6.3	6.7
99		R	1	52	92	439	44.9	4.6	1,681	0.431	6.7	7.2
50	5	D	57	82	879	2,007	523	9.99	2,737	1.691	6.5	6.8
51		M	7	55	252	644	147	9.88	1,636	0.661	6.7	7.1
52		R	1	36	180	379	41.8	6.04	1,403	0.275	6.2	6.8
53	7	D	20	101	338	968	148	9.99	2,705	0.88	6.4	6.9
54		M	3	82	248	534	132	9.99	2,112	0.681	6.3	6.8
55		R	6	46	127	372	83.5	7.15	1,741	0.423	6.2	6.9

Sample Number ¹	Location Paddock ²	Position ³	NO ₃ -N mg/kg	NH ₄ -N mg/kg	P mg/kg	K mg/kg	S mg/kg	Org-C %	Fe mg/kg	Cond. dS/m	pH (CaCl ₂)	pH (H ₂ O)
56	9	D	18	50	331	373	219	6.76	1,923	0.793	6.9	7.2
57		M	4	27	152	988	387	6.26	1,271	1.071	7.2	7.5
58		R	2	27	63	964	146	6.53	1,480	1.049	7	7.6
59	11	D	27	100	374	1,244	126	9.99	2,224	0.688	6.4	6.8
60		M	5	44	133	761	97	7.95	1,149	0.47	6.4	6.9
61	13	D	68	74	479	1,236	147	8.44	2,551	0.444	6.5	6.9
62		M	16	47	354	888	207	6.46	1,558	0.543	6.9	7.3
63		R	15	52	274	542	93	7.58	1,539	0.412	6.7	7.1
64	14	D	43	95	413	1,305	42.1	7.86	2,416	0.38	6.2	6.8
65		M	18	55	243	762	58.2	6.41	1,713	0.374	6.5	7.1
66		R	5	34	123	286	26.5	6.05	1,951	0.229	6.2	6.9
102	16	D	7	109	336	833	116	7.82	1,794	0.892	6.4	6.7
103		M	1	107	80	253	39.4	6.95	2,338	0.346	6.3	7
104		R	2	83	72	226	61	6.33	1,965	0.413	6.2	6.8
Cowirra (Frahn)												
67	1	D	25	68	381	867	26.6	6.77	2,700	0.305	5.9	6.6
68		M	12	59	196	395	18.2	5.49	1,996	0.201	5.8	6.7
69		R	2	56	83	181	19	5.86	1,728	0.206	6.3	7.1
70	3	D	14	62	412	842	31.1	7.56	2,481	0.297	6.2	6.8
71		M	10	40	187	318	33.9	6.38	2,275	0.286	6	6.7
73	5	D	11	82	437	946	31	6.22	3,327	0.364	6.3	6.8
74		M	2	47	191	391	34.6	7.18	2,507	0.324	5.9	6.5
75		R	1	61	133	281	27	6.33	2,050	0.243	6.3	7
76	7	D	3	93	512	1,332	43.9	9.02	3,095	0.514	6.5	7
77		M	3	59	183	455	46.2	7.17	2,586	0.422	6.1	6.6
78		R	4	78	65	226	20.5	5.26	1,914	0.311	6.5	7.1
79	9	D	3	106	391	1,168	87.7	7.91	2,623	0.627	6.6	6.9
100		M	18	103	352	767	238	9.99	1,867	1.425	6	6.3
101		R	1	72	97	329	82.4	8.26	1,788	0.613	5.9	6.5
80	11	D	8	99	451	1,388	78.7	9.99	2,101	0.714	6.3	6.7
81		M	5	123	153	602	56.9	8.72	2,178	0.501	6.2	6.8
82		R	1	88	97	341	52.6	8.41	2,238	0.544	6.1	6.7
83	13	D	21	44	359	874	34.4	5.36	2,490	0.317	6.4	7
84		M	2	51	175	335	105	8.93	2,234	0.631	6.2	6.7
85		R	3	31	87	271	50.4	4.55	1,752	0.427	6.6	7
72		R	3	32	169	232	55.8	5.88	2,481	0.403	6.3	6.8

Sample Number ¹	Location Paddock ²	Position ³	NO ₃ -N mg/kg	NH ₄ -N mg/kg	P mg/kg	K mg/kg	S mg/kg	Org-C %	Fe mg/kg	Cond. dS/m	pH (CaCl ₂)	pH (H ₂ O)
Pompoota												
105	1	D	2	55	94	551	51	9.06	2,865	0.45	6.3	6.7
106		M	26	29	275	766	201	7.52	1,935	1.629	6.7	7
107		R	1	32	51	172	61.3	6.54	1,561	0.568	6.2	6.7
108	3	D	16	89	217	593	84.5	6.13	3,216	0.652	6.3	6.6
109		M	4	55	178	298	68.4	7.44	3,022	0.511	5.8	6.2
110		R	3	43	109	189	87.5	7.36	1,557	0.744	6.6	7
111	5	D	2	70	302	571	56.8	7.86	3,040	0.413	6.2	6.7
112		M	2	29	98	232	62.7	7.9	2,670	0.548	5.8	6.2
113		R	1	37	74	203	46.9	5.61	4,330	0.348	6	6.4
116	7	D	10	92	1,016	1,661	106	11.99	2,986	0.992	6.7	7.1
115		M	2	52	130	412	71.5	8.62	3,163	0.606	6.2	6.6
114		R	1	49	125	209	57.9	6.77	2,362	0.511	6.3	6.8
179	9	D	17	89	335	844	103	5.78	2,417	0.95	6.7	7.1
180		M	8	63	101	274	89.6	5.83	2,847	0.547	6.2	6.6
181		R	17	37	86	242	70.6	5.3	1,780	0.494	6.3	6.6
Jervois												
117	2	D	7	95	726	1,247	98.5	6.76	2,872	0.697	6.3	6.9
118		M	5	98	355	558	50.7	6.01	3,133	0.418	5.8	6.5
119		R	1	34	169	272	52.6	5.08	1,881	0.512	6.2	6.9
120	4	D	10	158	1146	1,497	130	6.61	1,859	0.74	6.4	6.9
121		M	1	69	319	489	64.8	5.38	3,340	0.44	5.5	6.3
122		R	1	132	451	532	66.3	6.05	2,151	0.532	5.6	6.4
123	6	D	22	162	561	882	110	6.61	2,148	0.868	6.4	6.9
124		M	1	112	265	466	81.6	5.37	4,071	0.564	5.9	6.6
125		R	1	101	152	251	57.3	6.03	2,644	0.444	6.6	7.1
126	8	D	4	140	598	1046	86	6.02	2,320	0.526	6.5	7
127		M	1	100	263	426	75	5.86	2,680	0.546	6.1	6.8
128		R	1	97	176	232	55.6	6.34	2,369	0.412	6.2	6.9
129	10	D	8	70	835	1,037	138	6.07	1,572	0.884	6.5	7.1
130		M	1	33	194	494	72.5	5.63	2,835	0.516	5.9	6.7
131		R	1	54	191	392	64	6.46	2,079	0.529	6.2	6.8
132	B	B	1	107	515	838	441	5.22	1,257	1.537	6.9	7.3
133	B	B	3	121	840	1,168	777	6.08	1,235	2.558	7.1	7.4
134	B	B	1	87	690	1,656	479	5.01	1,510	2.54	7.1	7.6
135	B	B	1	97	246	736	200	5.84	1,275	1.329	7	7.4

Sample Number ¹	Location Paddock ²	Position ³	NO ₃ -N mg/kg	NH ₄ -N mg/kg	P mg/kg	K mg/kg	S mg/kg	Org-C %	Fe mg/kg	Cond. dS/m	pH (CaCl ₂)	pH (H ₂ O)
Woods Point												
136	2	D	1	103	407	841	187	5.51	2,393	1.022	6.9	7.4
137		M	1	117	283	375	228	5.96	2,143	1.031	7	7.4
138		R	1	62	168	235	54.6	5.1	1,965	0.41	6.7	7.2
139	4	D	1	87	406	958	274	5.78	2,580	0.689	6.8	7.2
140		M	22	81	260	496	287	6.39	2,486	1.122	6.8	7.3
141		R	7	69	149	307	164	5.88	2,229	0.882	6.5	7
142	6	D	21	81	441	1,098	122	5.29	2,540	1.139	7	7.4
143		M	3	93	202	440	51.9	6.13	2,525	0.478	6.8	7.6
144		R	1	45	80	262	70	5.34	2,250	0.526	6.3	6.8
145	B	B	8	42	245	657	91	6.01	2,403	0.701	6.7	7.2
146	B	B	10	93	345	588	128	5.53	2,422	0.793	6.6	7.1
147	B	B	8	47	183	388	130	6.04	2,541	0.955	6.6	7.1
148	B	B	39	66	230	533	166	5.56	2,206	1.12	6.5	6.8
149	B	B	14	56	262	462	217	5.74	2,000	1.634	6.7	7.1
150	B	B	18	46	344	585	126	6.59	2,305	0.829	6.9	7.2
151	B	B	29	57	335	1,187	442	5.82	2,012	2.297	7.1	7.4
152	B	B	6	103	158	703	332	5.41	1,860	1.891	6.7	7.1
153	B	OFF	12	66	199	716	320	5.77	2,425	1.954	6.3	6.6
154	B	ON	19	41	118	690	334	5.8	1,192	2.007	7.1	7.4
155	B	ON	26	48	112	674	510	5.76	1,249	2.125	6.7	7
156	B	OFF	30	59	215	531	112	6.33	2,366	1.007	6.4	6.8
157	B	OFF	37	61	239	730	315	5.52	2,788	1.823	6.6	6.9
158	B	ON	10	40	89	630	834	5.89	1,214	2.358	7.2	7.3
159	8	D	13	89	556	1,213	117	6.16	2,299	1.183	7.2	7.6
160		M	9	79	282	402	50.9	5.48	2,166	0.536	6.7	7.1
161		R	6	83	209	228	64.7	5.17	2,159	0.433	6.5	7
162	10	D	5	94	309	818	113	6.05	2,886	0.836	7	7.4
163		M	7	86	253	485	142	6.12	2,041	0.968	6.8	7.2
164		R	3	62	126	379	62.2	5.18	1,982	0.534	6.7	7.2
165	12	D	9	87	277	680	228	5.8	2,843	1.489	6.9	7.2
166		M	16	95	261	443	208	5.67	2,824	1.294	6.7	7
167		R	7	54	80	220	53.4	4.02	2,595	0.609	6.5	7
168	14	D	15	93	381	936	338	5.53	2,848	1.784	7.1	7.4
169		M	22	81	174	326	132	5.46	2,663	0.887	6.8	7.1
170		R	9	66	98	203	109	3.42	2,752	0.78	6.4	7
182	17	D	5	72	259	953	84.9	6.25	3,290	0.623	7	7.4

Sample Number ¹	Location Paddock ²	Position ³	NO ₃ -N mg/kg	NH ₄ -N mg/kg	P mg/kg	K mg/kg	S mg/kg	Org-C %	Fe mg/kg	Cond. dS/m	pH (CaCl ₂)	pH (H ₂ O)
183		M	1	80	128	367	77.8	6.34	3,301	0.611	6.3	6.8
184		R	1	45	65	214	58.1	6.06	3,587	0.447	6	6.6
171	20	D	28	114	268	1,262	569	5.55	3,050	2.398	6.7	6.9
172		M	9	84	147	546	202	5.49	2,603	1.182	6.2	6.7
173		R	16	54	95	293	168	5.91	2,450	0.727	6.1	6.5
185	22	D	2	54	179	435	367	5.88	5,096	1.008	6.4	6.8
186		M	2	44	96	281	175	6.19	3,816	0.787	6.2	6.6
187		R	3	38	185	346	102	5.62	3,360	0.587	7.1	7.4
188	24	D	14	81	154	744	494	5.89	5,766	1.232	6	6.4
189		M	6	54	94	278	82.5	5.5	4,129	0.469	5.7	6.5
190		R	4	37	76	214	86.7	6.01	3,023	0.558	6.2	6.6
177	B	OFF	84	43	171	1,176	1,162	6	3,590	3.876	7	7.1
178	B	ON	62	30	306	1,812	1,168	5.55	1,206	5.254	7.6	7.8
174	24	D	22	52	131	874	1,322	5.64	5,648	2.551	6.1	6.3
175		M	24	55	99	447	119	5.3	4,830	0.7	5.7	6.1
176		R	9	41	98	312	129	5.79	3,142	0.658	5.8	6.2
MEDIAN			5	55	173	464	87	6.06	2,466	0.56	6.4	6.9

- 1 Report by MBP Consulting (2004) contains maps and further details on the location of sample sites corresponding to the sample number.
- 2 Paddocks all sampled from north to south end of farm and paddocks numbered from north boundary.
- 3 R = river end; M = middle; D = drain end; B = back swamp sample, refer to map/s; Off = water off end; On = water on end (in reference to back swamps where more than the middle line of paddock is sampled).