APPENDIX A - Summary of Queensland Pilot Wetland Data Report

1. Background Information

1.1 Scope of the Research Program

The pilot wetland program was structured as a black box experiment that focussed on quantifying the inlet and outlet characteristics of the various wetland systems.

The parameters measured included biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids (SS), nitrogen species, phosphorus species, pH, faecal coliforms, total dissolved solids (TDS), dissolved oxygen (DO) and temperature.

Limited information was also taken on Faecal *streptococci* removal performance.

The extent of data collected varied for each site, with the amount of data collected depending on a variety of parameters including, in particular, the resources available to undertake the testing.

1.2 The Objectives of the Program

The main objectives of the pilot program were to generate information that would enable design of wetlands to satisfy the following treatment objectives:

- effluent polishing, in terms of BOD and SS removal or reduction
- nutrient reduction, in terms of nitrogen and phosphorus
- disinfection, in terms of Faecal Coliforms or *Ecoli*
- sediment removal; and
- algal removal, particularly from upstream processes such as oxidation ponds or maturation lagoons.

The above objectives are in the interest of complying with discharge standards, preserving water quality, enabling reuse, maintaining public health standards and ecological sustainability.

1.3 Outline of the Pilot Wetlands

The sites were mainly selected on the basis of consideration of geographical location, climate and quality of treated sewage to be used as influent to the wetlands. The sites were selected on a scoring system and through consultation with local government.

Table 1.1: Summary Information on Pilot Free Water Surface Wetlands summarises the details of the sites selected and design details of the wetlands constructed.

Table 1.2: Initial Species Planted in Queensland's Constructed Wetlands shows the initial species planted at constructed wetlands and indicate the species that survived and those that died. **Table 1.2** also indicates the degree of colonising noted.

At Mossman, it was particularly difficult to find suitable plants that would readily establish. Aquatice weeds such as water lettuce would is lonise and dominate systems.

1.4 Other Wetlands Included in the Wetland Pilot Program

An investigation was also undertaken of a Sub Surface Flow (SSF) wetland at Wamuran. In summary, the investigation monitored a SSF wetland constructed with the objective to provide secondary treatment for sewage from a single household (Mitchell, 1995).

A detailed analysis of this data was not undertaken.

The system included 5 circular dual gravel pits followed by a pond. The system was small scale at approximately 2 metres in diameter.

The system showed a median performance similar to that achieved from a secondary treatment system. Median influent BOD and suspended solids concentrations were lower than typical sewage. The system showed high removal rates for nitrogen (typically 85%) and phosphorus (typically 70%), however long term performance was not assessed.

Table 1.1: Summary Information on Pilot Free Water Surface Wetlands

Location (local government)	Climate	Treatment Objective	Upstream Treatment Process	Discharge	Wetland Type	Construction Completed	Wetlands Cells	Dimensions (m) No. x L x W	Depth (mm)	Nominal Detention Time (days)	Comments
Mossman (Port Douglas)	Wet Tropical	a, b, c	Oxidation Ditch	Golf course	FWS	Jul 95	1 U shape	1 x 100 x 8	500	3.6	Selected to demonstrate impact of monsoon weather conditions
Edmonton (Cairns)	Wet Tropical	a, b, c	Oxidation Ditch	Mangrove estuary	FWS	Apr 94	3 Linear	2 x 63.5 x 5.5 1 x 63.5 x 15.5	500	10 – 16	Selected on basis that influent was very high quality and extent of advanced secondary or tertiary treatment that could be achieved.
Ingham (Hinchinbrook)	Wet Tropical	a, b, c	Trickling Filter	River	FWS	Feb 93	3 U shape	3 x 220 x 12	500	4 –12	
Mt St John (Townsville)	Dry Tropical	a, b, c	Trickling Filter	Natural wetland	FWS	Mar 93	4 Linear 1 U shape	4 x 60 x 4 1 x 120 x 4	400	7 – 10	Selected on the basis of dry tropical conditions and to test a wide variety of wetland plants
Mt Bassett (Mackay)	Dry Tropical	a, b, c	Trickling Filter & AS	Mangrove estuary	FWS	May 94	2 U shape	2 x 300 x 10	300	3.2	
Emu Park (Livingstone)	Sub Tropical	a, b	AS	Land disposal	FWS	Jan 94	5 Linear	5 x 40 x 2.5	400	7	Selected on the basis of determining the potential to polish good quality effluent in arid coastal conditions
Blackall (Blackall)	Arid	a, c	Trickling Filter	Park & tree lot irrigation	FWS	Feb 93	4 Linear	4 x 120 x 7	600	4.6 – 5.4	Selected to test the arid western climatic conditions and their effects on a selected range of macrophytes.
Goondiwindi	Arid	a, b	Trickling Filters and Lagoons	Pasture irrigation	FWS	Jun 94	5 Linear	1 x 45 x 5 4 x 60 x 8	500	7	
Logan (Logan City)	Sub Tropical	a,b, nutrient balance	Oxidation Ditch	Returned to STP	FWS	Apr 94	3 Linear	3 x 7 x 1	150 - 700	7 – 15	
Wamuran (Caboolture)	Sub Tropical	secondary treatment	Septic Tank	Ground soakage	SSF	Oct 92	5 Circular	2 m diameter	N/A	2 – 15	

Notes:
a – effluent polishing, b – nutrient reduction, c – disinfection
AS – Activated sludge secondary process
STP = Sewage Treatment Plant
FWS – Free water surface wetland, SSF – Sub-surface flow wetland
L = wetland length
W = wetland width
Nominal detention time – based on the estimated detention time measured during the operation of each wetland.

Table 1.2: Initial Species Planted in Queensland's Constructed Wetlands

Species	Mossman	Edmonton (Cairns)	Ingham	Townsville	Mackay	Emu Park	Blackall	Goondiwindi	Logan	Wamuran
Typha domigensis	í	í	í	í	í	í	í	í		
Typha orientalis	Typha			Typha						í
Phragmites australis			í	í		í			í	í
Schoenoplectus validus		í	í		í	í		í		
Schoenoplectus litoralis									í	
Eleocharis sphacelata		í	í	í	í			í		
Eleocharis equisetina									í	
Cyperus exaltus		í	í	í			í	í		
Cyperus involucratus				Cyperus						í
Duckweed	í	*	*	í	*	*	*			í
Marsilea (Nardoo)		í	í	í						
Nymphoides indica		í			í +					
Oltelia ovalifolia					í +					
Persicaria							í			
Potamogeton					í +					
Juncus spp.							í			
Scieria poiformis	í		í							
Pistia stratiotes				í						í

Notes - No information was available on the initial planting at Mossman
+ denotes died
* denotes colonised open water
{ denotes species initially planted

2. Analysis of Data

There is a considerable amount of data generated from the pilot wetland program.

The data analysed in this report is almost exclusively that data generated from the sampling and analysis undertaken by the participating local government authorities.

There is a significant quantity of other related information and data available from parallel and related studies on the pilot wetlands that is not analysed in this report. Reference is directed to the various reports and papers documenting some of the other information available.

2.1 Acknowledgment

We acknowledge the time and effort put in by the local government officers and the staff at DNR in providing the set of analysis data in a useable and complete form.

2.2 Methodology

The methodology used to analyse the data was to undertake the following steps:

1. Complete a validation check on data received from DNR. The result of the check showed that the majority of the data was suitable for use.

2. Development of a set of standard/ proforma spreadsheets. These were set up to allow the different data sets from the different wetland projects to be added and sorted into a standardised form that could be then easily cross referenced. Within each of the spreadsheets, a set of graphs was produced to allow graphic output to be readily generated and reviewed.

3. Graphing of a number of correlations extracted from the literature to determine if any of the standard correlations documented can be fitted to the data sets produced.

4. Statistical analysis of the data sets to produce estimates of the minimum, percentile, average, median and maximum values to be determined.

5. Comparison of data sets between wetland data files to determine if there are any general relationships and conclusions that can be drawn from the data.

In general, mass removal rates and mass loading rates were analysed in preference to concentrations. This decision was taken given the potential for the generation of misleading results if concentration alone was considered. It is well recognised that given the loss of water from wetland systems through, for example, evapo-transpiration, that certain parameters may be concentrated in solution.

Data Analysis Undertaken
The data analysis undertaken included:

- Statistical analysis of the following raw data
  - Flowrate
  - Temperature
  - pH
  - Dissolved oxygen
  - BOD
  - COD
  - SS
  - Ammonia
  - Total nitrogen
  - Filterable reactive phosphorus
  - Total phosphorus
  - Bacteriological

- Manipulation of the data to calculate the following parameters. Statistical analyses were also performed on these parameters
  - Hydraulic loading rate (based on the volume loaded to the wetland per day divided by the area of the wetland)
  - Detention time (based on the volume of the wetland divided by the average of the influent and effluent flowrates)
  - Loading rates of BOD, COD, SS, ammonia total nitrogen, FRP and total phosphorus (based on the influent flow multiplied by the influent concentration and divided by the area of the wetland)
  - Removal performance (based on a mass removal through the wetland. This is calculated by the influent mass minus the effluent mass all divided by the influent mass).

The calculation protocol used was to determine if there was a complete set of data for a particular date and perform the calculations on that data set. It is acknowledged that there are other calculation methods that can be used. Examples of these methods include:

- Base the removal performance on concentration rather than mass. The limitation of this calculation method is that it does not take account of losses of water through the system and hence a potential increase in the concentration of the parameter. The same limitation applies where there are large additions of water to the system and hence a diluting effect of the parameters.

- Time shift the effluent data by a time equivalent to a detention time in the system. This is an attempt to represent the effect of the wetland on a parcel of water as it passes through the wetland. This is achieved by taking the influent entering the wetland at time = 0, calculating the detention time of that influent water and using the mass out of the wetland at one detention time later.

- Base the removal performance on seasonal or periodic averages or medians to generate a few data points. This is the method principally used by DNR in the calculation of performance in the various publications associated with the pilot wetland program.

- Graphical representation of the following relationships for relevant parameters:
  - Parameter v date (all wetlands on one graph)
  - Removal performance v date
  - Removal performance v mass loading rate
  - Removal performance v hydraulic loading rate
  - Removal performance v temperature
  - Various parameters for each bay v date (one wetland on each graph)
  - Ammonia removal performance v pH

- Correlations were also graphed to show the fit between the measured data and the levels predicted by various correlations. The correlations were generally drawn from Reed (1995) and included:

$BOD_{effluent} = A * BOD_{influent} + B * HLR$

- where A = 0.192 and B = 0.097
- BOD in mg/L
- HLR is Hydraulic Loading Rate in cm/day

$SS_{effluent} = SS_{influent} * (A + B * HLR)$

- where A = 0.1139 and B = 0.00213
- SS in mg/L
- HLR in cm/day

Correlation 1 for NH4
$NH4_{effluent} = \exp(d * \ln(NH4_{influent}) + e * \ln(HLR) - f)$

- where d = 0.688, e = 0.655 and f = 1.107
- NH4 in mg/L
- HLR in cm/day

Correlation 2 for NH4
$NH4_{effluent} = NH4_{effluent} = A * NH4_{loading\ rate} - B$

- where A = 18.31 and B = 0.16063
- NH4 in mg/L
- $NH4_{loading\ rate}$ in $g/m^2/day$

N_{total} effluent = A * N_{total} influent + B * ln (HLR) – C

- A = 0.193, B = 1.55 and C = 1.75
- where N_{total} in mg/L
- HLR in cm/day

It should be noted that the removal performance is based on mass removal performance unless effluent flow rate was not available.

Mass removal performance is referenced to the influent level of each parameter. It is important to have this reference as without consideration of the influent level, misleading conclusions can be drawn. Also due consideration needs to be given to the possible overloading of systems and this effect on the results.

2.3 Results of Data Analysis

Given the vast quantity of data available, the reporting of results is structured to consider the data generated on each measured performance parameter for each wetland site. This was followed by the consideration of the performance parameter across the wetland sites.

Summary tables and plots are provided at the end of this section to summarise the performance of each wetland and draw some general comments.

2.3.1 Biochemical Oxygen Demand

Overall Assessment

The overall performance and comments to be drawn from assessment of the data are summarised in **Table 2.1: Summary Information for BOD**.

In general terms, the following comments can be made about the data:

Wetlands operated at a nominal detention time of greater than approximately 4 days can demonstrate effective BOD removal with an effluent quality of less than 20 mg/L on a 50th percentile basis and often on a 85th percentile. One qualification on this statement is that if the influent BOD is less than approximately 5 to 10 mg/L, there may be deterioration in the level of BOD and the removal efficiency will be low or negative. This qualification is supported by experience at Edmonton and literature.

As noted at Mackay if algal effects or dispersion of material into the water column cannot be controlled, high effluent BOD can be the result.

Also as noted at Mackay and to a lesser degree at Ingham, with trickling filter effluent with a high ammonia loading and a short detention time in the wetland of 3 to 4 days, there was reduced ability to develop an effective growth of emergent or floating macrophytes. The effect of the open water is to generate a high algal load that can exert a BOD in the effluent if not effectively removed.

It is important to note that this hypothesis has not been tested to any extent in the wetland pilot program. However, the experience at Ingham has been demonstrated to some degree in the full scale system at Ingham where experience shows that as the water progresses through the wetland system the ability to generate dense growth macrophytes increases. The effect of the dense growth is to reduce the potential for algal blooms and can provide an effective filtering process before discharge.

A representation of the average removal performance is shown as **Figure 2.1: Average BOD Removal Performance**.

2.3.2 Chemical Oxygen Demand

Overall Assessment

The overall performance and comments to be drawn from assessment of the data are summarised in **Table 2.2: Summary Information for COD**.

In general terms, the following comments can be made about the data:

For influent COD levels below 75 mg/L (as noted in Mackay and Logan), the data indicates a decrease in removal efficiency. This suggests that the larger proportion of the COD at these levels is soluble, non-biodegradable and not removed through wetland systems. Wetland degradation products can, in fact, add to the COD as shown at Cairns.

The data shows a general increase in removal performance with mass loading rate and hence influent COD. This is to be expected as the higher COD being applied to the wetlands may have a greater biodegradable component.

The data also showed a general decrease in removal efficiency with temperature. Upon assessment of the data this can be explained given, with higher temperatures, the influent COD was generally lower and hence it can be expected that the biodegradable component may be lower.

2.3.3 Suspended Solids

Overall Assessment

The overall performance and comments to be drawn from assessment of the data are summarised in **Table 2.3: Summary Information for SS**.

In general terms, the following comments can be made about the data:

There can be extended periods after commissioning of the wetland before algal blooms can be controlled to the point that reliable quality effluent can be produced. Wetlands designed for treatment plant effluent have a propensity to generate algae given the availability of nutrients and the environmental conditions of high temperature and sunlight levels favouring growth.

In cases (eg. Mackay) where open water area was maintained at 25 to 40%, algal blooms and the consequent effect of high suspended solids were found to be difficult to control, particularly in bay 1, where high suspended solids levels persisted through almost the entire trial period.

Where good quality (ie. 5 to 10 mg/L suspended solids) effluent is produced from an upstream process, the use of wetlands to maintain or better the quality is considered marginal.

A representation of the average removal performance is shown as **Figures 2.2: Median SS Removal Performance**.

2.3.4 Ammonia

Overall Assessment

The overall performance and comments to be drawn from assessment of the data are summarised in **Table 2.4: Summary Information for Ammonia**.

In general terms, the following comments can be made about the data:

At low influent ammonia levels (ie. less than 1 mg/L), some improvement in performance and buffering to spikes can be expected.

At influent ammonia of 5 to 10 mg/L, the effluent ammonia levels may follow or lag the influent profile with limited ammonia removal. This observation is made on limited information.

At elevated influent ammonia levels (ie. greater than 10 mg/L), the effluent profile generally follows the influent profile with some reduction of ammonia.

A representation of the average removal performance is shown as **Figure 2.3: Median Ammonia Removal Performance**.

2.3.5 Total Nitrogen

Overall Assessment

The overall performance and comments to be drawn from assessment of the data are summarised in **Table 2.5: Summary Information for Total Nitrogen**.

Where the dominant form of nitrogen in the influent or where nitrification occurs to produce nitrate, high levels of nitrate removals are evident.

A representation of the average removal performance is shown as **Figure 2.4: Median Total Nitrogen Removal Performance**.

2.3.6 Filterable Reactive Phosphorus

Overall Assessment

The overall performance and comments to be drawn from assessment of the data are summarised in **Table 2.6: Summary Information for Filterable Reactive Phosphorus**.

On a mass basis, the long term median removal is in the range of 20 to 35%.

On a concentration basis, the long term removal is close to zero.

A representation of the average removal is shown as **Figure 2.5: Median Filterable Reactive Phosphorus Removal Performance**.

2.3.7 Total Phosphorus

Overall Assessment

The overall performance and comments to be drawn from assessment of the data are summarised in **Table 2.7: Summary Information for Total Phosphorus**.

Removal of phosphorus can be expected in the early operating period of a wetland as the macrophytes become established. After establishment poor removal performance, if any, can be expected.

On a mass basis, the long term media removal is in the range of 20 to 35%. On a concentration basis, the long term removal is close to zero.

A representation of the average removal is shown as **Figure 2.6**: **Median Total Phosphorus Removal Performance**. At some wetlands, export of phosphorus on concentration basis is evident.

2.3.8 Faecal Coliforms and Faecal Streptococci

Overall Assessment

The overall performance and comments to be drawn from assessment of the data are summarised in **Table 2.8: Summary Information for Faecal Coliforms** and **Table 2.9: Summary Information for Faecal Streptococci**.

A 1.5 to greater than 2 log reduction can be expected from wetlands with a detention time of greater than 10 days.

2.3.9 Studies Carried out on the Logan Wetlands

Performance data for Logan wetlands is summarised in **Table 2.10**. Further studies were carried out at the Logan wetlands. The studies included:

- Tracer studies on the three wetlands to confirm retention time. A tracer study was undertaken in both phases 1 and 2 of the wetland operation.
- Determination of a water balance over the wetlands.
- Measurement of the diurnal variation of nutrients.

- Intensive monitoring over all three wetlands at the end of phase one to determine the nutrient profile through the wetlands.
- Harvesting of the plants to determine the effect of plant age and growth rate with nutrient uptake.

A full account of these investigations is not given in this report. Selected papers give an account of phase 1 of the study (eg. McCourt and Woolley 1997), however phase 2 has not been reported in the literature.

A wetland system comprising three replicate polyethylene tanks, each 7 m x 1 m and divided into 7 x 1 m^2 zones was constructed at the Queens Road Sewage Treatment Plant, Logan City.

Zone 1 at the inlet was planted with *Phragmites australis* (soil depth 0.5 m, water depth 0.3 m), zones 3 and 5 with *Schoenoplectus litoralis* (soil depth 0.2 m, water depth 0.6 m), and outlet zones 6 and 7 with *Eleocharis equisetina* (soil depth 0.65 m, water depth 0.15 m). Zones 2 and 5 were open water (soil depth 0.1 m, water depth 0.7 m) which was naturally colonised by *Lemna* during the trial. Mature plants from a natural wetland were transplanted on 22 January 1996.

In Phase 1, secondary treated sewage was introduced on 27 March 1996 at a constant flow rate of 456 L/day to give an hydraulic loading rate of 650 m^3/ha/day and a theoretical detention time of 7 days. Phase 2 commenced on 11 February 1997 with a flow rate of 216 L/d and a hydraulic loading rate of 309 m^3/ha/day giving a theoretical detention time of 15 days.

Tracer Studies
Lithium tracer trials were carried out in October 1996 during phase 1 of the investigation and in April 1997 during phase 2 to determine the actual detention times in the system and compare these to the theoretical times calculated.

A pulse of lithium solution was added to the inflow to the wetlands and regular monitoring undertaken at the outflow to develop a profile of the effluent lithium concentration with time. The centroid of the data was taken as the measured detention time.

During phase 1 of the investigations tanks 1, 2 and 3 were nominally operated with an equal theoretical detention time of approximately 7 days. The results from the tracer studies undertaken show that the estimated detention time is lower at 3.6 days for tank 1, 4.4 days for tank 2 and 3.3 days for tank 3.

The recoveries of lithium through the trial were high (typically greater than 90%) giving a level of confidence in the results.

Calculations were also undertaken to determine the detention time based on the outflow from the system. The calculated retention times were 6.2, 6.8 and 5.8 days.

A similar investigation was undertaken during phase 2 in April 1997.

The results showed that the actual detention times were 17.7, 17.9 and 17.4 days compared to the theoretical detention time of 15 days. This result tends to imply that, at a nominal 15 day detention time, the shortcircuiting of water through the wetland is reduced or possibly that the evapo-transpiration losses from the wetland may be significant compared to the volume of inflow.

Calculations based on the outflow volumes show that the detention times were 22, 21 and 16 days.

Water Balance
A water balance was calculated for the two phases of the investigation.

During phase 1, the inflow to each wetland tank was approximately 456 L/day with the median outflow of 338 L/day for tank 1, 329 L/day for tank 2 and 360 L/day for tank 3.

The median water loss over phase 1 being approximately 25 to 30%, ranging from 12% in the winter months to as high as 47% in the summer months. The water loss is attributed to transpiration and evaporation as the wetlands were established in polyethylene tanks.

Of the water lost from the system approximately 80 to 98% of the water was lost through transpiration.

The water balance was repeated for the operation during phase 2.

The median inflow was 216 L/day with the median outflows of 102 L/day for tank 1, 95 L/day for Tank 2 and 130 L/day for tank 3.

The median water loss was approximately 50%. With the higher retention time and the lower flowrate per area, as expected the loss from the system due to evapo-transpiration was a significantly higher proportion of the total flow through the system and partly goes to explain the results from the tracer studies.

It should be noted that the median water loss due to evapo-transpiration for the phase 1 period was approximately 114 L/day and during phase 2 was approximately 109 L/day. This similar result from the two phases gives some confidence in concluding that the evapo-transpiration loss from the wetland was approximately 110 L/day over an area of 7 m^2. Also given that the evaporation was a small component of the water loss (say 10%), the transpiration loss from the wetland can be estimated at approximately 14 L/m^2.day or 14 mm/day.

Nutrient Mass Balance
Extensive sampling and investigations have been undertaken to characterise the location and fate of nutrients in the Logan wetland. The characterisation included harvesting the biomass from the system and determining the total biomass, nitrogen and phosphorus in the system.

Table 2.11 summarises the information available on nitrogen and phosphorus accumulations in the system.

The conclusions to be drawn from **Table 2.11** include:

- The accumulation of nitrogen in the plant tops accounts for 10 to 22% of the influent nitrogen.
- There is an apparent increase in the accumulation of nitrogen and phosphorus over the 12 month period after harvesting. However, given the change in the loading rate of phase 2 compared to phase 1, a definitive conclusion that harvesting increases the accumulation rate of wetland plants cannot be drawn.
- The average accumulation of nitrogen in the plant tops was 43 g/m^2. This is based on 605 grams accumulating in the plant tops over two growth cycles over the 7 m^2 for each wetland.
- The accumulation of phosphorus in the plant tops accounts for approximately 5 to 9% of the influent phosphorus.
- The accumulation of phosphorus in the plant tops was 8 g/m^2 based on 115 grams accumulating in the plant tops over two growth cycles over the 7 m^2 for each wetland.
- The undefined percentage of nitrogen increased during phase 2. It appears that the increased removal of nitrogen is due to increased levels of nitrification and denitrification brought about by the increased detention time in the system.
- The undefined percentage of phosphorus increased significantly during phase 2. It is not clear how to account for the extra unaccounted phosphorus in phase 2.

3. Pilot Wetland Data - Plant Top Harvesting

An assessment was made of the benefits of harvesting on the accumulation rates of nitrogen and phosphorus in the wetland.

Table 2.12 shows the results of calculating the accumulation of nutrients at various phases of regrowth.

The conclusions to be drawn from the data presented in **Table 2.12** are:

- After 9 months of regrowth, the estimated amount of nitrogen and phosphorus accumulated in the plant tops was greater than that accumulated over the first 12 months of operation. Although not shown in this table, the total biomass grown in the plant tops over this period also equalled that grown over the first 12 months of operation. Further research would be required to determine if a 9 month or longer harvesting period is required to optimise the accumulation of nitrogen and phosphorus in the plant tops and hence optimise the removal of nitrogen and phosphorus due to harvesting.
- There was an increase in the rate of nutrient accumulation over the period from August 1997 to November 1997, which coincided with the period from 6 months to 9 months regrowth. It is not clear from the data if any other environmental factors influenced the growth of the wetland over this same period.

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Table 2.1: Summary Information for BOD

Parameter	Edmonton			Ingham			Townsville					Mackay		Blackall			
Bay Number	1	2	3	1	2	3	1	2	3	4	5	1	2	1	2	3	4
Median influent (mg/L)	6.6			23			27					18		21			
Median effluent (mg/L	7.3	5.9	7.0	16			8	9	10	9	8	16	12	11	15	11	11
Minimum effluent (mg/L)	1.0	1.0	1.5	6			2	3	2	0	0	4	2	3	1	3	2
Maximum effluent (mg/L)	15	14	18	35			38	30	25	21	24	80	74	32	35	29	35
85 %ile effluent (mg/L)	11	10	11	23			14	20	14	13	16	29	28	16	24	18	18
Comments	85 %ile meets 20 mg/L						85%ile meets 20 mg/L					Long startup period with high algae		Bay 2 operates at higher BOD. May be related to algal levels			
Median retention time (days)	16	10	11	4.3 (Note insufficient data available for period with 12 d detention time)			7 – 10					3.2	3.2	4.6	4.9	5.4	5.4
Median removal rate (%) mass basis	-1	20	-9	79			Insufficient data					63	72	65	61	72	64
Median removal rate (%) conc basis	-23	7	-17	30			70	74	68	70	71	9	33	54	34	47	53
Comments	Low influent BOD dramatically effects removal rate											High water loss from system		60% mass loss can be expected			
Seasonal variation in upstream process												No significant variation		Not seasonal but high variation 3/94 to 7/95			
Seasonal variation in wetland process							Inconsistent variation not seasonal					Inconsistent variation not seasonal					
Median wetland temperature	25.5	25.0	25.5	No data			Insufficient data					25	25	19	19	19	19
Possible correlation with removal perf.	No apparent correlation											No apparent correlation		No apparent correlation			
Median mass loading rate (kg/ha/day)	2.1	4.0	3.2	24			Insufficient data					21		33	33	33	33
Possible correlation with removal perf.	Low loading and low conc = poor removal			Insufficient data			Insufficient data					No apparent correlation		No apparent correlation			
Median hydraulic loading rate (ML/ha/day)	0.3	0.5	0.5	Insufficient data			Insufficient data					1.2		1.2	1.2	1.2	1.2
Possible correlation with removal perf.	No apparent correlation			Insufficient data			Insufficient data					No apparent correlation		Insufficient data			
Median pH	6.7	6.7	6.7				Insufficient data					7.3		7.5	7.6	7.6	7.5
Possible correlation with removal perf	No apparent correlation			Insufficient data			Insufficient data					No apparent correlation		No apparent correlation			
Comments	None			None			None					None		None			
Possible correlation with published correlations	No apparent correlation			Insufficient data			Insufficient data					No apparent correlation		No apparent correlation			
Comments	BOD not in suitable range for correlation											Correlation under-predicts concentration		Correlation under-predicts concentration			

Table 2.2: Summary Information for COD

Parameter	Mossman	Edmonton			Mackay		Logan Phase 1 (1/96 to 2/97)			Logan Phase 2 (2/97 to 2/98)		
Bay Number	1	1	2	3	1	2	1	2	3	1	2	3
Median influent (mg/L)	91	23			75		109			57		
Median effluent (mg/L	75	34	31	31	69	51	67	57	51	46	36	38
Minimum effluent (mg/L)	40	7	7	7	16	7	5	9	10	16	4	14
Maximum effluent (mg/L)	109	129	55	59	344	357	136	235	263	92	136	99
85 %ile effluent (mg/L)	134	44	39	40	133	138	115	132	104	70	60	51
Comments		Effluent COD higher than influent										
Median retention time (days)	3.6	16	10	11	3.2	3.2	3.6	4.4	3.3	17.7	17.9	17.4
Median removal rate (%) mass basis	11	-42	-15	-20	55	65	57	60	59	69	74	66
Median removal rate (%) conc basis	11	-44	-23	-32	6	26	39	48	53	19	37	33
Comments					High water loss from system		Phase 1 showed highly variable influent and effluent					
Seasonal variation in upstream process	Insufficient data	Inconsistent variation not seasonal			Inconsistent variation not seasonal		Inconsistent variation not seasonal					
Seasonal variation in wetland process	Insufficient data	No apparent correlation			No apparent correlation		no apparent correlation					
Median wetland temperature	27	25.5	25.0	25.5	25	25	-	-	-	-	-	-
Possible correlation with removal perf.	Insufficient data	General decrease in removal performance with increasing temperature due to lower influent levels at higher temperatures			General decrease in removal performance with increasing temperature due to lower influent levels at higher temperatures.		Insufficient data					
Median mass loading rate (kg/ha/day)	125	6.1	10	10	83		24			5.9		
Possible correlation with removal perf.	Insufficient data	General decrease in removal performance with increasing loading rate			General increase in removal performance with an increase in loading rate		No apparent correlation					
Median hydraulic loading rate (ML/ha/day)		0.3	0.5	0.5	1.2		0.22			0.1		
Possible correlation with removal perf.	Insufficient data	No apparent correlation			No apparent correlation		No apparent correlation					
Median pH	6.5	6.7	6.7	6.7	7.3		7.2	7.2	7.2	7.2	7.2	7.2

Table 2.3: Summary Information for SS

Parameter	Edmonton			Ingham			Townsville					Mackay		Blackall			
Bay Number	1	2	3	1	2	3	1	2	3	4	5	1	2	1	2	3	4
Median influent (mg/L)	4.8			24			25					23		34			
Median effluent (mg/L	4.0	5.4	4.0	16			9	12	9	7	6	72	38	22	30	17	19
Minimum effluent (mg/L)	<1	<1	<1	1			0	1	0	0	0	8	3	<1	<1	<1	<1
Maximum effluent (mg/L)	25	15	12	83			220	112	120	145	147	234	191	248	291	152	110
85 %ile effluent (mg/L)	12	10	8	40			20	33	23	18	17	127	113	58	85	49	50
Comments	85 %ile meets 30 mg/L			85 %ile does not meet 30 mg/L			85%ile likely to meet 30 mg/L					Bay 1 showed erratic & unacceptable performance over entire trial period Bay 2 acceptable after 18 months		Erratic influent concentration. Periodic good performance			
Median retention time (days)	16	10	11	4.3 (Note no data available for period with 12 d detention time)			7 – 10					3.2	3.2	4.6	4.9	5.4	5.4
Median removal rate (%) mass basis	37	11	19	Insufficient data			Insufficient data					14	54	60	40	73	60
Median removal rate (%) conc basis	18	0	20	25			64	48	67	74	76	-214	-68	57	26	59	50
Comments				Erratic variation in removal performance			Erratic variation in concentration and removal performance particularly for bay 2					Significant & lingering impact of algal bloom		Greater than 50% removal can be expected			
Seasonal variation in upstream process	No apparent correlation			Tends to be low in summer			No apparent correlation					No apparent correlation		Erratic not related to season			
Seasonal variation in wetland process	No apparent correlation			Lesser variation with season			No apparent correlation					No apparent correlation		No apparent correlation			
Median wetland temperature	25.5	25.0	25.5	24			Insufficient data					25	25	19	19	19	19
Possible correlation with removal perf.	General decrease in removal performance with temperature			Insufficient data			Insufficient data					No apparent correlation		No apparent correlation			
Median mass loading rate (kg/ha/day)	1.2	2.1	2.0	Insufficient data			Insufficient data					27	27	53	53	53	53
Possible correlation with removal perf.	General increase in removal performance with increasing loading rate			Insufficient data			Insufficient data					General increase in removal performance with increasing loading rate		General increase in removal performance with increasing loading rate			
Median hydraulic loading rate (ML/ha/day)	0.3	0.5	0.5	Insufficient data			Insufficient data					1.2		1.2	1.2	1.2	1.2
Possible correlation with removal perf.	No apparent correlation			Insufficient data			Insufficient data					No apparent correlation		No apparent correlation			
Median pH	6.7	6.7	6.7	Insufficient data			Insufficient data					7.3		7.5	7.6	7.6	7.5
Possible correlation with removal perf.												No apparent correlation					
Comments	None			None			None					None		None			
Possible correlation with published correlations	No apparent correlation			Insufficient data			Insufficient data					No apparent correlation		No apparent correlation			
Comments	None			None			None					None		None			

Table 2.4: Summary Information for Ammonia

Parameter	Mossman	Edmonton			Ingham			Townsville					Mackay		Blackall			
Bay Number	1	1	2	3	1	2	3	1	2	3	4	5	1	2	1	2	3	4
Median influent (mg/L)	0.75	0.5			7.7			11.2					23		8.7			
Median effluent (mg/L	0.2	0.6	0.5	0.8	6.9	5.9	3.5	2.5	2.5	3.1	2.2	1.8	10	14	11	5.5	6.3	8.2
Minimum effluent (mg/L)	0	0.1	0.1	0.3	2.1	1.6	1.9	0.1	0.6	0.4	0.3	0.4	1.1	1.4	2.1	3.5	0.8	0.7
Maximum effluent (mg/L)	0.65	1.8	1.8	2.8	8.4	7.6	8.5	13	21	13	15	11	21	20	15	14	13	12
85 %ile effluent (mg/L)	0.4	0.9	0.8	1.5	8.3	7.1	5.3	8.7	8.1	8.2	9.3	6.5	15.5	17	13	12	12	11
Comments	Low influent ammonia	Low influent ammonia			Limited data set			Effluent ammonia profile followed the influent profile but at a lower concentration. Effluent consistently 5 to 9 mg/L below the influent.					Effluent ammonia profile follows the influent profile. Effluent consistently 8 to 10 mg/L lower.		Effluent ammonia profile generally similar or lagging the influent profile without significant removal			
Median retention time (days)	3.6	16	10	11	12			7 – 10					3.2	3.2	4.6	4.9	5.4	5.4
Median removal rate (%) mass basis	74	18	30	-36	Insufficient data			Insufficient data					72	72	-3	39	49	29
Median removal rate (%) conc basis	74	45	34	0	17	39	55	76	76	74	75	78	49	42	2	27	10	10
Comments	Not a meaningful result as influent is low	Not a meaningful result as influent is low			Limited data set			Good removal performance at elevated ammonia concentrations					Good removal performance at elevated ammonia concentrations		Limited data set but possible correlation with season			
Seasonal variation in upstream process	No apparent correlation	No apparent correlation			Insufficient data			Erratic but generally not considered to be seasonal					Generally higher ammonia in winter		Generally higher ammonia in winter			
Seasonal variation in wetland process	No	No	No	No	Insufficient data			No - follows influent profile					X follows influent profile		Follows influent profile and shows some expected variation with season			
Median wetland temperature	27	25.5	25.0	25.5	24			Insufficient data					25	25	19	19	19	19
Possible correlation with removal perf .	No apparent correlation	No apparent correlation											General correlation on concentration basis. Poorer on mass basis.		General correlation – Winter temperature 12 to 15 C and summer temperature 22 to 25. Highest variation in T of all wetlands trialed			
Median mass loading rate (kg/ha/day)	1.0	0.1	0.1	0.1	Insufficient data			Insufficient data					25		11	11	11	11
Possible correlation with removal perf.	No apparent correlation	No apparent correlation											No apparent correlation		No apparent correlation			
Median hydraulic loading rate (ML/ha/day)	1.4	0.3	0.5	0.5	Insufficient data			Insufficient data					1.2		1.2	1.2	1.2	1.2
Possible correlation with removal perf.	No apparent correlation	No apparent correlation											No apparent correlation		No apparent correlation			
Median pH	6.5	6.7	6.7	6.7	Insufficient data			Insufficient data					7.3		7.5	7.6	7.6	7.5
Possible correlation with removal perf	No apparent correlation	No apparent correlation											General correlation on concentration basis. Poorer on mass basis.		No apparent correlation			

Continued next page.

Parameter	Mossman	Edmonton	Ingham	Townsville	Mackay	Blackall
Comments	No meaningful correlations as influent is low for Mossman and Edmonton		Insufficient data	Insufficient data	Insufficient data	General good removal in summer and lesser removal in winter. Insufficient data to substantiate.
Possible correlation with published correlations	No apparent correlation	No apparent correlation	Insufficient data	Insufficient data	General correlation with correlation 1 but not with correlation 2	General correlation with correlation 1 but not with correlation 2
Comments	None	None	None	None	Correlation should not be used for predictive purposes.	Correlation should not be used for predictive purposes

Table 2.5: Summary Information for Total Nitrogen

Parameter	Mossman	Edmonton			Ingham			Townsville					Mackay		Blackall			
Bay Number	1	1	2	3	1	2	3	1	2	3	4	5	1	2	1	2	3	4
Median influent (mg/L)	5.3	6.1			19.5			32					34.5		17			
Median effluent (mg/L	0.7	1.4	1.5	1.9	14	10	6	7.5	8.8	7.9	7.2	6.0	16	17	14	13	10	11
Minimum effluent (mg/L)	0.1	0.1	0	0.1	8	6.5	<1	2.4	2.2	0.4	2.0	2.0	3.1	5.8	10	5.6	4.9	6.5
Maximum effluent (mg/L)	15	20	8.3	14	21	14	9.4	17	21	19	18	21	31	25	17	20	16	14
85 %ile effluent (mg/L)	1.2	2.3	2.5	3.1	16	12	8.7	12	13	12	12	9.4	26	21	17	15	14	14
Comments		Influent N predominantly in nitrate form			Insufficient data			Median influent has approximately 20 mg/L nitrates					Insufficient data		Ammonia is the dominant nitrogen in effluent. Relatively complete nitrate reduction in all except bay 2			
Median retention time (days)	3.6	16	10	11	12			7 – 10					3.2	3.2	4.6	4.9	5.4	5.4
Median removal rate (%) mass basis	87	87	88	80	Insufficient data			Insufficient data					55	62	26	45	65	41
Median removal rate (%) conc basis	87	85	85	78	37	56	74	75	72	76	76	81	38	55	15	23	34	30
Comments	High removal performance	High removal performance						Removal is predominantly nitrates					Insufficient data					
Seasonal variation in upstream process	No apparent correlation	No apparent correlation			Insufficient data			Variable but not seasonal					Insufficient data		Insufficient data			
Seasonal variation in wetland process	No apparent correlation	No apparent correlation			Insufficient data			Variable but not seasonal					Insufficient data		Insufficient data			
Median wetland temperature	27	25.5	25.0	25.5	24			Insufficient data					25	25	19	19	19	19
Possible correlation with removal perf.	No apparent correlation	No apparent correlation			No apparent correlation								No apparent correlation		No apparent correlation			
Median mass loading rate (kg/ha/day)	7.2	2.4	3.5	3.7	Insufficient data			Insufficient data					42.2		23	23	23	23
Possible correlation with removal perf.	General increase with increased loading rate	No apparent correlation											No apparent correlation		No apparent correlation			
Median hydraulic loading rate (ML/ha/day)	1.4	0.3	0.5	0.5	Insufficient data			Insufficient data					1.2		1.2	1.2	1.2	1.2
Possible correlation with removal perf.	Insufficient data	General decrease with increasing HLR											No apparent correlation		No apparent correlation			
Median pH	6.5	6.7	6.7	6.7	Insufficient data			Insufficient data					7.3		7.5	7.6	7.6	7.5
Possible correlation with removal perf	No apparent correlation	No apparent correlation											No apparent correlation		No apparent correlation			
Comments																		
Possible correlation with published correlations	No apparent correlation	General correlation however data very scattered			No apparent correlation			No apparent correlation					No apparent correlation		No apparent correlation			
Comments	Predicted always higher than measured	Correlation should NOT be relied on for prediction			None			None							Correlation predicts lower than measured			

Table 2.6: Summary Information for Filterable Reactive Phosphorus

Parameter	Mossman	Edmonton			Ingham (Only data from 8/94 onward shown)			Townsville					Mackay		Blackall			
Bay Number	1	1	2	3	1	2	3	1	2	3	4	5	1	2	1	2	3	4
Median influent (mg/L)	4.5	7.5			8.3			6.2					5.8		3.3			
Median effluent (mg/L	3.2	6.5	6.8	7.3	6.1	5.2	5.4	6.5	6.5	6.5	6.5	6.6	5.9	5.7	4.7	4.7	4.0	4.3
Minimum effluent (mg/L)	0	<1	<1	1.0	2.4	3.2	3.5	1.9	2.5	2.8	3.7	3.1	1.3	1.0	2.8	2.6	1.6	2.5
Maximum effluent (mg/L)	7.2	17	17	14	6.7	6.8	6.8	9.4	9.6	9.7	10	9.7	8.5	10	7.2	8.6	7.5	8.1
85 %ile effluent (mg/L)	4.8	8.7	8.9	9.1	6.3	6.2	6.1	7.7	7.6	7.9	8.0	8.0	7.2	7.6	5.3	6.1	5.7	5.0
Median retention time (days)	3.6	16	10	11	4.3			7 – 10					3.2	3.2	4.6	4.9	5.4	5.4
Median removal rate (%) mass basis	27	20	17	16	28	26	21	Insufficient data					35	35	-38	4	28	-11
Median removal rate (%) conc basis	27	15	15	7	7	18	16	-3	-1	-6	-7	-8	0	0	-29	-39	-17	-23
Comments	Good removal for 10 months	No significant difference between influent and effluent level over the pilot program			Insufficient data			No significant difference between influent and effluent level. Periods where effluent level was consistently higher than the influent level					Good removal for 10 months followed by poor removal		Poor removal performance over entire pilot program			
Seasonal variation in upstream process	No apparent correlation	No apparent correlation			Insufficient data			No apparent correlation					No apparent correlation		No apparent correlation			
Seasonal variation in wetland process	No apparent correlation	No apparent correlation			Insufficient data			No apparent correlation					No apparent correlation		No apparent correlation			
Median wetland temperature	27	25.5	25.0	25.5	24			Insufficient data					25	25	19	19	19	19
Possible correlation with removal perf.	No apparent correlation	No apparent correlation			No apparent correlation								No apparent correlation		No apparent correlation			
Median mass loading rate (kg/ha/day)	6.2	2.1	3.3	3.4	10.5			Insufficient data					6.8		4.9	4.9	4.9	4.9
Possible correlation with removal perf.	No apparent correlation	No apparent correlation			No apparent correlation								No apparent correlation		No apparent correlation			
Median hydraulic loading rate (ML/ha/day)	1.4	0.3	0.5	0.5	Insufficient data			Insufficient data					1.2		1.2	1.2	1.2	1.2
Possible correlation with removal perf.	No apparent correlation	No apparent correlation			No apparent correlation								No apparent correlation		No apparent correlation			
Median pH	6.5	6.7	6.7	6.7	Insufficient data			Insufficient data					7.3		7.5	7.6	7.6	7.5
Possible correlation with removal perf.	No apparent correlation	No apparent correlation			No apparent correlation								No apparent correlation		No apparent correlation			

Table 2.7: Summary Information for Total Phosphorus

Parameter	Mossman	Edmonton			Ingham			Townsville					Blackall			
Bay Number	1	1	2	3	1	2	3	1	2	3	4	5	1	2	3	4
Median influent (mg/L)	4.8	7.8			7.5			6.8					3.3			
Median effluent (mg/L	2.8	6.9	6.9	7.7	8.0	7.7	7.9	7.2	6.8	7.2	7.1	6.8	4.7	4.7	4.0	4.3
Minimum effluent (mg/L)	0	<1	1.0	1.2	3.4	3.3	3.4	3.6	3.3	4.0	3.9	3.3	2.8	2.6	1.6	2.5
Maximum effluent (mg/L)	6.1	14	25	18	8.5	9.1	9.2	9.7	11	11	11	11	7.2	8.6	7.5	8.1
85 %ile effluent (mg/L)	4.3	10	9.6	10	8.3	8.3	8.6	8.5	9.0	8.5	8.8	8.5	5.3	6.1	5.7	5.0
Comments																
Median retention time (days)	3.6	16	10	11	4.3			7 – 10					4.6	4.9	5.4	5.4
Median removal rate (%) mass basis	30	25	17	18	15	15	15	Insufficient data					-38	4	28	-11
Median removal rate (%) conc basis	30	20	17	13	4	10	12	-1	3	-5	-3	0	-29	-39	-17	-23
Comments		Removal of 1 to 2 mg/L over pilot period						Poor performance over entire period					Poor performance over entire period			
Seasonal variation in upstream process	No apparent correlation	No apparent correlation			Insufficient data			No apparent correlation					No apparent correlation			
Seasonal variation in wetland process	No apparent correlation	No apparent correlation			Insufficient data			No apparent correlation					No apparent correlation			
Median wetland temperature	27	25.5	25.0	25.5	24			Insufficient data					19	19	19	19
Possible correlation with removal perf.	No apparent correlation	No apparent correlation			No apparent correlation								No apparent correlation			
Median mass loading rate (kg/ha/day)	6.5	2.0	3.4	3.5	6.6			Insufficient data					4.9	4.9	4.9	4.9
Possible correlation with removal perf.	No apparent correlation	No apparent correlation			No apparent correlation								No apparent correlation			
Median hydraulic loading rate (ML/ha/day)	1.4	0.3	0.5	0.5	Insufficient data			Insufficient data					1.2	1.2	1.2	1.2
Possible correlation with removal perf.	No apparent correlation	No apparent correlation											No apparent correlation			
Median pH	6.5	6.7	6.7	6.7	Insufficient data			Insufficient data					7.5	7.6	7.6	7.5
Possible correlation with removal perf	No apparent correlation	No apparent correlation											No apparent correlation			
Possible correlation with published correlations	Poor correlation	No apparent correlation			No apparent correlation			No apparent correlation					No apparent correlation			
Comments		Calculated values lower than measured														

Table 2.8: Summary Information for Faecal Coliforms

Parameter	Edmonton			Townsville					Blackall			
Bay Number	1	2	3	1	2	3	4	5	1	2	3	4
Median influent (CFU/100mL)	79 500			84 000				1 600				
Median effluent (CFU/100mL)	1 100	4 700	2 900	650	700	280	315	290	1 600	1 600	900	300
Minimum effluent (CFU/100mL)	10	30	70	15	20	10	5	1	350	800	8	22
Maximum effluent (CFU/100mL	80 000	80 000	80 000	31 000	14 600	34 000	18 600	20 000	30 000	16 000	2 300	1 600
85 %ile effluent (CFU/100mL)	4 200	14 000	14 200	4 000	2 300	3 400	6 000	1 700	5 400	10 900	2 000	1 500
Comments									Insufficient data			
7 – 10	16	10	11					4.6		4.9	5.4	5.4
Median removal rate (%) conc basis	98.7	94.1	96.4	99.2	99.2	99.7	99.6	99.6	0	0	75	82
Comments	Longer detention time gives greater removal							Insufficient data				
Seasonal variation in upstream process	No apparent correlation			No apparent correlation				No apparent correlation				
Seasonal variation in wetland process	General variation with season			Insufficient data				Insufficient data				
Possible correlation with published correlations	No apparent correlation			No apparent correlation				No apparent correlation				

Table 2.9: Summary Information for Faecal Streptococci

Parameter	Edmonton		
Bay Number	1	2	3
Median influent (CFU/100mL)	4 300		
Median effluent (CFU/100mL)	1 400	2 000	2 000
Minimum effluent (CFU/100mL)	50	100	100
Maximum effluent (CFU/100mL)	9 200	36 000	80 000
85 %ile effluent (CFU/100mL)	4 300	6 900	5 400
Median retention time (days)	16	10	11
Median removal rate (%) conc basis	85	60	60
Seasonal variation in upstream process	No apparent correlation		
Seasonal variation in wetland process	General variation with season		

Table 2.10: Performance Data for Logan Wetlands

Parameter	SS						Ammonia						Nitrogen					
	Phase 1 (1/96 to 2/97)			Phase 2 (2/97 to 2/98)			Phase 1 (1/96 to 2/97)			Phase 2 (2/97 to 2/98)			Phase 1 (1/96 to 2/97)			Phase 2 (2/97 to 2/98)		
Bay Number	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Median influent (mg/L)	10			8.2			3.3			2.4			23			19		
Median effluent (mg/L	2	3	2	3.4	2.6	2.2	0.9	0.2	0.7	0	0	0	7.7	7.5	10	1.7	1.3	1.3
Minimum effluent (mg/L)	1	1	1	0.2	0.2	0	0	0	0	0	0	0	0.6	0	0	0.5	0.3	0.2
Maximum effluent (mg/L)	30	60	110	50	33	21	4.0	2.7	4.4	0.1	0	0	16	19	27	4.9	7.9	7.3
85 %ile effluent (mg/L)	3.2	6.2	4.0	11.5	8.7	5.4	2.4	2.0	3.4	0.1	0	0	13	15	15	3.0	2.5	2.5
Comments	85 %ile meets 30 mg/L						Low influent ammonia						Median influent has approximately 20 mg/L nitrates. Initial poor performance period included in phase 1			Median influent has approximately 15 mg/L nitrates. Very stable performance		
Median retention time (days)	3.6	4.4	3.3	17.7	17.9	17.4	3.6	4.4	3.3	17.7	17.9	17.4	3.6	4.4	3.3	17.7	17.9	17.4
Median removal rate (%) mass basis	90	82	88	81	86	86	85	95	90	99	100	100	79	75	70	96	97	96
Median removal rate (%) conc basis	80	70	80	59	68	73	72	94	79	99	99	99	67	67	57	91	93	93
Comments	Greater than 50% removal can be expected						Not a meaningful result as influent is low						Removal is predominantly nitrates					
Seasonal variation in upstream process	Variation not related to season						Generally higher ammonia in winter						No apparent correlation					
Seasonal variation in wetland process	No apparent correlation						Not apparent						No apparent correlation					
Median wetland temperature	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Possible correlation with removal perf.	No apparent correlation						Insufficient data						Insufficient data					
Median mass loading rate (kg/ha/day)	2.2			0.8			0.7	0.7	0.7	0.2	0.2	0.2	5.0			2.0		
Possible correlation with removal perf.	General increase in removal performance with increasing loading rate						No apparent correlation						No apparent correlation					
Median hydraulic loading rate (ML/ha/day)	0.22			0.11			0.22			0.11			0.22			0.11		
Possible correlation with removal perf.	No apparent correlation						No apparent correlation						No apparent correlation					
Median pH	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2
Possible correlation with removal perf.	No apparent correlation						No apparent correlation						No apparent correlation					
Comments	None						No meaningful correlation as influent ammonia is low											
Possible correlation with published correlations	No apparent correlation						No apparent correlation						No apparent correlation					
Comments	None						None						None					

Table 2.10: Performance Data for Logan Wetlands (continued)

Parameter	Filterable Reactive Phosphorus						Total Phosphorus					
	Phase 1 (1/96 to 2/97)			Phase 2 (2/97 to 2/98)			Phase 1 (1/96 to 2/97)			Phase 2 (2/97 to 2/98)		
Bay Number	1	2	3	1	2	3	1	2	3	1	2	3
Median influent (mg/L)	6.7			6.7			7.1			9.0		
Median effluent (mg/L	6.6	6.2	6.6	6.5	6.5	6.8	6.9	6.9	6.8	8.2	7.8	8.5
Minimum effluent (mg/L)	2.1	1.1	1.1	4.9	4.3	4.6	2.1	2.1	2.2	5.6	5.8	6.2
Maximum effluent (mg/L)	7.4	7.4	7.6	8.3	7.8	9.1	10	9.5	10	13	12	11
85 %ile effluent (mg/L)	7.1	7.1	7.0	7.6	7.2	7.5	8.6	8.4	8.8	9.5	9.0	9.2
Comments												
Median retention time (days)	3.6	4.4	3.3	17.7	17.9	17.4	3.6	4.4	3.3	17.7	17.9	17.4
Median removal rate (%) mass basis	34	33	32	53	61	47	34	27	33	55	62	47
Median removal rate (%) conc basis	0	0	0	0	0	0	3	3	4	9	13	6
Comments	Poor removal performance over entire pilot program						Poor performance over entire period except for short period in September 1997 showing consistent removal performance of 20%					
Seasonal variation in upstream process	No apparent correlation						No apparent correlation					
Seasonal variation in wetland process	No apparent correlation						No apparent correlation					
Median wetland temperature	-	-	-	-	-	-	-	-	-	-	-	-
Possible correlation with removal perf.	Insufficient data						Insufficient data					
Median mass loading rate (kg/ha/day)	1.5			0.7			1.6			0.9		
Possible correlation with removal perf.	No apparent correlation						No apparent correlation					
Median hydraulic loading rate (ML/ha/day)	0.22			0.11			0.22			0.11		
Possible correlation with removal perf.	No apparent correlation						No apparent correlation					
Median pH	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2
Possible correlation with removal perf.	No apparent correlation						No apparent correlation					
Comments							No apparent correlation					
Possible correlation with published correlations												
Comments												

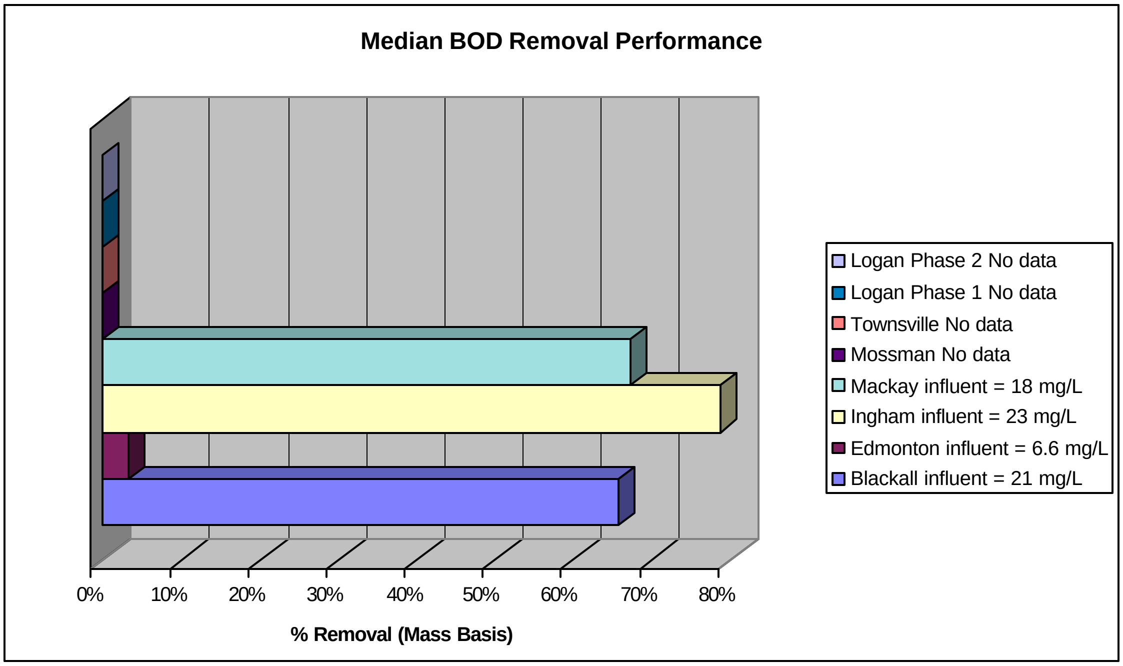
Table 2.11: Nutrient Mass Balance (Average over the 3 Tanks)

	phase 1 Nitrogen	phase 2 Nitrogen	Entire trial Nitrogen	phase 1 Phosphorus	phase 2 Phosphorus	Entire trial Phosphorus
mass in influent(g)	2 786	1 521	4 307	1 008	732	1 740
mass out in effluent (g)	789	64	853	695	329	1 024
mass out (%)	28	4	20	69	45	59
plant tops + lemna (g)	266	337	605	49	66	115
plant tops + lemna (%)	9.5	22	14	4.9	9.0	6.6
Roots and Rhizomes (g)	-	-	112	-	-	44
Roots and Rhizomes (%)	-	-	2.6	-	-	2.6
Stems (g)	-	-	144	-	-	49
Stems (%)	-	-	3.3	-	-	2.8
Soils (g) change from original	-	-	513	-	-	-796 (Note loss of P from soil)
Soils (%)	-	-	12	-	-	-45
undefined (g)	1 731	1 119	2 080	264	336	1 303
undefined (%)	62	74	48	26	46	75

Table 2.12: Accumulation Rate of Nutrients After Harvesting

time	Plant Tops (nitrogen) (g/wetland)	Plant Tops (Phosphorus) (g/wetland)	Comments
phase 1 – 12 months initial growth	267	49	
3 months regrowth	112	14	
6 months regrowth	120	20	
9 months regrowth	304	51	equivalent accumulation after 9 months of regrowth
12 months regrowth	337	66	

Figure 2.1: Average BOD Removal Performance



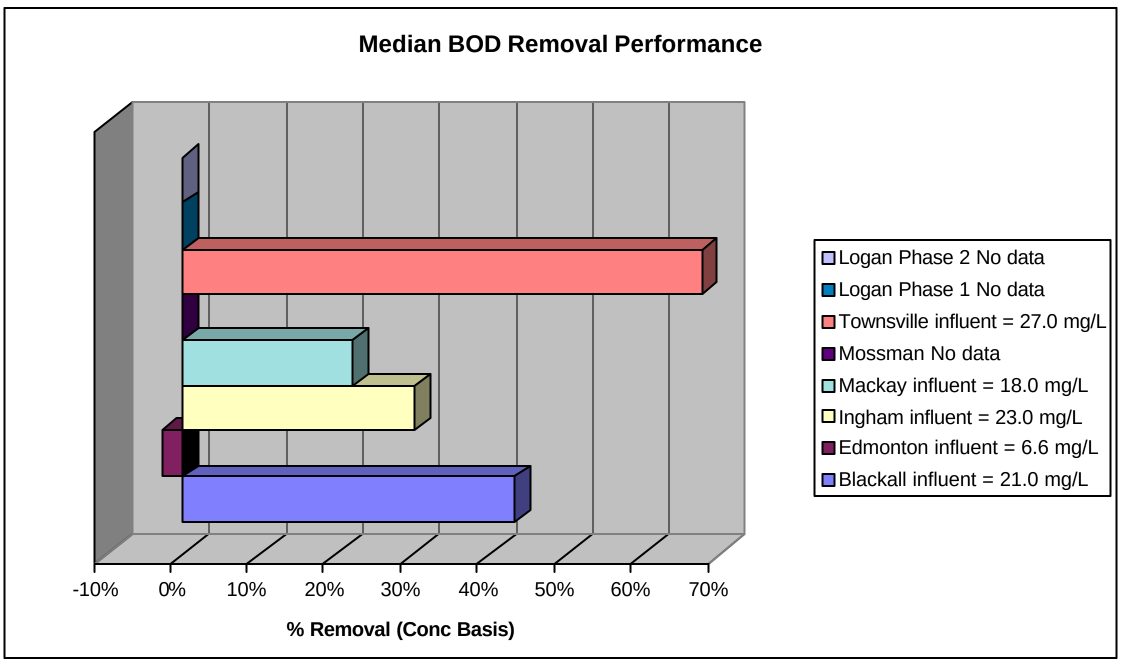
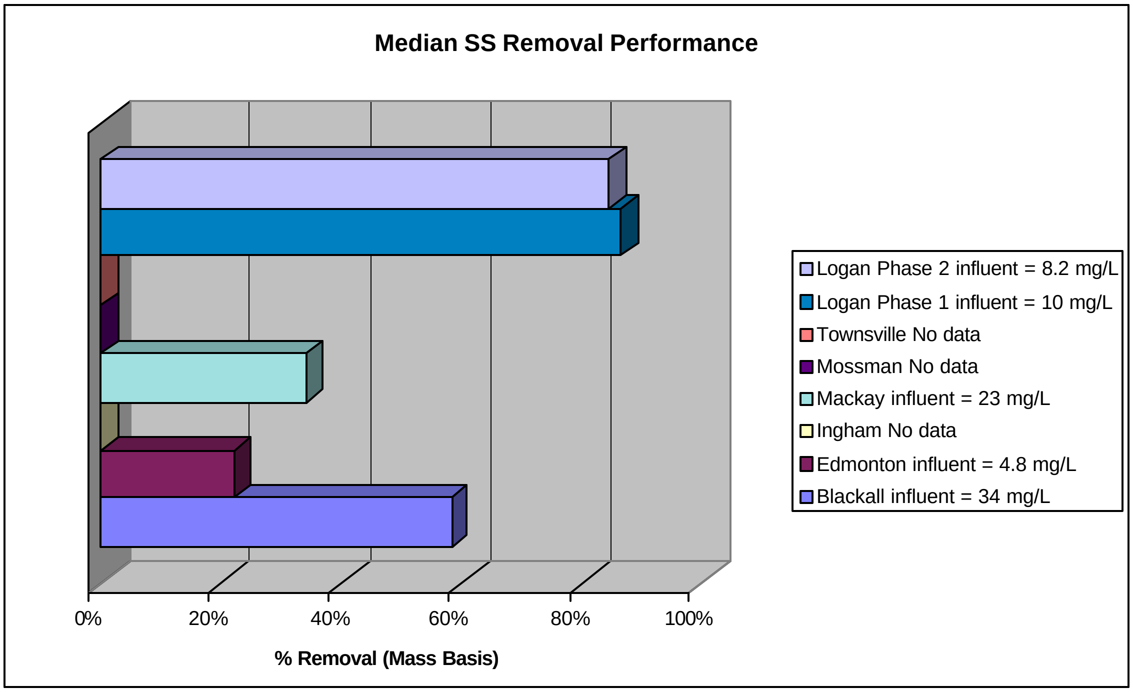


Figure 2.2: Median SS Removal Performance



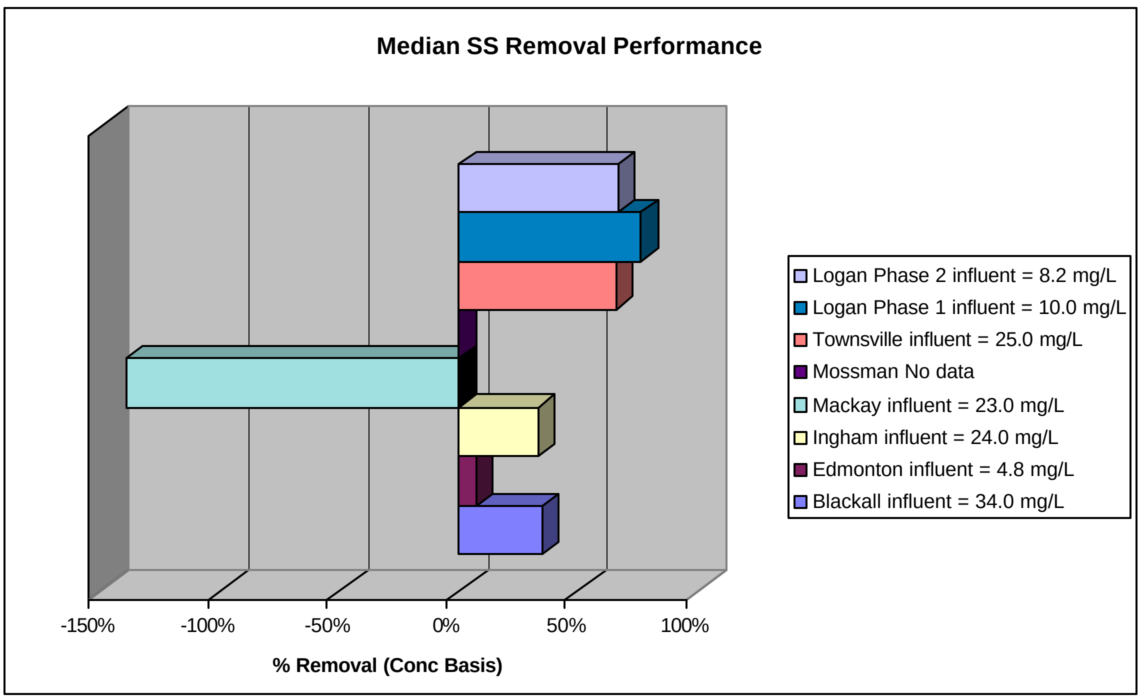
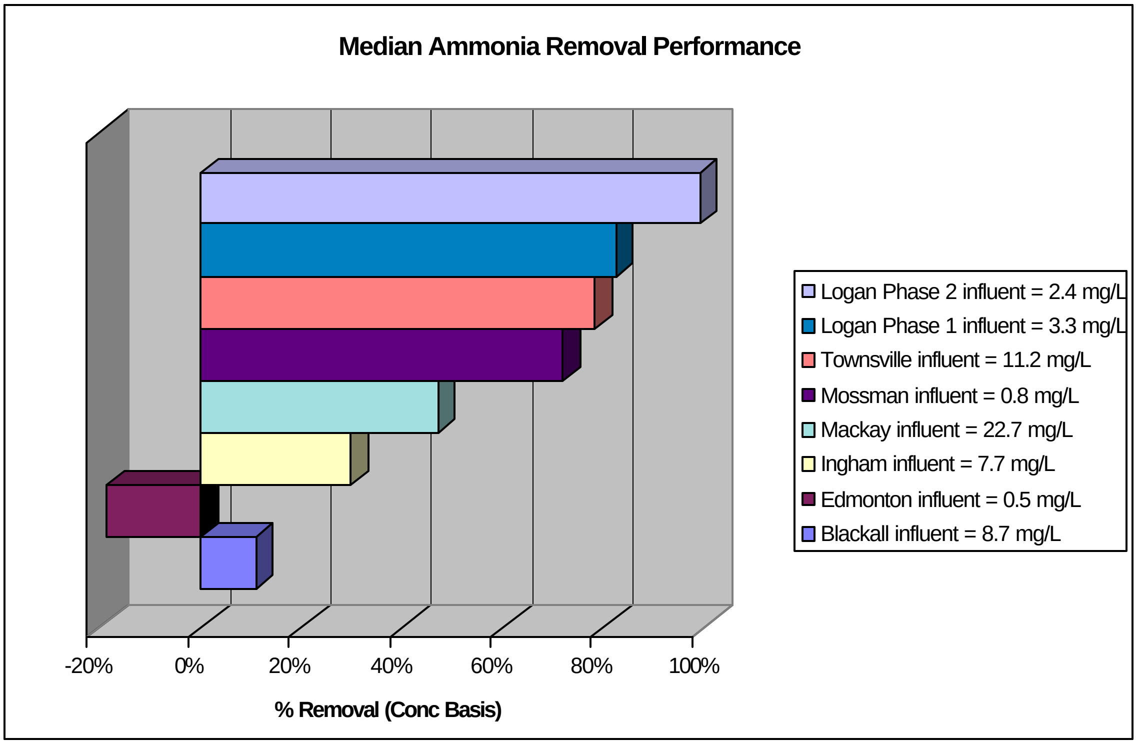


Figure 2.3: Median Ammonia Removal Performance



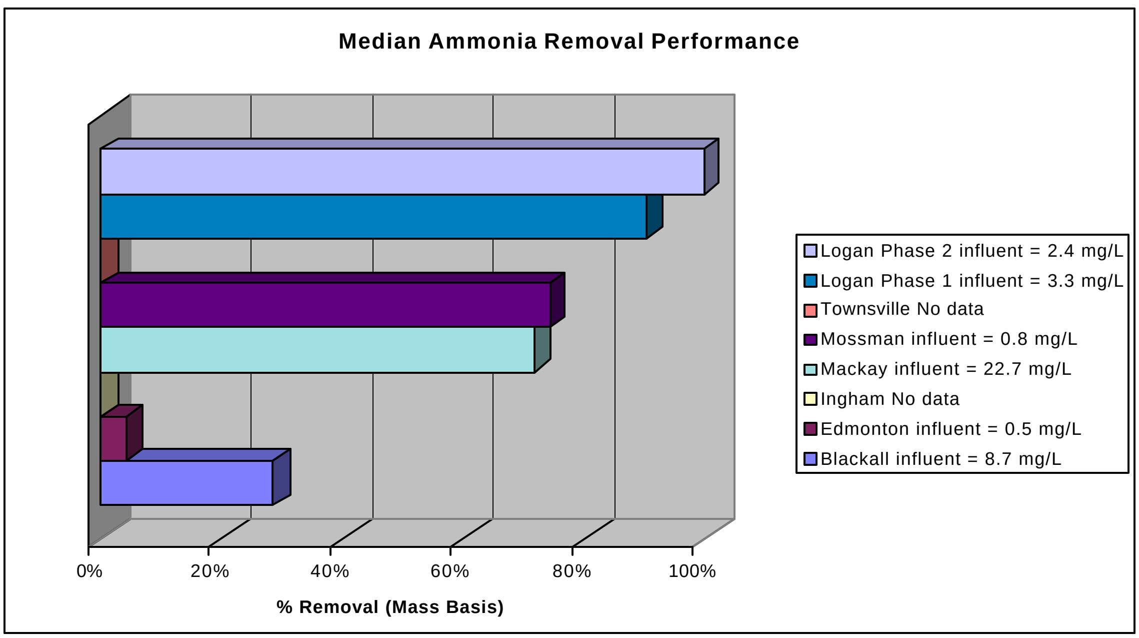
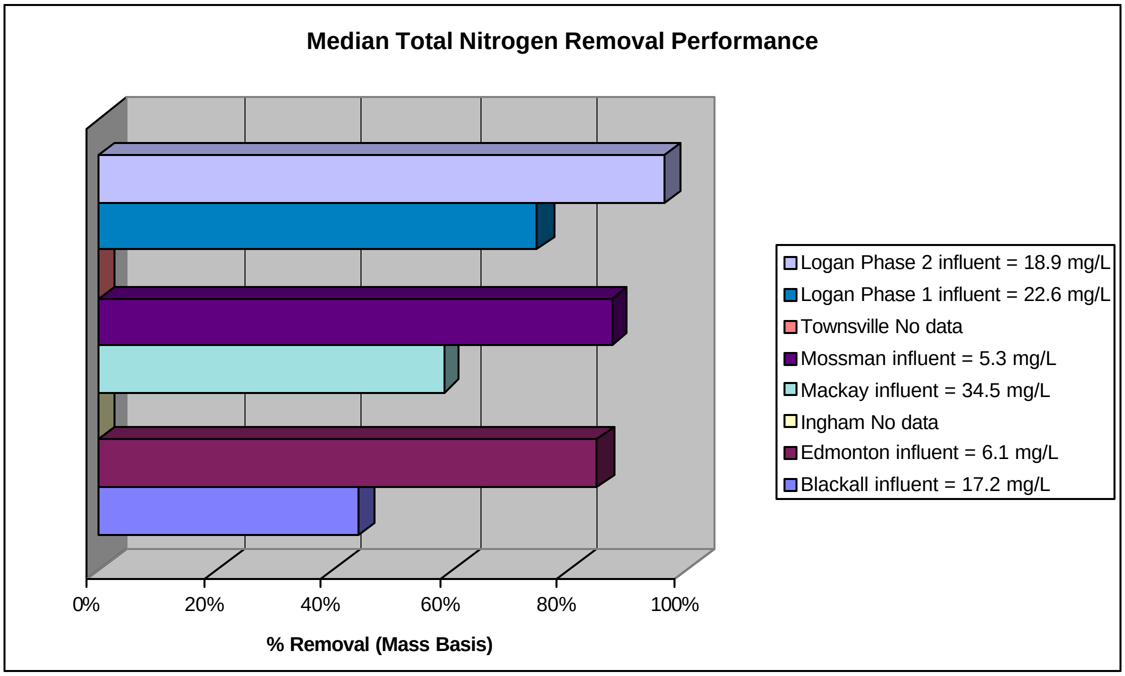


Figure 2.4: Median Total Nitrogen Removal Performance



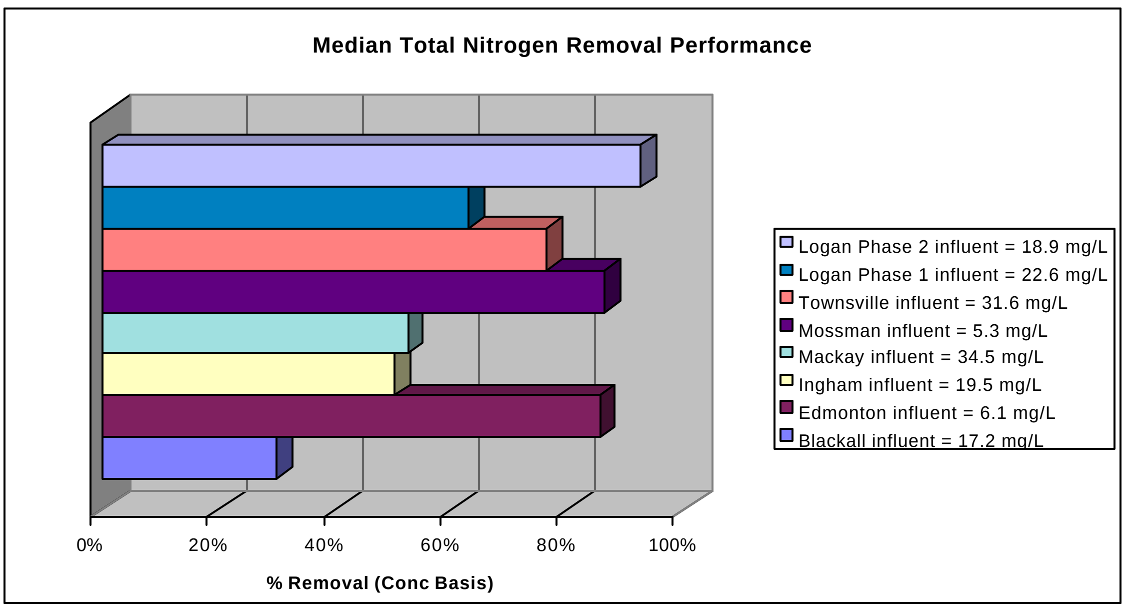
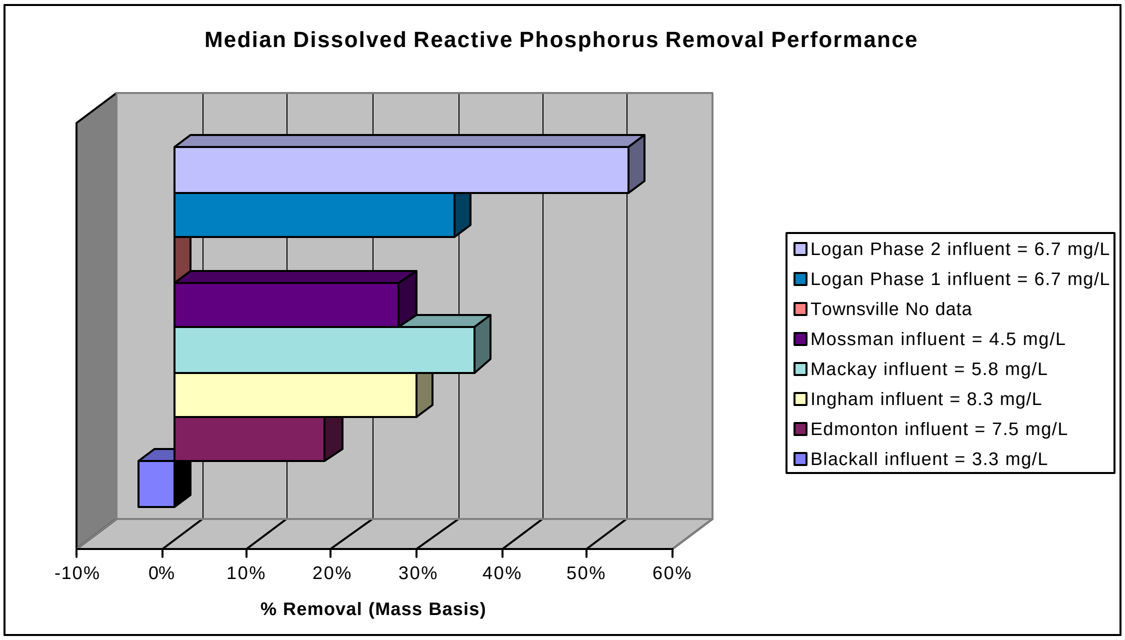


Figure 2.5: Median Filterable Reactive Phosphorus Removal Performance



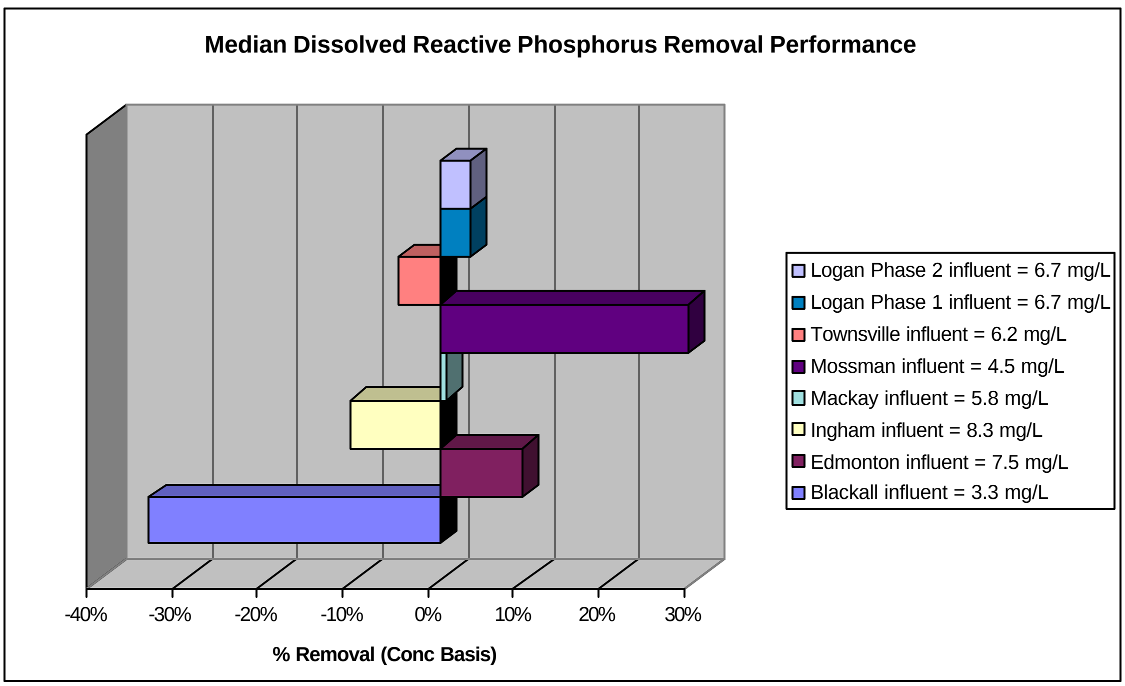


Figure 2.6: Median Total Phosphorus Removal Performance