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(Bottled) Water snobbery has replaced wine snobbery. Time

More people are apparently craving something simpler, plain, unflavoured, non-carbonated water. Wall Street Journal

(Bottled) Water....is so pure and clean and so Nineties. The Independent

As quoted in Green M, Green T and Long J (1994). *The good water guide. The world's best bottled waters.* Rosendale Press.

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Living with water: security supply, surplus and sustainability

Thursday 21 October 1999

Australian Mineral Foundation

20 abstracts have been received, necessitating running two streams.

To be opened by Her Worship the Lord Mayor, Ms Jane Lomax-Smith. Keynote speaker Dr Barbara Hardy AO

A pre conference tour is under consideration. Contact Dr David Walker tel (08) 8303 4319; email david.walker@adelaide.edu.au

Modelling chlorine levels in the Mannum-Adelaide pipeline and in the upper reaches of the River Torrens

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Summary: A first order, hydraulically calibrated EPANET computer model of the Mannum-Adelaide Pipeline was developed which is capable of determining concentrations of free and total chlorine residuals throughout the system. Extensive laboratory studies were conducted to determine an appropriate kinetic decay model and associated rate constants for bulk chlorine decay. Analysis of the laboratory results showed that second order exponential decay models accurately described the decay of residual chlorine under a wide range of conditions. Functions were developed which related bulk decay rate coefficients to certain water quality characteristics. A hydraulic water quality model was developed which predicts chlorine levels in a 3 km region downstream of the Mount Pleasant Dissipator for a wide range of input conditions. A computer program was developed of the river model, which is coded in Fortran 77. A number of simplifying assumptions were made in the development of the model including dividing the modelling region into reaches, one-dimensional flow and steady-state conditions. Chlorine concentrations were modelled using a second order decay equation and the flow velocities in the river were predicted for a wide range of input conditions using Manning's equation. Historical and field sample data were used to calibrate the hydraulic and water quality characteristics of the EPANET and river models. The models developed in this study will be used to assess the likely environmental impact of releasing chlorinated water into the River Torrens. The pipeline model will also serve as a tool to optimise chlorine dosing levels, whilst maintaining an acceptable level of disinfection throughout the system.

1 INTRODUCTION

1.1 Aims

The aim of this research is to study chlorine levels in the Mannum-Adelaide Pipeline and in the upper reaches of the River Torrens. This is of interest because of the possible environmental impacts that may result from releasing chlorinated water into a natural watercourse. The Environment Protection Agency (EPA) have expressed their concern with chlorinated water being discharged into the River Torrens because of the possible deleterious effects on the aquatic fauna, in particular the macroinvertebrates.

The study of chlorine levels in the Mannum-Adelaide Pipeline is also of interest to minimise the chlorine dosing costs whilst maintaining an acceptable standard of residual protection for consumers that receive their water directly from the pipeline. The aim of the project is to develop models of the Mannum-Adelaide Pipeline and of the upper reaches of the River Torrens. It is envisaged that the models will predict the chlorine levels throughout the pipeline and provide indicative chlorine levels in the River Torrens downstream of the Mount Pleasant Dissipator.

In the development of the pipeline and river models, it is essential that laboratory studies be conducted to analyse the decay of chlorine under a range of environmental conditions. It was planned to compare alternative kinetic decay models with experimental results to determine which model provides the most accurate prediction of the bulk decay of free and total chlorine. A relationship can then be developed to correlate the decay rate coefficient (for each model) with various environmental conditions exposed to samples during the experiments.

1.2 Background

The Mannum-Adelaide Pipeline runs from the River Murray at Mannum to the Anstey Hill Water Filtration Plant (WFP) in Adelaide

(Figure 1). The system is comprised of two major pipeline sections, the pumping section from Mannum to the open-air Summit Storage basin in the Adelaide Hills, and the gravity feed section from the Summit Storage to the Anstey Hill WFP. The pipeline is approximately 60 km in length and three pumping stations are employed to lift water from the River Murray to Summit Storage.

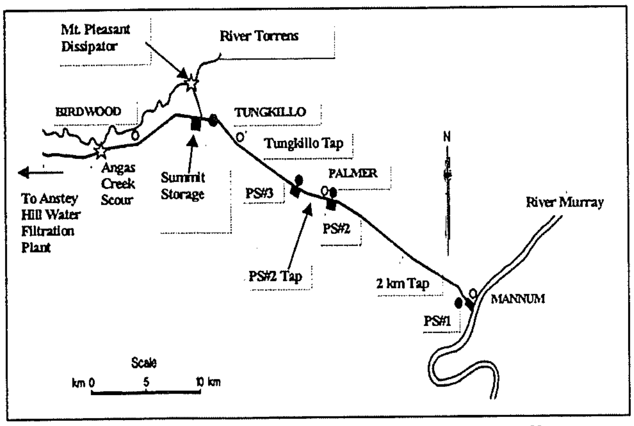

Figure 1: The Mannum-Adelaide pipeline modelling region

To ensure microbiological water quality for consumers who receive their water directly from the pipeline, a chlorine residual is maintained. This is achieved via two chlorine dosing stations; the first is located at Pump Station No. 1, Mannum and the second at Summit Storage. At various times, chlorinated water is discharged into the River Torrens to supplement the supplies available from the natural catchment inflow.

The Mount Pleasant dissipator is located 3 km downstream of Mount Pleasant Township and 6 km downstream of the head of the River Torrens catchment. Flow is diverted off the Mannum-Adelaide Pipeline along the Mount Pleasant Branch Main located just before Summit Storage on the pumping section of the pipeline, which supplies the dissipator (Figure 1).

The dissipator performs two functions, the first is to release water into the River Torrens, and the second is to dissipate the energy head of the water flowing through the branch main in order to reduce exit velocities and minimise river bank erosion and scouring.

2 METHODS

2.1 Laboratory Studies

2.1.1 Background

Extensive laboratory studies were conducted to analyse the bulk decay of chlorine under a range of environmental conditions. Water samples taken from the River Murray at the intake to the pipeline were dosed with chlorine, and the change in free and total chlorine levels were measured with time. Several kinetic decay models were fitted to the data and their respective decay rate coefficients were determined. The laboratory tests were performed under a range of environmental conditions likely to be encountered in the pipeline.

Laboratory tests included studying the effects of:

- temperature;
- dissolved organic carbon (DOC); and
- velocity gradient (mixing energy).

The velocity gradient is defined by:

$$G = \sqrt{\frac{P}{\mu V}} \qquad (1)$$

where:	G	velocity gradient (s^{-1})
	P	power (W)
	μ	viscosity of water (Pa.s)
	V	volume (m^3)

The effects of pipe wall decay were not incorporated in the experiments due to the difficulty in assessing biofilm effects in the laboratory.

2.1.2 Method

The Latin square technique (Brownlow *et al.* 1996) was used to analyse chlorine decay under a range of conditions. Various combinations of DOC, temperature and mixing energy were considered as indicated by the Latin Square set up in Tables 1 and 2. Each square represents one test and the letters A to E represent temperatures.

Table 1: Latin Square representation of letters

A	B	C	D	E
9°C	14°	19°	24°	29°

Table 2: Latin Square used in laboratory studies

DOC (mg/L)	Velocity Gradient (s^{-1}): 0	90	180	270	360
2	A	B	C	D	E
5	E	A	B	C	D
7.5	D	E	A	B	C
10	C	D	E	A	B
12.5	B	C	D	E	A

Free and total chlorine concentrations were measured using the N,N-diethyl-p-phenylenediamine (DPD) Ferrous Titrimetric Method. DOC concentrations were altered either by dilution or by adding measured amounts of natural organic matter. Velocity gradients were simulated by using standard rotating paddles.

2.1.3 Analysis of results

Following Dugan *et al.* (1995) and Vasconcelos *et al.* (1997), several different kinetic models for chlorine decay were analysed. They included:

- *First Order Model* - rate of decay is proportional to the concentration of the chlorine remaining

$$dC/dt = -kC$$
$$\Rightarrow C_t = C_0 e^{-kt} \qquad (2)$$

where: C_t concentration at time t (mg/L)
C_0 initial concentration (mg/L)
k decay rate coefficient (hr^{-1})
t time (hr)

- *Second Order Model* - rate of decay is proportional to the concentration of chlorine remaining squared

$$dC/dt = -kC^2$$
$$\Rightarrow (1/C_t) = (1/C_0) + kt \qquad (3)$$

- *Combined First Order Model* - a rapid first order model is applied for $t \leq 4$ hours, and a slower first order model for $t \geq 4$ hours

$$t \leq 4 \text{ hours:} \quad C_t = C_0 e^{-k_1 t} \qquad (4)$$
$$t \geq 4 \text{ hours:} \quad C_t = C_4 e^{-k_2 t} \quad k_1 > k_2 \qquad (5)$$

where: C_4 concentration at 4 hours

- *Combined First & Second Order Model* - a rapid second order model is applied for $t \leq 4$ hours, and a slower first order model for $t \geq 4$ hours

$$t \leq 4 \text{ hours:} \quad (1/C_t) = (1/C_0) + k_1 t \qquad (6)$$
$$t \geq 4 \text{ hours:} \quad C_t = C_4 e^{-k_2 t} \qquad (7)$$

For each experiment, a least squares technique was used to fit each of the four bulk decay models to the data collected.

2.2 The Mannum-Adelaide Pipeline EPANET Model

2.2.1 Modelling the system

Maul *et al.* (1985) observed that total chlorine decay is comprised of the bulk decay of chlorine due to the reactions with dissolved organic matter and the pipe wall decay due to the reactions with the organic biofilm and tubercles on the interior pipe wall. As indicated by Le Chavellier *et al.* (1988), transport of the disinfectant from the bulk liquid phase into the biofilm is a very important factor in understanding chlorine decay rates. In order to forecast chlorine concentrations along the pipeline, the model must take into account these decay mechanisms.

The USEPA's EPANET network simulation program was used to perform extended period hydraulic simulation and dynamic water quality modelling of the Mannum–Adelaide Pipeline. EPANET models the bulk reactions using first order kinetics and first order mass-transfer limited kinetics for the wall reactions.

The pumping section of the Mannum-Adelaide Pipeline and the Mount Pleasant Branch Main was modelled to predict chlorine concentrations along the pipeline and to provide an initial chlorine concentration at the Mount Pleasant Dissipator for input into the River model.

Water quality can only be successfully modelled if velocities are accurately simulated in the hydraulic model. The hydraulic model must therefore be well calibrated and accurately reflect the hydraulic behaviour (Chambers *et al.* 1995).

2.2.2 Hydraulic calibration

Information on the tanks, pumping stations, chlorine dosing stations, pipe sizes, lengths, roughness coefficients, elevations and baseline water demands was collected and placed into an EPANET input data file.

In order to calibrate the hydraulics in the EPANET model, the actual tank levels at the three pump stations and at Summit Storage were compared to the tank levels predicted by the model. Flow meters were not used because the information collected from these was not of a suitable level of accuracy (Adoms, V., 1998, *pers. comm.*, 4 May). The tank levels and the pumping regime for a 24-hour period was retrieved in the form of a spreadsheet from information recorded by the SA Water Bulk Water Control Room. All of the information was recorded at six minute intervals for the 24-hour period being simulated. The information collected included the baseline demands just after the Summit Storage and the demand from the Mount Pleasant Dissipator. These demands were averaged over the 24-hour period and then placed into the EPANET input data file.

Using this information, the system was calibrated by sequentially adjusting the Hazen–Williams roughness coefficients of different sections of pipe to ensure that the predicted tank levels were within ± 5% of the actual tank levels. Once the calibration had been performed, two more 24-hour period simulations were used to verify the hydraulic model. It was found that in both simulations the predicted tank levels were within ± 5% of the actual tank levels. This provided verification that the model was hydraulically calibrated.

2.2.3 Field sampling

In order to investigate the nature of water quality variability under dynamic conditions within the system, use was made of historical data collected routinely by SA Water. Taps are located at points along the Mannum–Adelaide Pipeline from which samples are taken and free and total chlorine residual and temperature measured (Figure 1). To determine the DOC of the water, a sample was taken on the River Murray at Mannum for laboratory analysis.

In addition to the historical water quality data, field trips were also conducted to collect a larger number of samples along the specific area being modelled. The first field trip was conducted on the 29th August 1998 and the second field trip was conducted on the 7th September 1998.

2.2.4 Water quality calibration

To perform the water quality calibration and verification, the hydraulic data for the dates of the two field trips was retrieved from the SA Water Bulk Water Control Room. From this information the pump regime, initial tank levels and baseline demands at the Summit Storage and Mount Pleasant Dissipator were determined and placed into EPANET data sets. The chlorine dosing rate for the periods being modelled was collected from SA Water, Murray-Mallee Region, Murray Bridge. On the date of both field trips, the Mannum Chlorinator was dosing chlorine at 6.5 mg/L (Adams, K., 1998, *pers. comm.*, 21 September). With the installation of a Water Filtration Plant at Mannum, the Mannum Chlorinator is currently situated after the tanks at Pump Station No. 1.

2.2.4.1 Determination of decay coefficients

Different sections of pipe have differing properties, and in order to calibrate the model successfully, it is important to model the different sections of pipeline with different decay coefficients. EPANET has the potential to accept a different decay rate for each pipe, or groups of pipes, within the network. Therefore, the pipeline was divided into sections of uniform properties. Each sampling point was incorporated into a different pipe group so that the slight differences in temperature from sampling tap to sampling tap could be taken into account. In addition, sections of pipe with the same diameter and flow were kept within a single group to keep sections of similar velocity gradient together.

Two alternative reaction models were tested on the Mannum-Adelaide Pipeline. The first model (reaction model #1) assigned a first order, bulk decay rate coefficient for the first hour after chlorination and a first order, bulk decay rate coefficient for all time greater than one hour.

The second model (reaction model #2) assigned a first order, bulk decay rate coefficient for the first hour after chlorination, a first order, bulk decay rate coefficient for time greater than one hour but less than four hours (i.e. $1<t<4$ hours) and a first order, bulk decay rate coefficient for time greater than four hours. (i.e. $t>4$ hours). Hydraulic simulations were conducted and it was found that the chlorinated water takes approximately four hours to reach the second sampling point (Pump Station No. 2 Sampling Tap). Therefore, the second section of pipe between the 2 km Sampling Tap and the Pump Station No. 2 Tap was simulated in this reaction model by using the bulk decay rate coefficient for time greater than one hour, but less than four hours. The remaining sections were modelled using the first order, bulk decay rate coefficient for time greater than four hours. For both reaction models, the laboratory derived power equations were used to determine the decay coefficients input into EPANET.

An EPANET simulation was then performed for the 29th August 1998 and the 7th September 1998 to model the chlorine levels observed in the field. Separate simulations were conducted to model free and total chlorine concentrations and to trial reaction model #1 and reaction model #2.

2.3 River model

2.3.1 Assumptions

Modelling a natural system such as the River Torrens is difficult due to the complexity of the river. The factors that must be taken into account include the random variations in the physical properties of the river, man-made and natural obstructions in the river and uncertain inputs and outflows into and out of the river. A number of simplifying assumptions were made to develop a model of the river in a practical sense which delivered an appropriate degree of accuracy, whilst not becoming overly complicated. These assumptions included:

- the modelling region was divided into 12 representative reaches, each of which have constant physical properties;
- flow velocities were assumed to be distributed uniformly throughout the channel cross sections;
- the river was assumed to be completely mixed in both the vertical and transverse directions; and
- free and total chlorine was assumed to decay according to a second order reaction.

Manning's equation was used to represent the steady-state flow in each of the reaches for the hydraulic calibration of the model.

$$Q = \frac{1}{n} A m^{\frac{2}{3}} s^{\frac{1}{2}} \tag{8}$$

where: Q discharge (m^3/s)
n Manning's roughness coefficient
m hydraulic radius (m)
s bed slope (m/m)

2.3.2 Selection of the modelling region

The modelling region extends from the Mount Pleasant Dissipator to the extension of Carnells Bdy Rd, a total distance of 2972 m (Figure 2). The choice of this modelling region provided a suitable trade-off between accuracy of results within the modelling region and encompassing the zone of influence of chlorine for a wide range of conditions.

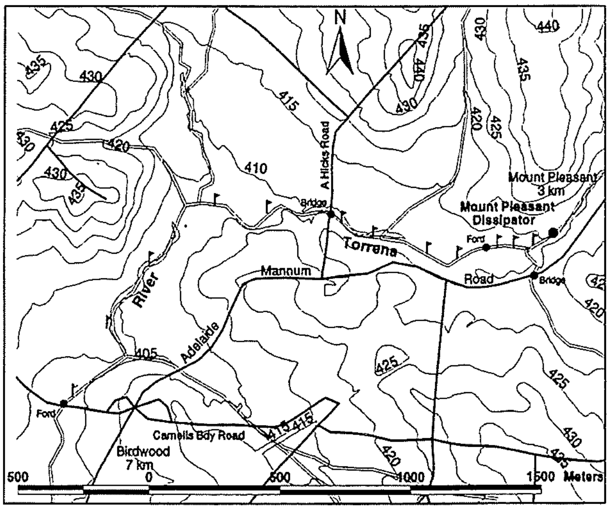

Figure 2: Modelling region in the upper reaches of the River Torrens

2.3.3 Model inputs

The inputs to the river model include the natural streamflow, dissipator discharge and dissipator free and total chlorine concentrations.

When chlorinated water is discharged from the dissipator, it enters the river and is diluted by the natural streamflow. The initial mixed chlorine concentration, C_0', is given by Equation (9).

$$C_0 = \frac{C_0' Q_{in}}{(Q_{in} + Q_R)} \tag{9}$$

where:

C_0 initial mixed chlorine conc^n (mg/L)
C_0' initial dissipator chlorine conc^n (mg/L)
Q_{in} dissipator discharge (m^3/s)
Q_R natural streamflow (m^3/s)
C_0' is predicted by the EPANET model of the Mannum-Adelaide Pipeline.

Q_{in} is obtained through the SA Water telemetry system, which monitors all flows through the Mount Pleasant Branch Main connected to the dissipator.

Q_R is monitored by a flow gauging station located approximately 500 m upstream of the dissipator, which is managed by the Department of the Environment, Heritage and Aboriginal Affairs (DEHAA). The external inputs or outputs between the flow gauging station and the dissipator are negligible, and therefore flows at the gauging station can be considered identical to those at the dissipator (Stace, P. *pers. comm.*).

Historical data was used for the selection of Q_R. 25 years of daily flows from the gauging station were obtained and separated into monthly data sets. Histograms were then created for each month by statistically analysing the monthly data. The 50, 75 and 95% confidence intervals obtained from the histograms were used as the Q_R input to the river model.

2.3.4 Field data collection techniques

Extensive field studies were undertaken to gather the necessary physical and water quality data for the River model. Downstream distances were measured by counting the number of paces taken and converting the number of paces into a distance in metres. Channel cross sectional geometry was measured using a tape measure tied to ranging poles either side of the river to give the transverse distances and dumpy level and staff to give the vertical distances. The bed slope of the river was approximated to the slope of the water surface (Streeter and Wylie 1981), and bed slopes were calculated using measured downstream water surface elevations and measured downstream distances. Free and total chlorine concentrations were measured using the Palintest equipment.

3 RESULTS

3.1 Laboratory Studies

Table 3 compares the proposed kinetic models on the basis of their average r^2 (coefficient of determination) value for all of the experiments conducted. Results indicate that all the models provided good fits, however the second order model generally provided the most accurate fit. The second order model also more accurately described the decay of chlorine in samples containing higher concentrations of DOC (> 7.5 mg/L), while the first order models produced poor fits for this range.

Table 3: Analysis of average r^2 values for each model

	1st Order	2nd Order	Combined 1st Order $t \leq 4$	$t \geq 4$	Combined 1st/2nd Order $t \leq 4$	$t \geq 4$
Average	0.8737	0.9703	0.9481	0.9416	0.9691	0.9416
Median	0.8931	0.9899	0.9881	0.9829	0.9956	0.9829

3.1.1 Development of decay rate function

An expression was developed to relate the bulk decay rate coefficient to specific environmental conditions. A power function was used as shown in Equation (10).

$$k = K_o(T)^{\alpha}(DOC)^{\beta}(G)^{\gamma} \tag{10}$$

where:

T temperature (°C)
DOC DOC concentration (mg/L)
G velocity gradient (s^{-1})
K_0, α, β, γ constants

Taking the log of Equation (10), the following equation is obtained:

$$\ln k = \ln K_o + \alpha \ln T + \beta \ln DOC + \gamma \ln G \tag{11}$$

Multiple linear regression analysis was applied to Equation (11) to determine the unknown constants α, β, γ and K_o.

A decay rate coefficient expression of the form of Equation (10) was developed for both free and total chlorine decay, for each kinetic model mentioned in Section 2.1.3. Table 4 presents the derived r^2 values for each function.

Table 4: r^2 values for each decay rate function

(No. of samples = 25)

	1st Order	2nd Order	Combined 1st Order $t \leq 4$	$t \geq 4$	Combined 1st/2nd Order $t \leq 4$	$t \geq 4$
Free Cl_2	0.5436	0.9275	0.7234	0.3223	0.8961	0.3223
Total Cl_2	0.6337	0.9177	0.8676	0.3670	0.9311	0.3670

The first order decay rate coefficient expressions for free and total chlorine gave poor r^2 values due to the poor fit of first order decay models associated with high DOC samples. This was confirmed when the higher DOC sample data (DOC > 9.5 mg/L) were excluded from the multiple regression analysis, giving higher r^2 values (Table 5).

Table 5: r^2 values for each decay rate function

(No. of samples = 16)

	1st Order	2nd Order	Combined 1st Order $t \leq 4$	$t \geq 4$	Combined 1st/2nd Order $t \leq 4$	$t \geq 4$
Free Cl_2	0.9297	0.9504	0.9080	0.8241	0.8344	0.8241
Total Cl_2	0.9273	0.9403	0.9128	0.8810	0.8747	0.8810

The power factors calculated indicate the relative influence of each parameter. Small values of γ indicate that the mixing energy has a lesser influence on the rate of decay of chlorine, while larger values of α and β indicate that temperature and DOC have a greater influence on the rate of decay of chlorine. The following models were developed:

1st Order Model:

$$k_{free} = 1.3\times10^{-3}(T)^{0.75}(DOC)^{1.24}(G+1)^{0.04} \quad (12)$$

$$k_{total} = 1.3\times10^{-3}(T)^{0.75}(DOC)^{0.99}(G+1)^{0.04} \quad (13)$$

2nd Order Model:

$$k_{free} = 7\times10^{-6}(T)^{1.65}(DOC)^{3.34}(G+1)^{0.03} \quad (14)$$

$$k_{total} = 2.1\times10^{-5}(T)^{1.45}(DOC)^{2.32}(G+1)^{0.04} \quad (15)$$

3.2 Mannum-Adelaide Pipeline Model

To determine the accuracy of the EPANET models, the total and free chlorine concentrations produced by the alternative first order reaction models were compared with the concentrations measured in the field at the time of sampling.

3.2.1 Calibration study results

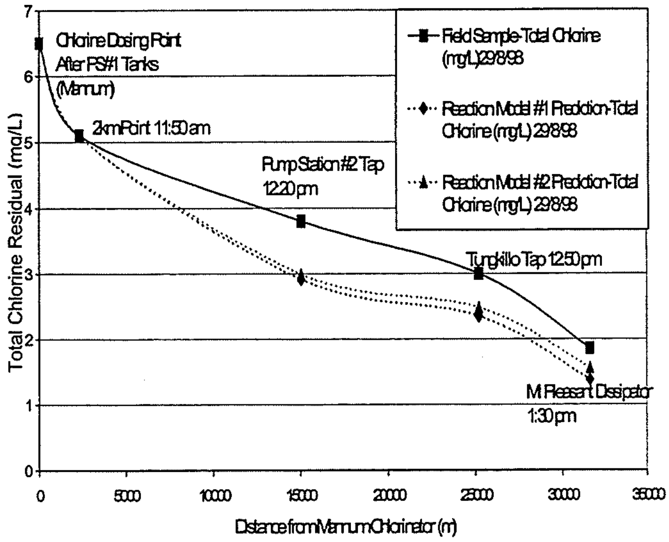

Figure 3: Model output, showing the total chlorine residual at the sampling locations using a rapid initial decay rate for time < 1 hour 29/8/98

For the simulation on the 29th August 1998, Figure 3 shows a graphical comparison of the predicted and observed total chlorine concentrations.

It can be seen in this figure that the two reaction models provide a good prediction for the first sampling point. However, both models under-predict the chlorine concentrations at the remaining locations. A similar scenario for the predicted free chlorine concentrations was also observed.

After observing the graphical representation of the results, it is apparent that the chlorine concentrations are displaced shortly after the 2 km Tap and the maximum error occurs in the vicinity of the Pump Station No. 2 Sampling Tap. After further analysis of the EPANET model, it was found that the initial chlorine decay rate (0<t<1 hour) was too rapid and was not providing a good representation of the observed chlorine concentrations in the field. This could be attributed to the idealised conditions present in the laboratory studies (i.e. uniform mixing), thus giving rise to a more rapid initial decay in the laboratory as opposed to the initial decay observed in the field. Non-uniform mixing during initial stages in the pipeline may have reduced the initial decay rate of the chlorine.

The initial chlorine level is a factor influencing the initial decay rate of chlorine. Studies by Vasconcelos *et al.* (1995) have found that the lower the initial chlorine concentration is, the higher the rate of chlorine consumption is. Since the chlorine was dosed at a lower rate in the laboratory, the initial decay of chlorine was more rapid in the laboratory (5.5 mg/L) than observed in the field, which is consistent with our findings.

The erratic nature of this initial decay process is difficult to predict (Vasconcelos *et al.* 1995) and to calibrate the model for the conditions observed in the field, the initial rapid decay was assumed to only apply to the first 30 minutes of travel time within the pipe. After analysing various alternative models, this was found to provide the most accurate prediction of the observed chlorine concentrations. The same decay coefficient for time less than one hour was used, but was applied to a smaller section of pipe corresponding to a travel time of 30 minutes.

Using the adjusted model, another simulation for the 29th August 1998 was conducted. By reducing the section of pipe modelled using the rapid initial decay, a better fit to the observed field data was obtained.

3.2.2 Verification of study results

In order to verify the calibrated model, a simulation was conducted to model the observed field data collected on the 7th September 1998. Both reaction models had been calibrated to model the initial rapid decay of chlorine using a large first order decay coefficient for the first 30 minutes of travel time in the pipeline.

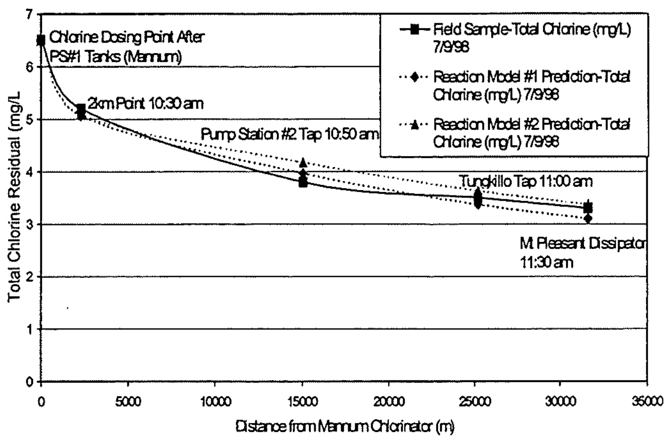

Figure 4: Model output on 7/9/98, showing the total chlorine residual at the sampling locations using a rapid initial decay rate for time < 0.5 hours

Figure 4 shows the predicted and observed total chlorine concentrations for the simulation on the 7th September 1998. This figure shows that both reaction models provided a good fit to the observed total chlorine concentrations. Reaction model #2 slightly over-predicted the total chlorine concentration at the three points after the 2 km Tap. It was found that both reaction models also provided a very good fit to the observed free chlorine concentrations.

The results from the simulation on the 7th September 1998 provided verification that the calibrated model was capable of providing a good fit to the observed free and total chlorine measurements in the field.

Table 6 shows a comparison of the reaction models. To compare the reaction models in the calibration and verification, the average absolute error, the average percentage error and the correlation between predicted and observed values was calculated.

Table 6: Comparison of alternative chlorine reaction models

Reaction Model	Simulation	Ave. Abs. Error (mg/L)	Ave. Percen. Error (%)	Correlation Between Predicted and Observed data (%)
Reaction Model #1	29th Aug. 1998			
t<0.5 h, 1st order	Total Chlorine	0.145	5.79	99.3
bulk decay, k_1 ;	Free Chlorine	0.173	8.67	99.9
t>0.5 h, 1st order	7th Sept. 1998			
bulk decay, k_2	Total Chlorine	0.155	4.12	98.3
	Free Chlorine	0.080	2.22	99.8
Reaction Model #2	29th Aug. 1998			
t<0.5 h, 1st order	Total Chlorine	0.168	6.87	99.0
bulk decay, k_1 ;	Free Chlorine	0.210	7.14	99.3
0.5h<t<4 h, 1st order	7th Sept. 1998			
bulk decay, k_2 ;	Total Chlorine	0.170	4.422	97.7
t>4 h, 1st order bulk decay, k_3	Free Chlorine	0.128	3.346	99.8

For all simulations, reaction model #1 provided the best correlation with observed values and the least average absolute error. Reaction model #1 also provided the least average percentage error with the exception of the free chlorine simulation on the 29th August 1998. From the results presented in Table 6, it is evident that reaction model #1 provided the better fit to the observed field data.

3.3 River Model

3.3.1 Hydraulic calibration

Calibration of the hydraulic component of the river model involved determining a value of Manning's *n* for each of the reaches. Manning's *n* values were found to vary between 0.0589 and 0.3387, which were indicative of the rocky, obstructed, meandering nature of the river. These values also confer with Lambert (1997) and Chow (1951) for very rocky non-straight natural channels.

3.3.2 Water quality calibration - field data

Calibration of the water quality component of the model involved determining second order total and free chlorine decay rate coefficients. The water quality data obtained in the field was plotted with respect to time and second order decay rate coefficients were fit to the data using a least squares technique.

The second order total and free chlorine decay coefficients from the calibration run on October 13th, 1998 are:

$k_{tot} = 0.4109\ hr^{-1}$ $\quad\quad$ $k_{free} = 1.1324\ hr^{-1}$

Figure 5 shows the observed results plotted with the results predicted using the second order decay model for October 13th, 1998.

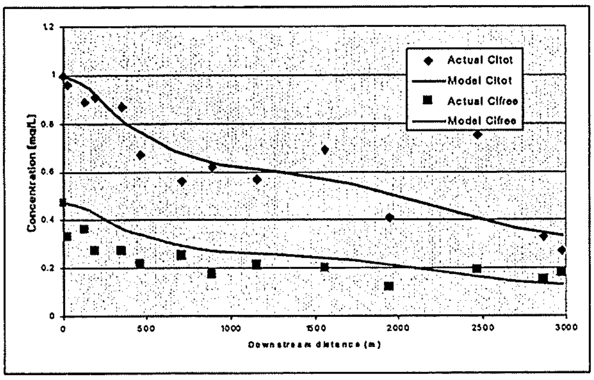

Figure 5: Observed and predicted results (field) vs. downstream distance 13/10/98

The results observed in the field using the Palintest equipment fluctuate greatly, and only provide indicative levels of total and free chlorine concentrations.

The observed total chlorine concentrations decay rapidly for the first 700 m downstream of the dissipator and then decay gradually to the end of the modelling region. The total chlorine decay model provides a reasonably accurate fit to the observed data, but slightly under-predicts the initial decay of total chlorine.

The observed free chlorine concentrations decay rapidly in the first 500 m downstream of the dissipator and then remain relatively constant at around 0.2 mg/L for the remainder of the modelling region. The free chlorine model under-predicts the initial decay of chlorine and as a consequence, the observed free chlorine concentrations are over-predicted for the majority of the modelling region.

The accuracy of the free and total chlorine decay models using field derived decay rate coefficients is summarised in Table 7.

Table 7: Accuracy of total and free chlorine decay models (field derived coefficients)

	Total Cl	Free Cl
Average absolute error (mg/L)	0.08	0.07
Average relative error (%)	12.64	32.31
Correlation	0.87	0.85

3.3.3 Laboratory derived decay rate functions

The second order laboratory derived decay rate functions (Eq. 14 and 15) were adapted for use in the river model. As these functions were derived from tests conducted with no light and no liquid-air interface, a multiplying factor was included in each of the functions to model the additional loss of chlorine via these mechanisms. The total chlorine multiplying factor is 1.25 and the free chlorine multiplying factor is 1.47.

The mixing energy term, *G*, was ignored in the computation of chlorine decay coefficients for the river due to the small relative effect of mixing energy on decay rates found in the laboratory studies.

The second order laboratory derived decay rate functions adapted for use in the river model are:

$$k_{total} = (1.25)(2.06\times10^{-5})(T)^{1.44537}(\mathrm{DOC})^{2.32123} \quad (16)$$

$$k_{free} = (1.47)(7.05\times10^{-6})(T)^{1.65091}(\mathrm{DOC})^{3.3727} \quad (17)$$

The observed temperature and DOC for the calibration run on October 13th, 1998 was:

$T = 17.4°C$, $\quad\quad$ DOC = 6.5 mg/L

The second order total and free chlorine decay coefficients obtained using Eq. (16) and (17) are:

k_{tot} = 0.1233 hr^{-1} k_{free} = 0.5977 hr^{-1}

Figure 6 shows the results produced using the laboratory derived decay coefficients compared with the observed results. This figure shows that the decay model using the laboratory derived decay coefficients does not accurately predict the decay of free or total chlorine. In both cases (total and free chlorine) the model fails to predict the initial decay of chlorine, resulting in chlorine concentrations being over-predicted throughout the modelling region. The free chlorine model converges to the observed results by the end of the modelling region, but only because free chlorine concentrations remain relatively constant throughout the modelling region after

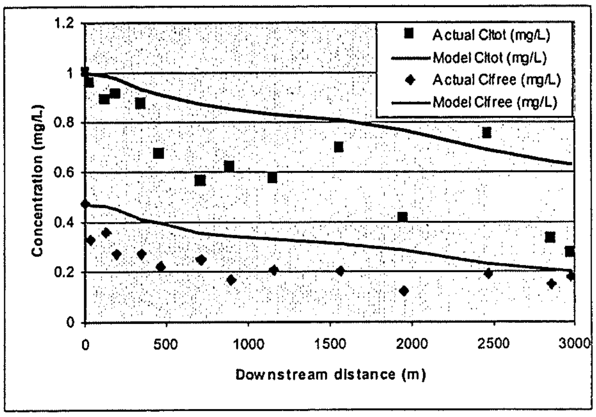

Figure 6: Observed and predicted results (laboratory) vs. downstream distance 13/10/98

the initial decay, enabling the model prediction to "catch up".

The accuracy of the free and total chlorine decay models using the laboratory derived decay rate coefficients is summarised in Table 8.

Table 8: Accuracy of total and free chlorine decay models (laboratory derived coefficients)

	Total Cl	Free Cl
Average absolute error (mg/L)	0.18	0.11
Average relative error (%)	38.79	51.59
Correlation	0.85	0.81

3.3.4 Fortran 77 computer model

A computer program coded in Fortran 77 has been developed to provide a user-friendly interface for the river model. An IBM-compatible computer is required to run the computer model. The program will run from either an MS-DOS box in Windows 95/98, or directly from MS-DOS.

The program has been designed so that the user is prompted for all inputs to the model step-by-step. The results for the simulation are output to a separate output file which is specified by the user, and can either be viewed directly or can be opened in a spreadsheet application for further manipulation or graphical display of results. The output file contains all of the user-defined input data, concentrations of total and free chlorine at various times and corresponding distances downstream of the dissipator and the zone of influence of total and free chlorine for specified concentration limits.

4 CONCLUSION

Analysis of results from the laboratory studies concluded that DOC levels significantly influenced the rate of decay of chlorine. Temperature also had a significant effect on chlorine decay, while mixing energy induced little significance on the decay.

The results from the pipeline reaction models analysed suggest that chlorine kinetics can be effectively modelled using first order equations for the decay in the bulk flow. It is evident that more data needs to be collected to accurately model the rapid initial decay of chlorine. Once the rapid initial decay used in the pipeline models had been calibrated, the predicted chlorine concentrations provided a very good fit to the chlorine concentrations observed in the field. Reaction model #1 provided a better prediction of the chlorine residuals in both the calibration study and in the verification study.

Despite the accuracy produced by the first order model, it is evident from the laboratory studies that second order kinetics provide a superior prediction of chlorine decay under a range of environmental conditions. This was indicated by the accuracy of the second order fit to the laboratory data. The EPANET water quality simulation software (version 1.1e) uses first order kinetics to model the chlorine decay kinetics in the bulk flow. The results of this study show that the software should be modified to incorporate second order kinetics. In general, given the limitation of a first order model, the reaction models provided an accurate prediction of the observed chlorine residuals. At most sampling points the model slightly under-predicted the chlorine concentrations in the pipeline. The results produced suggest that the influence of pipe wall decay is not significant in the Mannum–Adelaide Pipeline.

The ability of the model to match the chlorine concentrations at the sampling locations is reflected by the high correlation values in Table 6. In all simulations, the correlation between the observed and predicted chlorine concentrations exceeded 0.977. This is consistent with other studies conducted in the U.S. by Vasconcelos *et al.* 1997, aimed at modelling chlorine decay in distribution systems.

On average, the reaction models were able to reproduce the chlorine concentrations observed in the field with an absolute error in the range of 0.080 to 0.210 mg/L and a percentage error between 2.22 and 8.67 %. Compared with other studies, the errors produced from the calibrated model are small, however, some of these errors can be attributed to the variability in the method used for measuring the chlorine residual. The Palintest DPD method was used in this study to measure the total and free chlorine residual. For the Palintest DPD method, the variability can be as high as 15% (Gordon *et al.* 1992).

The developed model provides a powerful tool to assist SA Water in selecting operational strategies to balance between the needs of providing residual protection for consumers who receive their water directly from the pipeline and to also consider the needs of the environment.

Chlorine concentrations being released from the Mount Pleasant dissipator are likely to have an adverse effect on the environment. The affected zone of the River Torrens, under conditions of moderate to high chlorine levels and negligible natural flow, is 3-5 km downstream of the Mount Pleasant Dissipator.

Total chlorine concentrations at the dissipator were found to vary between 1 mg/L and 3 mg/L, depending on chlorine dosing levels, water quality parameters and pumping regimes. The persistence of chlorine downstream of the dissipator was found to be greatest when natural streamflow was negligible. When natural streamflow was high, chlorine levels were observed to fall rapidly immediately downstream of the dissipator through dilution processes.

The results produced using the laboratory derived total and free chlorine decay rate coefficients were found to significantly over-predict the observed data. It is likely that the studies conducted in the laboratory did not adequately simulate all of the possible decay mechanisms of the natural stream.

The accuracy of the Palintest equipment used to measure the total and free chlorine concentrations is questionable, especially further downstream when concentrations are negligible. The model cannot be calibrated and verified accurately when the field data is imprecise.

5 RECOMMENDATIONS

Further laboratory studies should be conducted to analyse alternative kinetic decay models under a greater range of conditions. More detailed analysis of the initial rapid decay should be conducted to improve the accuracy of prediction models.

The results from the field investigations indicate that chlorine concentrations entering the River Torrens via the Mount Pleasant Dissipator were at times excessive. For example, on September 22nd, 1998, the total and free chlorine concentrations at the Mount Pleasant Dissipator were as high as 3.8 mg/L and 3.0 mg/L respectively. The pipeline model can be utilised to significantly reduce these levels of chlorine by predicting residual concentrations just prior to the Summit Storage (a booster chlorination plant is located at the outlet to the Summit Storage). Given an initial dosage rate, DOC concentration, temperature, and pumping schedule, the model will provide predicted chlorine concentrations along the pumping section of the Mannum-Adelaide Pipeline and the Mount Pleasant Branch Main. In addition, the model can also be used so that dosage rates could be adjusted to produce the minimum required residuals.

DOC levels may vary from week to week, therefore, a more frequent analysis of the DOC is required. Only a small change in DOC can have a significant effect on the chlorine decay rate. Water quality probes and data loggers could be used to verify actual chlorine concentrations along the pipeline, to compliment the model and to enhance its accuracy. A remote telemetry system could be used to relay information from strategically placed data loggers to a control station. It will then be possible to use the data collected to perform a continuous, on-line calibration of the chlorine decay model as conditions change with time.

At present, a conservative approach is taken by dosing analysts. This is largely due to the lack of information relating to the decay of chlorine in the system. Given a chlorine decay model, it is possible to predict the decay of chlorine in the system and hence, reduce the amount of chlorine dosed. The savings achieved could considerably outweigh the cost of purchasing water quality devices (probes and data loggers), and would provide further savings in the future.

A simple analysis of costs incurred from chlorination during a typical year totalled $525 000. Assuming it is possible to achieve a 10 % reduction in the amount of chlorine dosed, a total saving of $52 500 can be achieved. A further benefit in reducing the initial chlorine dose is a reduction in the amount of chlorine discharged into the River Torrens.

The developed model of the River Torrens gives indicative values of the zone of influence of chlorine within the modelling region. Further studies could be performed in this field to improve the accuracy of the model, including:

- studies into the decay mechanisms of chlorine within the natural river system so that decay rate coefficients derived in the laboratory more accurately model the observed data;
- investigation of different decay models such as n^{th} order, parallel first order and limited first order models;
- closer investigation of the gradually-varying and unsteady-flow regions within the modelling region including the effects of control structures;
- more accurate in-field chlorine measurement apparatus;
- development of a time-varying model which considers changes in input conditions and inputs within the modelling region (such as the five small ungauged creeks); and
- developing a velocity profile for each of the reaches to more accurately predict the travel times of the flow.

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Investigation of water quality decline in a natural wetland

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Summary: Gordon Swamp is a 25 hectare freshwater wetland located 20 km south of Naracoorte, in the south east of South Australia. A reduction in the health of the wetland led to a water quality investigation involving laboratory and *in situ* testing. The monitoring program analysed parameters including turbidity, total suspended solids, nutrient concentrations, ionic composition and algal biomass of the water in the wetland and the drainage channel. The water was found to be highly turbid and this was adversely affecting the health of the aquatic communities. Further investigations into the catchment and nature of the sediment revealed that the sediment was predominantly fine dispersible inorganic particles, being eroded from a drainage channel incised through a clay basin in the catchment. To ameliorate the problem a solution was developed which involves preventing further erosion of the channel, and removing the sediment that is currently suspended in the wetland. Only 8% of the original wetlands of the south east of South Australia remain, many of which are severely degraded, such as Gordon Swamp. Conservation efforts, therefore, should be focused on rehabilitating the degraded remains of this once extensive ecosystem.

1 INTRODUCTION

Gordon Swamp is a freshwater wetland located 20 km south of Naracoorte, in the south east of South Australia. This natural wetland is located in an agricultural area, and the wetland and surrounds have been grazed for over a century. Originally an ephemeral wetland, the water regime has been altered through the development of a drainage scheme aimed at securing more productive agricultural land in the catchment, creating a permanent wetland system.

The local catchment of Gordon Swamp may be seen in Figure 1, including the excavated drainage channel that has been constructed to drain the large depression east of the wetland. The catchment for Gordon Swamp extends beyond Figure 1, as it is the last in a chain of swamps originating beyond the Victorian border. These swamps originally filled and overflowed into each other during periods of high rainfall, however, excavated channels linking several of these have led to the increased volume of water entering Gordon Swamp.

The capacity of Gordon Swamp and many neighbouring wetlands is defined by their location in low points of the karst landscape. Karst topography in this region is characterised by sinks, solution valleys and other features produced by groundwater eroding the Gambier limestone. This calcrete layer is overlain by ancient sand dunes of the Pleistocene era and intermittent clay basins (Drexel and Preiss, 1995).

Gordon Swamp has a surface area of 25 hectares and a capacity of 200 ML. Bathymetric studies have shown that the average depth of the wetland when at capacity is 1.1 m with several deeper sections which have a depth of over 2.2 m.
Since 1973, the current landowners have noticed a steady decline in the flora and fauna populations in the wetland, and a simultaneous increase in turbidity levels. The wetland is currently highly turbid, with no aquatic macrophytes present, but has a high phytoplankton concentration.

Gordon Swamp is a remnant wetland and the importance of preserving Gordon Swamp cannot be underestimated, as only approximately 8% of the former vast wetland areas in the south east still exist (South Eastern Wetlands Committee, 1984). The current landowners of Gordon Swamp request for assistance in rehabilitating this area highlights the growing recognition of the importance of the remnant wetland ecosystems. This study is one of the first to attempt to quantify the water quality of these wetlands, and accordingly develop methods for their rehabilitation.

2 AIMS

The aims of this study were to:

- Investigate the water quality of Gordon Swamp;
- Identify the cause of the decline in the health of the wetland;
- Locate source of any contaminants; and
- Design a cost-effective remediation program.

3 METHODS

3.1 Hydrological regime

Preliminary calculations undertaken using historical data found that the largest portion of flow into Gordon Swamp was through the excavated drainage channel. To assess the hydrological regime of Gordon Swamp over the study period, therefore, a water level gauge was installed in the wetland, and a V-notch weir constructed in the drainage channel to quantify the inflows. To verify these results, daily rainfall data, and a log of flow observations made by the landowners during the study period, were both obtained.

3.2 Water quality testing

Preliminary water quality testing was undertaken in the initial stages of the study to identify the water quality parameter(s) likely to be causing the observed decline in the health of Gordon Swamp. To assess any water quality variation across the wetland, *in situ* testing and sample collection was undertaken at six sites in the wetland. A suitable list of parameters to be tested at Gordon Swamp was developed from a review of water quality monitoring programs in the literature. The total dissolved solids (TDS) concentration was measured *in situ* with a TDScan3, while pH and temperature were measured *in situ* with a Hanna Instruments H19023C pH, mV, °C meter. Secchi depth was also measured *in situ*, using a Secchi disk.

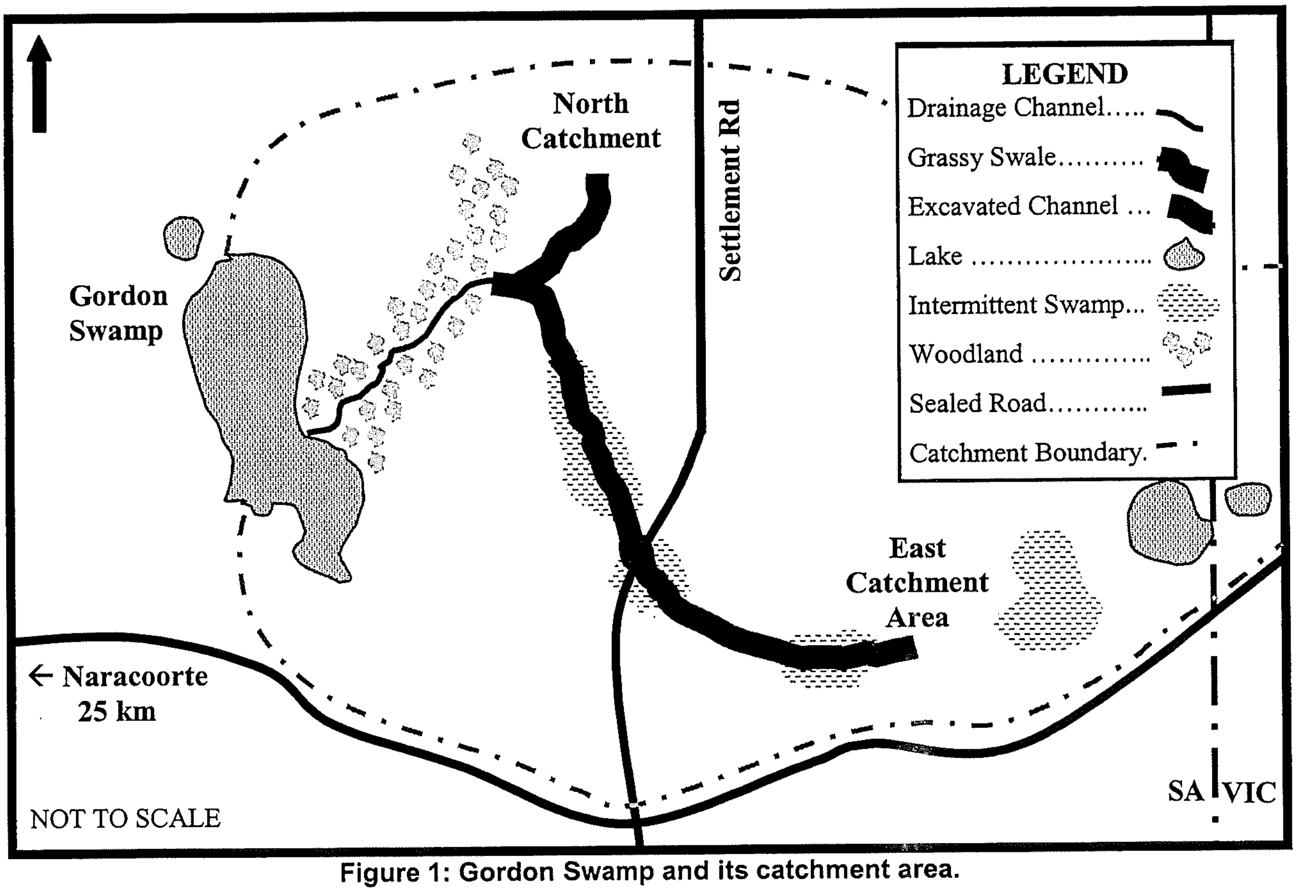

Figure 1: Gordon Swamp and its catchment area.

Water samples were taken from mid-depth at each site, to obtain an average value of water quality in the water column (Chamberlain and Howard, 1996). Analysis of nitrate, phosphate, iron, copper and sulphate concentrations in these samples were undertaken using Palintest©. Laboratory tests were performed at the University of Adelaide, measuring turbidity (using a Jackson Tube and a 2100P Turbidimeter), chlorophyll-a (using a Spectronic 21) which is a measure of phytoplankton biomass, and total suspended sediment (TSS) concentration (using vacuum filtration - 1.2μm GF/C filter paper).

To obtain a representation of what the water quality of Gordon Swamp was likely to have been before it deteriorated, the same water quality testing was also undertaken at Rule Swamp (Chapman, 1996), which is a relatively undisturbed wetland located near Gordon Swamp which has similar catchment characteristics (Slocombe, 1998).

Duplicate and replicate samples were taken at random intervals to assess the accuracy of the equipment used during testing, as part of the quality assurance for the testing program. In addition to this, a selection of water samples was sent to the Australian Water Quality Centre (AWQC) for analysis and to assess the accuracy of the testing methods being performed.

Where possible, the results of the testing were compared with the Australian and New Zealand Environment and Conservation Council (ANZECC) Guidelines for Protection of Aquatic Ecosystems.

To assess the nature of the suspended matter causing the elevated turbidity of Gordon Swamp, analysis of the matter was undertaken by comparing the turbidity results obtained at the wetland, with the quantified contribution of each of the four components of turbidity. These components are the attenuation of light due to the water itself, dissolved yellow substances produced through the decomposition of organic matter (gilvin), inorganic particulate matter (tripton) and phytoplankton (Kirk, 1983).

In addition to this, a water sample from Gordon Swamp was centrifuged to concentrate the suspended matter. The mineralogy of the sediment in the centrifuged fraction was assessed by use of a Philips PW1050 XRay Diffractometer.

3.3 Source of suspended sediment

Several possible sources for the suspended inorganic sediment found to be causing turbidity in Gordon Swamp were identified. These included resuspended sediments from within the wetland, the local catchment area, or the catchment area east of the property boundary.

The possibility of elevated turbidity levels being caused by resuspended sediment from the wetland floor was assessed through performing a settling test in the laboratory on a water sample collected from Gordon Swamp. This involved allowing the water in a 1L bottle to settle naturally under controlled conditions. Turbidity levels in the bottle were measured at 24 hour intervals using a 2100P Turbidimeter.

To identify whether the major source of eroded sediment in Gordon Swamp was the excavated channel west of Settlement Road (Figure 1), or some remote source, several monitoring instruments were installed. These included three turbidity meters (Turbidity Sensor TS300) located at points along the channel, and two transects of erosion pins. The turbidity meters were installed to measure the variability in turbidity along the excavated channel.
To obtain a quantitative measure of channel erosion, two transects of erosion pins were placed in the drainage channel (Lawler, 1993). The steel erosion pins were 30 cm in length and 3 mm in diameter.

A continuing water quality monitoring program was established to record any changes in water quality in the wetland during the monitoring period from April to September 1998. Weekly water samples were sent to the University of Adelaide for analysis. In addition, a Turbidity Sensor TS300 was installed in the wetland at the mouth of the inlet channel, to monitor the turbidity of the water in the wetland over the study period.

Additionally, the mineralogy of sediment collected from the clay walls of the drainage channel was determined using a Philips PW1050 XRay Diffractometer. This is the same instrument used to determine the mineralogy of the centrifuged water sample from Gordon Swamp.

3.4 Developing solutions

Initially, a literature review was undertaken to identify a range of possible ways to reduce turbidity levels in Gordon Swamp.
In response to this, both *in situ* and laboratory experiments were undertaken to assess the effectiveness of gypsum as a flocculant to remove sediment currently suspended in the wetland. An *in situ* test was performed in an isolated section of the wetland, with 22 kg/m^3 of gypsum being applied. Two laboratory tests were then performed to determine the application rate and settling time required to most effectively reduce the high turbidity levels in Gordon Swamp. In the first test, four different application rates were applied to four 1L containers of water from the wetland. Turbidity in these containers was compared to a control in which no gypsum was applied. Manual agitation was introduced into the second test, as well as higher application rates of gypsum.

To assess the effectiveness of straw bale-geotextile fabric sediment filters (Hunt, 1992) in reducing sediment load in the flow, two such filters were installed across the drainage channel. These structures are simple to erect and inexpensive, they act as sediment traps and may be employed to prevent streambank erosion. Turbidity meters were installed on the sediment filters to assess the effectiveness of these structures in decreasing the sediment load.

4 RESULTS AND DISCUSSION

4.1 Hydrological regime

During the period of the study, five major flow events were observed (Table 1). Due to structural problems with the weir design, the magnitudes of these flow events were not accurately recorded. The increase in water level recorded in Gordon Swamp was used to estimate the amount of water entering the wetland during the period of the study and was calculated to be approximately 144 ML.

Table 1: Flow events in the drainage channel

Flow Event	Date of Observed Flow	Period of Recorded Flow	Max. Flow Measured (m^3/sec)
1	28 - 30 July	not recorded	not recorded
2	12 - 14 Aug.	23 hours	0.009
3	12 - 17 Sept.	26 hours	0.01
4	22 - 25 Sept.	19.5 hours	0.41
5	6 - 7 Oct.	not recorded	not recorded

Observations made by the landowners over the study period showed that flow into Gordon Swamp during the first three flow events, originated primarily in the north catchment area (Figure 1). The timing for these flows correlated with intense rainfall events identified in the rainfall records for the period. Flow from the last two events originated primarily in the east catchment area. It was therefore concluded that flow in the eastern drainage channel does not occur until the wetlands and runaway holes located in the east catchment area have filled and are overflowing. Due to the nature of the catchment, determining an accurate hydrological regime for the wetland system is a complex problem.

4.2 Water quality testing

A summary of the results obtained from the preliminary water quality testing may be seen in Table 2. Little variation in the parameters measured at each of the six sites in Gordon Swamp was found, and therefore an average value for the wetland was calculated. From Table 2 it can be seen that TDS, chlorophyll-a, TSS, iron and phosphate concentrations measured in Gordon Swamp were considerably higher than those measured in Rule Swamp. Additionally, Secchi depth in Rule Swamp was found to be considerably greater than in Gordon Swamp, indicating a higher transparency. By comparison with the ANZECC Guidelines, it can be seen that chlorophyll-a concentrations in Gordon Swamp indicated high algal growth.

Analysis of duplicate and replicate water samples taken during preliminary testing showed that the error in the procedures and equipment was minimal for all tests, with the exception of those undertaken using the Palintest©. This can be seen by the large variation in the laboratory results of ionic composition obtained.

Table 2: Preliminary water quality results of Gordon Swamp (17 June 1998) and Rule Swamp (18 June 1998)

	Gordon Swamp Range	Gordon Swamp Average	Rule Swamp	ANZECC*
In Situ Results				
Temp. (°C)	9.0 - 15	12.2	11.0	< 2°C increase
pH	7.5 – 8.6	8.1	7.6	6.5-9.0
TDS (μS)	400 – 470	434	280	-
Secchi Depth (m)	0.09 – 0.14	0.11	>0.70	-
Laboratory Results				
Chlorophyll-a (μg/L)	56.2-89.9	80.6	11.2	>40=high algal growth
TSS (mg/L)	100-154	103	0	<10% change in seasonal mean conc.**
Turbidity (JTU)	180-260	207	-	
Fe (mg/L)	0.18-0.40	0.34	0.12	1.0
PO_4 (mg/L)	0.0–0.45	0.15	0.80	0.01-0.1

*Source: ANZECC, 1992.
** Note: ANZECC units are NTU not JTU.

Results from the samples analysed at the AWQC can be seen in Table 3.

TDS and lead concentrations were analysed by the AWQC and during the preliminary *in situ* and laboratory testing. Comparison of these results was therefore used to assess the accuracy of the equipment used in the preliminary testing. From Table 2 and Table 3 it can be seen that TDS concentrations measured by the AWQC were approximately half the values obtained in the preliminary testing. This indicated either an error in the calibration of the *in situ* measuring equipment used, or a deterioration of the sample in transit to the AWQC.

Phosphorus levels measured at the AWQC were found to be vastly different to the results obtained during laboratory testing. Results of the ionic composition of the water samples analysed in the laboratory using the Palintest© were found to be considerably variable. It was, therefore, concluded that the results obtained from the Palintest© were unreliable and all conclusions regarding the ionic composition of the wetland should be based on analysis by the AWQC.

Table 3: Australian Water Quality Centre results

	Site 1	Site 5	Rule	ANZECC
TDS (mg/L)	260	260	160	
Total Phosphorus (mg/L)	0.465	0.461	0.057	0.01-0.1
TKN as Nitrogen (mg/L)	5.14	5.19	2.58	
NO_2 & NO_3 (mg/L)	0.005	0.008	0.012	0.1-0.75
Cadmium (mg/L)	<0.0002	<0.0002	<0.0002	0.0002-0.002
Chromium (mg/L)	<0.005	<0.005	0.009	0.0002-0.005
Iron (mg/L)	2.92	2.7	1.77	1.0
Lead (mg/L)	0.008	0.008	0.001	0.001-0.005
Zinc (mg/L)	0.035	0.022	0.5	0.005-0.05

In accordance with the results obtained from the preliminary water quality testing, results from the AWQC highlighted excess TDS, TSS and phosphorus concentrations in Gordon Swamp. Iron and lead concentrations were also found to be elevated, however, these levels could be explained by the leaching of iron from humic soils during subsurface flows (Walker, K, 1998, pers. comm.), and past duck shooting in the wetland.

Phosphorus is an essential element in the growth of plants, and elevated nutrient levels are often associated with excess phytoplankton growth (Reynolds 1984). This was identified as being a possible cause for the high algal biomass found in the wetland. Nitrogen, however, is also an essential element in plant growth and analysis by the AWQC showed that nitrogen levels in Gordon Swamp were particularly low, thus possibly limiting the growth of phytoplankton.

High TSS, TDS and phytoplankton concentrations contributing to the turbidity in the wetland were therefore identified as being the likely cause for the decline in water quality at Gordon Swamp.

To identify the precise nature of the turbidity, the contribution of each of the four factors known to contribute to turbidity, the water itself, gilvin, tripton and phytoplankton, was analysed using the method outlined by Kirk (1983). The sum of the effects of these four components produces the vertical attenuation coefficient for downward irradiance, k_d, for the water. This value may be related to the euphotic depth of the water, Z_{eu}, by:

$$Z_{eu} = \frac{4.6}{k_d} \qquad (1)$$

The euphotic depth at Gordon Swamp was calculated from Secchi Depth measurements (Kirk, 1983) to be 0.184 m. This indicates a k_d value of 25 m^{-1}. The value of attenuation attributable to water alone ranges from 0.03 - 0.06 m^{-1}, hence it is only a small component of the total light attenuation. It was therefore concluded that the main contribution to light attenuation in the water column must be either organic matter, such as phytoplankton, or inorganic suspended sediments.

The weekly water samples obtained from Gordon Swamp were tested for chlorophyll-a concentration to determine the contribution phytoplankton was making to the turbidity. The contribution of phytoplankton to k_d may be represented as k_{PH}:

$$k_{PH} = B_C \times k_C \qquad (2)$$

Where:

B_C is the phytoplankton biomass concentration (mgchlam^{-3})

k_c is the specific vertical attenuation coefficient per unit of phytoplankton concentration (m^{2}mgchla^{-1}). k_C ranges from 0.0063 - 0.0142 m^{2}mgchla^{-1} for varying kinds of algal colonies (Kirk 1983).

Using the maximum values for B_C and k_C, a maximum possible value of light attenuation attributable to phytoplankton (k_{PH}) was calculated to be 0.426 10^{-3} m^{-1}. This value is less than 0.002% of the k_d calculated, indicating that turbidity in the wetland due to the phytoplankton population was insignificant.

It was concluded that the major contributor to light attenuation in the wetland must be inorganic suspended sediment. Analysis of soil and water samples from within Gordon Swamp was used to define the nature of this sediment.

The sediment from the water in Gordon Swamp was found to be primarily kaolinite, a fine dispersive clay. The same analysis was undertaken on a sample of sediment from the wetland. Similarly it was found to be primarily kaolinite, with a small portion of quartz and illite/muscovite.

These results demonstrated that fine, colloidal sediments suspended in the water column caused the turbidity in Gordon Swamp.

4.3 Source of suspended sediment

Following the identification of the nature of the turbidity as suspended inorganic sediment, the source of this sediment had to be located, so that a solution to the problem could be developed.

The results of the laboratory settling test, to determine whether the turbidity was caused by sediments being resuspended from the bottom of the wetland, are shown in Figure 2.

Figure 2 illustrates that there is minimal variation in the turbidity of the water sample from Gordon Swamp over an extended time period. The laboratory experiments thus demonstrated that the sediment in the wetland remained in suspension when stored undisturbed under laboratory conditions without resuspension by wind.

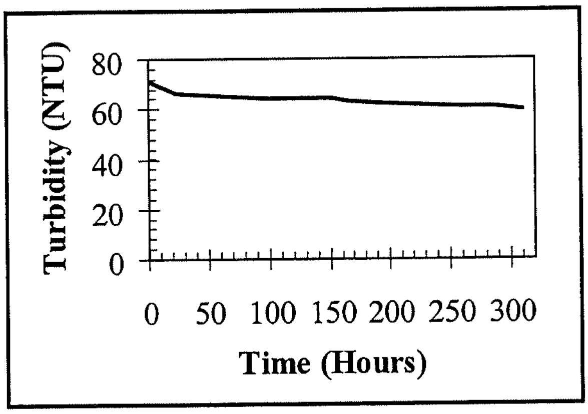

Figure 2: Results of settling test

Sampling from the base of the wetland revealed a thin layer of fine deposited sediments and humic matter overlaying coarse sands endemic to the area. The coarse sand nature of the wetland substratum indicated that it was not the source of sediment in the water column. Thus it was concluded that the fine suspended sediment originated from a source external to the wetland.

During a detailed catchment investigation it was found that there is a large clay basin immediately upstream of the wetland through which the drainage channel had been incised. Results of the mineralogy of the clay basin showed that the soil was primarily kaolinite, with some quartz, illite-smectite and feldspar. It was therefore concluded that the incised clay basin was a likely source of the suspended sediment in Gordon Swamp.

The results of the erosion pins located in the drainage channel indicated that there is some erosion of these channel sides and also some sediment deposition on the channel floor. However, these results were not conclusive and only provided an estimate of bank erosion.

In addition to the catchment investigation and soil analysis, ongoing water quality monitoring was also undertaken to determine the source of the suspended sediment in Gordon Swamp. Despite the intermittent results obtained, due to the large distance between the University of Adelaide and the study area, a good representation of the water quality in the catchment and Gordon Swamp was achieved.

The most conclusive of the *in situ* results obtained was the change in Secchi depth over the monitoring period and these results can be seen in Table 5. Despite variations in Secchi depth at different sampling locations, there is a distinct increase in Secchi depth from the 31 August to the 11 October 1998. This increase in Secchi depth is typically from 10 cm to 20 cm, which indicates a large increase in the transparency of the water, and in the depth of the euphotic zone.

An increase in temperature was observed across the wetland from June to August 1998. This increase was as much as 8°C. pH measurements ranged from 7.6 to 8.6, which were within the ANZECC Guidelines.

Table 5: Secchi depth measurements (m) over the monitoring period

	Sampling Site					
Date	1	2	3	4	5	6
17-Jun	0.14	0.09	0.09	0.11	0.11	-
31-Aug	0.11	0.10	0.10	0.10	0.10	-
11-Oct	0.26	0.18	0.25	0.21	0.23	0.23

Conclusive results were also obtained from the laboratory testing of water samples from Gordon Swamp and the catchment. Results of the testing of the chlorophyll-a concentration in the wetland indicated a marked decrease over the study period, from 180 mg/L in July to 10 mg/L in October, indicating a reduction in algal biomass in the wetland following the inflow events.

The TSS results from the catchment indicated that prior to Flow Event 4, flows both north and west of the junction in the drainage channel had suspended solids concentrations of less than 19 mg/L. During Flow Event 4, when the eastern drainage channel began to flow, TSS increased in both areas of the channel, and particularly in the channel downstream of the junction. This high TSS concentration had decreased once again by the 11 October 1998, however, it remained considerably higher than TSS concentrations recorded before Flow Event 4.

TSS concentrations in Gordon Swamp decreased considerably over the monitoring period, especially after each of the flow events. The results of laboratory testing undertaken on the weekly samples collected from two sites at the wetland can be seen in Figure 3. The results obtained from sites 1 and 5 exhibit a distinct similarity. It can therefore be concluded that there is minimal variation of the selected parameters over the wetland.

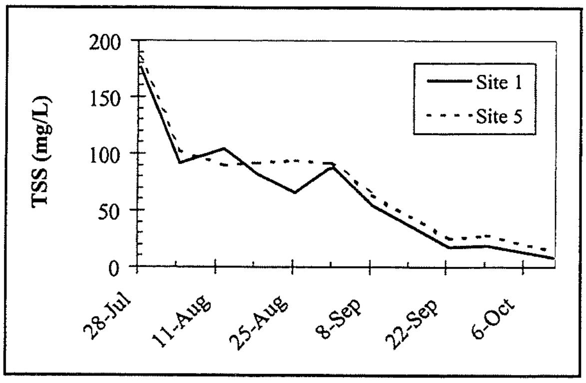

Figure 3: TSS results from sites 1 and 5

Turbidity readings were also obtained for water samples taken from the catchment area. Before Flow Event 4, the turbidity readings in the channel north and west of the junction were all lower than 35 NTU. After Flow Event 3, however, turbidity increased considerably west of the junction, and slightly also in the channel north of the junction. Turbidity in the channel west of the junction remained elevated on 11 October 1998, when the majority of flow was from the channel east of the junction.
The results of the turbidity readings of water samples from Gordon Swamp (NTU and JTU) indicated that there was a decrease in turbidity

in the wetland following the inflow events over the monitoring period.

In addition to the turbidity results obtained from the laboratory analysis of collected samples, results were obtained from turbidity sensors, which continually measured turbidity over the monitoring period. The continuous data obtained from the TS300 Turbidity Sensor located in Gordon Swamp at the mouth of the inlet channel (sampling site 2) can be seen in Figure 4. This sensor appeared to have recorded turbidity in the wetland quite accurately. This was determined by comparing the results obtained in the laboratory testing of samples collected at sampling site 2 with results logged by the sensor on that particular day.
The results from the turbidity sensor, following removal of apparently spurious data points, demonstrate a range of turbidity readings from 40 to 170 NTU.

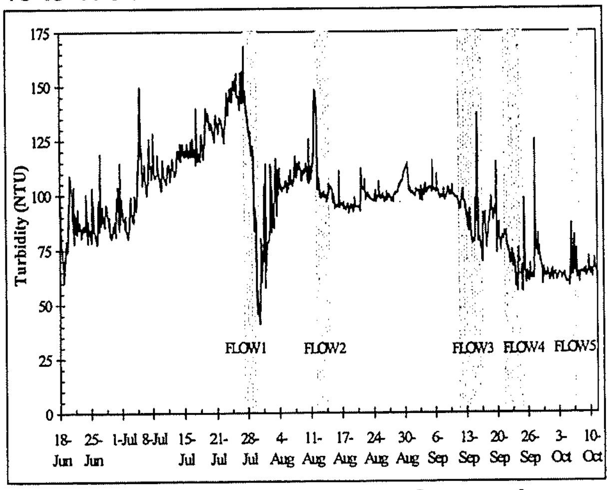

Figure 4: Turbidity in Gordon Swamp June - October 1998

The sharp decline in turbidity on 30 July 1998 (Figure 4) corresponds with the first flow into the wetland (Flow Event 1) from the drainage channel. This flow originated from the northern part of the catchment (Figure 1) where the runoff is transported via overland flow and through a grassy swale.

The turbidity decreased steadily following Flow Event 3 and Flow Event 4. It was not until Flow Event 5, when the east catchment area began to contribute quite considerably, that the turbidity rose once again (Figure 4).

The ongoing monitoring demonstrated that the water entering the wetland during the earlier flow events originated from the north catchment area and could be characterised by low turbidity and TSS concentrations. Following these inflows the TSS, turbidity and chlorophyll-a concentrations in the wetland also decreased, while transparency increased. Flow during the last two flow events, however, originated predominantly from the east catchment area, which extends into the neighbouring properties. Turbidity and TSS concentrations in flow in the channel increased dramatically during these flows. As a result of the testing program it was concluded that erosion of the excavated sections of the channel with exposed clay walls, were the likely source of the sediment entering Gordon Swamp.

4.4 Developing solutions

A three phase solution was designed to rehabilitate Gordon Swamp including:

- Phase I - Reduce fine clay sediment from inflowing waters.
- Phase II - Removing fine clay sediment currently suspended in Gordon Swamp.
- Phase III - Re-establish a healthy wetland ecosystem.

4.4.1 Streambank stabilisation

To achieve Phase I it is recommended that stabilisation of the streambanks of the excavated channel sections be undertaken to reduce erosion in these areas and flows from the upper catchment be filtered through a sediment filter if high sediment loads in these inflows persist. The streambank stabilisation process will involved the following stages:

- Excluding livestock from the channel via fencing, including a buffer zone;
- Reshaping rectangular sections of the channel into a trapezoidal cross-section with reduced side slopes;
- Creating level sill inlets for overland runoff entering the grassy swale to avoid erosive flow concentrations;
- Revegetating channel slopes; and
- Constructing check dams to slow the velocity of flow in the channel during revegetation.

The exclusion of livestock from the excavated channel bed can be achieved by fencing off this area, including a buffer zone. Fencing will allow for the revegetation of the channel and adjacent area while preventing further erosion in the channel.

Stabilisation of the channel bed can be achieved by revegetating exposed soils and regrading the channel to widen the channel and reduce the bank slopes. These modifications will decrease the erosion potential by reducing the velocity of the water and eliminating the potential for bank collapse (Institution of Engineers, Australia, 1996).

The scope of the project limits rehabilitation works to the west of Settlement Road (Figure 1). Assuming that highly turbid flows will continue to enter the channel from further upstream, sediment filters will be required to reduce the sediment load in this flow. The effectiveness of the straw-bale geotextile sediment filters installed during the study cannot be accurately assessed due to the limited number of flow events that occurred over the study period. Further investigation into suitable sediment filters is therefore recommended in the future.

4.4.2 Reducing existing suspended sediment

Several options were considered for the removal of suspended sediment in Gordon Swamp, including seasonal drying-out of the wetland, dredging, and the use of a chemical flocculant, such as aluminium hydroxide, lime or gypsum, to increase the sedimentation rate of the sediment (NSW Department of Housing, 1993). Due to the nature of the sediment in Gordon Swamp, it was decided that the use of a chemical flocculant was necessary. Gypsum was identified as being the only chemical that did not alter the pH of the receiving water, which would cause severe damage to the wetland ecosystem. Laboratory and *in situ* tests were therefore undertaken to determine the most appropriate loading rate for the gypsum.

The recommended application rate of gypsum is at least 32 kilograms per 100 cubic metres of water, and within about 36 to 48 hours the suspended solid content of the water should reduce to less than 50 mg/L (NSW Department of Housing, 1993).
Subject to being dosed with gypsum at a rate of 22 kg/100m^3, the TSS in Gordon South reduced from 67 mg/L to 30 mg/L in 30 days, indicating a positive result for the use of gypsum.

The results of the second gypsum laboratory test can be seen in Figure 5. The initial turbidity readings were recorded approximately 2 hours before gypsum was applied.

Directly after agitation, the turbidity measurements recorded were considerably higher than the results presented in Figure 5. The bottles that had higher gypsum loading rates showed the greatest increase in turbidity after agitation, due to the large amount of additional sediment in the bottles available for resuspension. Turbidity measurements after agitation of up to 400 NTU were recorded in the bottle containing 5.12g/L gypsum. These results have not been included in Figure 5, as the high turbidity readings taken directly after agitation misrepresent the effectiveness of the gypsum as a flocculant. However, the possibility of high turbidity levels being caused by resuspension of the large amounts of gypsum added to the wetland, should be taken into account when selecting a suitable dosing rate (Ganf, G., 1998, pers. comm.).

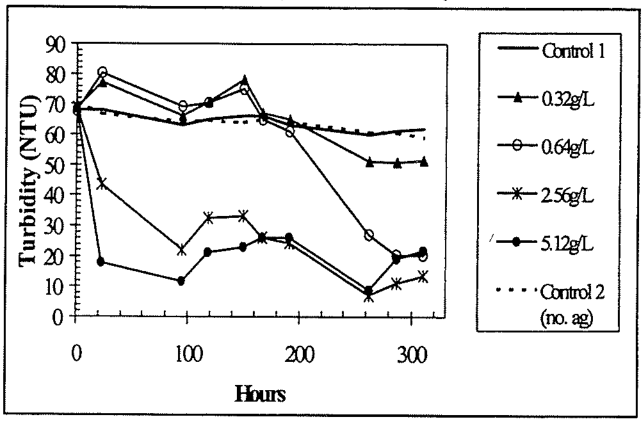

Figure 5: Results of gypsum test #2 without measurements taken directly after agitation

From Figure 5 it can be seen that the higher dosing rates of gypsum resulted in a more rapid reduction in turbidity in the water samples. The lowest two dosing rates had minimal success in reducing the turbidity below the natural reduction recorded in the controls.

From these preliminary results, the application of gypsum to Gordon Swamp is deemed to be a feasible solution. Despite the rapid reduction in turbidity recorded in the bottle with the highest loading rate, due to the risk of increasing turbidity through resuspension of the introduced gypsum, it is recommended that a loading rate of approximately 128 $kg/100m^3$ be used. This result should, however, be confirmed with further testing of gypsum in the wetland.

4.4.3 Rehabilitation of the wetland ecosystem

Following the completion of Phase I and Phase II solutions, Phase III will involve returning Gordon Swamp to a healthy, dynamic wetland ecosystem. This will involve the development of a revegetation plan for restoring aquatic vegetation to the wetland and to the fringing areas surrounding the wetland. This revegetation process must be an active program of reintroduction of the appropriate flora species, which will encourage the passive reintroduction of native fauna to the area.

5 CONCLUSIONS

Through an intensive program of water quality monitoring, soil testing and field investigations conducted over the five month study period, it was confirmed that the cause of the water quality decline in Gordon Swamp was elevated turbidity levels. The nature of this turbidity was identified as fine, dispersive, inorganic material. By extending the water quality monitoring program to include sampling from the catchment area, the source of this material was found to be erosion of the excavated drainage channel entering Gordon Swamp.

As a result of these findings a three phase solution to this problem has been developed. This includes removing fine sediment from waters flowing into Gordon Swamp from the drainage channel, removing sediment currently suspended in the wetland and a long-term rehabilitation of the wetland ecosystem.

6 FUTURE STUDIES

Over the limited study period, this research project has successfully identified the cause and source of water quality decline in a natural wetland, not previously studied. The conclusions of the project will form an integral part of a rehabilitation scheme and long-term management program for Gordon Swamp. To further enhance knowledge on this complex ecosystem, and therefore the methods required for its rehabilitation, it is recommended that further studies be undertaken. These studies should focus on gaining a more thorough understanding of the effectiveness of gypsum as a flocculant, the erosion processes acting in the drainage channel, including ways to minimise deposition in Gordon Swamp, and also on understanding the zoology and long-term water quality dynamics of the wetland.

7 ACKNOWLEDGMENTS

The authors gratefully acknowledge the support from Dr David Walker of the University of Adelaide and the hospitality of the McArthurs during the study period.

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Olive Irrigation

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Summary: Rapidly increasing areas of olive plantations will increase demand for irrigation water. The theoretical water volume and water salinity needs of olive trees are examined. Methods are indicated to reduce water applications without affecting yield or quality, through application of Regulated Deficit Irrigation and reduced water application during early growth. The economic returns on olive trees are put in the context of other crops.

1 OLIVES NEED LARGE VOLUMES OF IRRIGATION WATER

Olive trees are drought tolerant. Olives can grow without irrigation, but the yield from dryland olives is well below the yield from irrigated trees. Increasing areas of olives are being planted (Figure 1) which will lead to increasing demand for irrigation water.

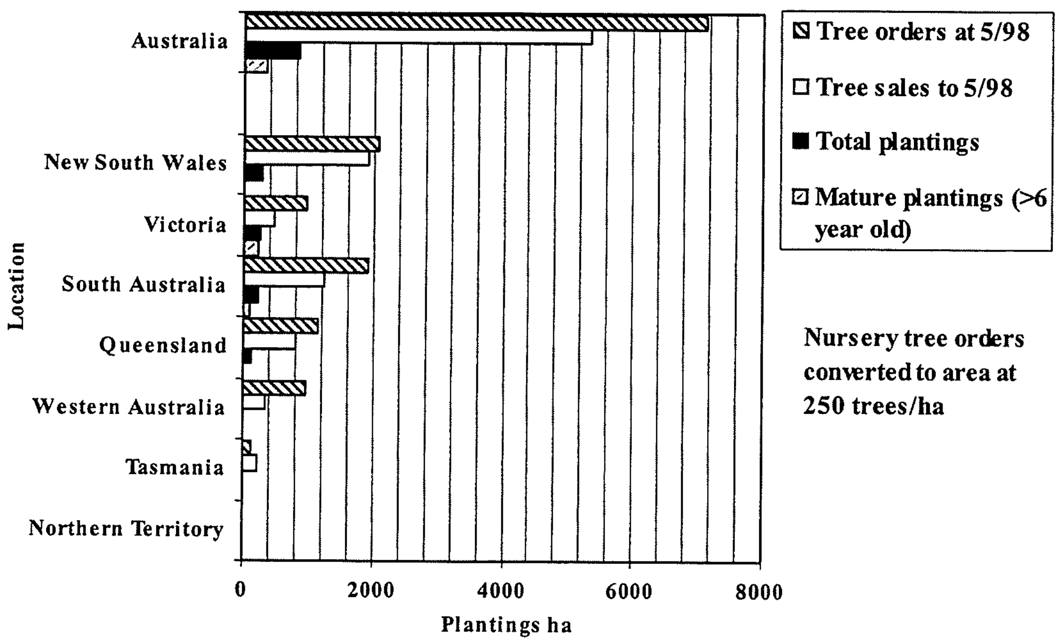

Figure 1: Areas of olive tree plantations by state

2 COSTS AND RETURNS

A conservative annual yield of fresh olives from fully-irrigated, mature, commercial, oil-variety olive trees is 20 000 fruit each, averaging 2.5 g or 50 kg/tree. Good commercial yields are 50 to 65 kg/tree and oil varieties should contain at least 20% oil by fresh weight. One tonne of fresh oil-variety fruit should contain 220 L of oil, because one litre of olive oil weighs 0.9 kg.

For trees planted at 250 trees/ha (eg 8m x 5m) a target fresh fruit yield is 12.5 t/ha or oil yield 2 750 L/ha. With biennial bearing, yields may fluctuate from 2 to 28 t/ha. In 1996-97, for the Australian fresh olive production of 642 t (367 growers), the average Australian yield from trees aged more than 6 years was 1.8 t/ha.

The 1996-97 farm gate price was $3 220/t (ABS). Olive Industry Development Officer Susan Sweeney advises that a realistic farm gate price for fresh olives is $0.70/kg ($700/t) and for oil the farm-gate bulk price is $4/L.

Costs of growing and machine harvesting olives total about $4 000/ha or $320/t. Minimising harvesting and pruning costs will be essential for profitable production. Capital outlay, excluding land, may be up to $13 000/ha. A computer spreadsheet is a valuable aid to planning and budgeting for an olive development. An olive budgeting spreadsheet designed by Duncan Tullet is available from PIRSA.

Before finally deciding to grow olives, investors should compare the costs and returns available from olives (gross margin $/ha, gross margin $/$ of capital invested, gross margin $/hour labour, gross margin $/kL irrigation water, years to break even etc.) with the costs and returns available from other crops for which markets are already well established, eg grapes, oranges, potatoes, apples etc. Figure 2 illustrates revenue for different crops relative to water input, and Figure 3 illustrates revenue in South Australia per unit area.

3 IRRIGATION REQUIREMENTS

3.1 Under-irrigation reduces fruit yield

For maximum production olive trees need large volumes of irrigation water (see Table 1 and Figure 6).

For maximum oil production at Mount Barker, South Australia, in addition to the rainfall in a year with average weather, under-tree sprinkler-irrigated olives, grown without a cover crop, need 440 mm of irrigation between 1 September and 31 March. At Loxton, oil-olives need 890 mm, at Pinnaroo 730 mm, at Virginia 670 mm, at Meadows 360 mm, at Keith 520 mm and at McLaren Vale 490 mm of irrigation. In an average year in South Australia, the monthly maximum of about 25% of the annual irrigation water is needed in January.

At Wagga Wagga, NSW, oil-olives need 490 mm, at Mildura, Vic, 900 mm, at Perth, WA, 540 mm, at Geraldton, WA, 970 mm, at Launceston, Tas, 220 mm, at Kingaroy, Qld, 150 mm and at Alice Springs, NT, 1410 mm. At Kingaroy, the maximum monthly requirement is in September and at Alice Springs it is in October. The January monthly irrigation requirement is highest in each of the other locations.

Research from the University of California by Dave Goldhamer at Fresno showed that sustained under-irrigation at every irrigation by 10% reduced yield by 10% and under-irrigation by 25% reduced yield by 25%.

Compared with a target yield of 12.5 t/ha ($8 750/ha), sustained under-irrigation by 20% could reduce yield and farm gate income by 20%, a reduction in income of $1 750/ha.

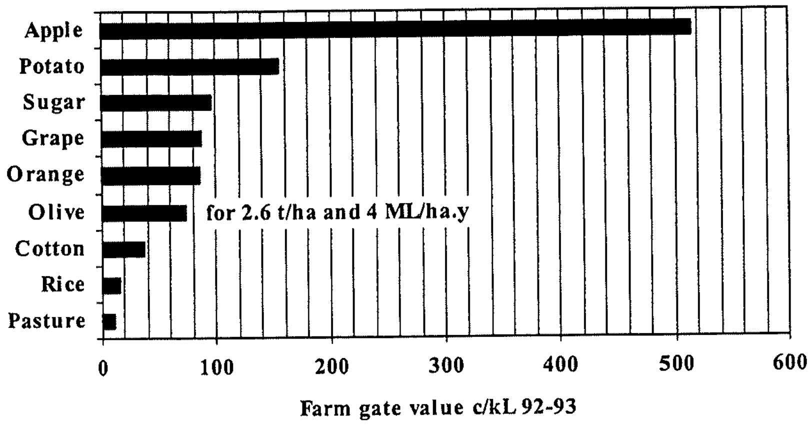

Figure 2: Farm gate value for crops relative to water input

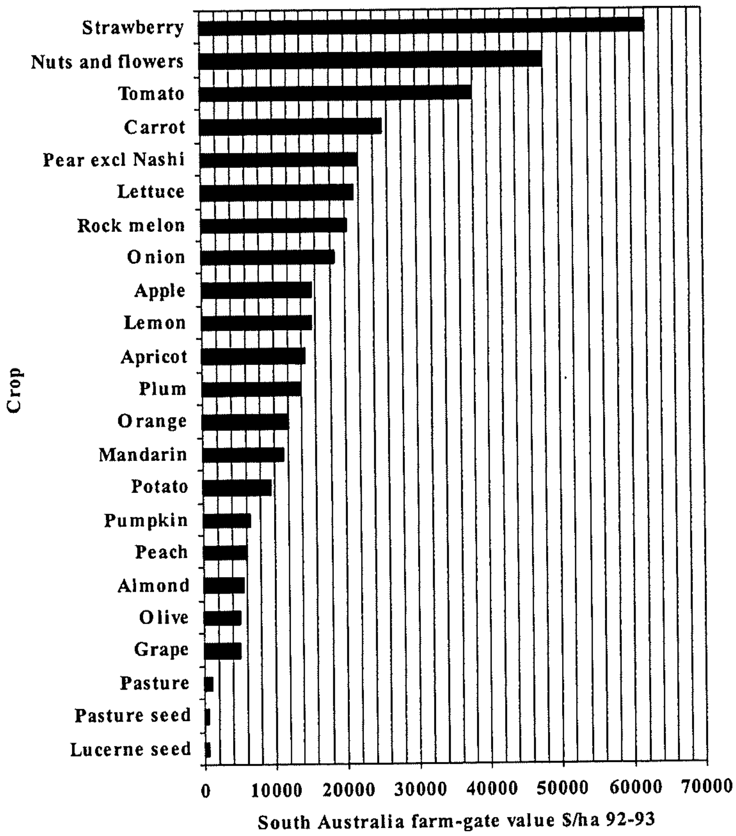

Figure 3: Farm gate value of different crops per unit area

3.2 Maximum irrigation requirement

The irrigation system should be designed with capacity to provide the maximum monthly irrigation requirement (typically the January figure) when pumping for a maximum of 20 h/day and 6 days/week ie. for 120 hours out of the available 168 h/week. The remaining 48 hours provide additional capacity to meet the highest irrigation demand in even the driest month of the driest year. The monthly evaporation figures in a drought year are typically not more than 10% above the monthly evaporation figures in an average year.

Table olives need more water. To grow large fruit (table olives) Goldhamer found that trees need about 20% more irrigation water than to grow olives for maximum oil production.

3.3 Salinity

Irrigation water salinities up to 1.8 deci-Siemen per metre (1 080 mg/L) do not affect olive fresh fruit yield. At 2.6 dS/m (1 560 mg/L) yield is reduced by 10% and at 5.6 dS/m (3 360 mg/L) yield may be reduced by up to 50% (Ayers).

4 REGULATED DEFICIT IRRIGATION (RDI)

Goldhamer has shown that deliberate under-irrigation of mature trees for 12 to 17 weeks starting after fruit set (about 15 November in South Australia) can reduce the annual irrigation water requirement (eg. by 25% and perhaps up to 40%) without changing the per tree yield of oil (Figure 4). Goldhamer suggests that RDI trials in South Australia on mature (7 year old) trees could start by providing half the full-irrigation requirement from about 1 December until about 28 February. Full irrigation should restart on about 15 January if the shoot growth (which will carry the next year's crop) (Figure 5) has not reached 30 cm by then. Independent research in Spain by Pastor and Orgaz and also by Girona supports trialing this RDI irrigation strategy. RDI can also be used to increase the volume ratio of olive flesh to stone.

RDI can be applied successfully only if:

- the irrigation system is spreading the water uniformly and delivering the same flow rate from every dripper or sprinkler. At an *Olive irrigation system evaluation field day* at Virginia, South Australia, participants measured non-uniform flows ranging from 153 L/m at sprinklers located near the pump to 22 L/m at distant sprinklers. Non-uniform water distribution is typical of most irrigation systems on most crops;
- basic irrigation principles are applied eg. the right amount of water on the right date (part of *Six steps to improve irrigation practices*); and
- based on observation and recording of regular soil and plant condition, irrigation practices are modified.

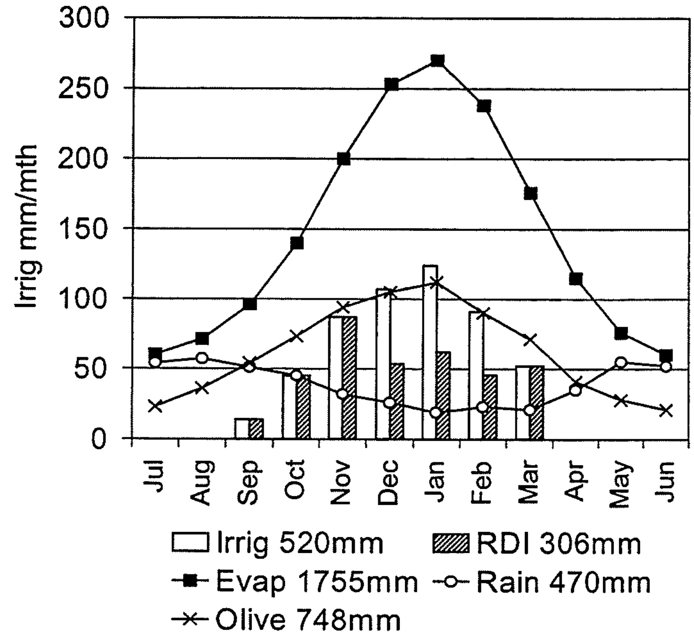

Figure 4: Olive irrigation requirement and weather (for maximum oil production at Keith, South Australia)

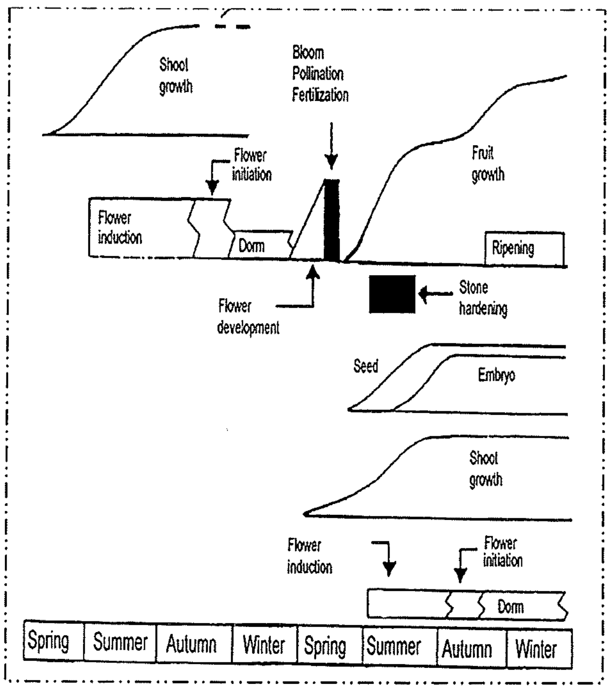

Figure 5: Olive Growth Stages

5 IRRIGATION OF YOUNG TREES

Goldhamer suggests the Fereres rule of thumb for the often-asked question about the amount of irrigation water to give to young trees:

If the olive canopy shades 10% of the floor of the orchard (at mid-day) then apply 20% of the irrigation water which will be needed by the mature orchard. For 20% shading apply 40% irrigation and for 50% shading apply 100% of the irrigation required by a mature orchard. A mature olive orchard planted at 8m x 5m shades about 60% of the orchard floor.

6 MORE INFORMATION

Copies of documents by Tony Thomson including *Six Steps to improve irrigation practices, Olive Irrigation – 1 and 2*", which includes Dave Goldhamer's two most recent papers, are available from Lenswood Centre ($10 each plus $4.50 to pack and post).

Table 1: Olive target irrigation needs, evaporation and rainfall

Region	Town	Evap	Rain	Month of maximum irrigation	Maximum monthly irrigation (Table) Oil	Irrigation target For maximum **size (table)**	For maximum **oil**
		mm/y	mm/y		mm/month	mm/y	mm/y
Barossa	Nuriootpa	1965	518		145	752	607
Angas Bremer	Langhorne Creek	1710	391		114	665	530
Northern Adelaide Plains	Virginia	1995	435		145	817	666
Southern Vales	McLaren Vale	1770	573		114	620	491
Mid North	Clare	2145	633		146	804	648
Lower South East	Penola	1485	659		98	466	341
Upper South East	Naracoorte	1528	580		104	484	382
Upper South East	Keith	1755	470		124	650	520
Adelaide Hills	Lenswood RC	1340	1164		54	217	150
Adelaide Hills	Macclesfield	1741	745		107	512	408
Adelaide Hills	Meadows	1724	886		102	466	363
Adelaide Hills	Mount Barker	1815	775		116	587	442
Adelaide Hills	Mount Pleasant	1951	683		135	670	536
Riverland	Berri	2176	269		157	1093	910
Mallee	Pinnaroo	1965	341		144	877	725
	Port Lincoln	1605	485		115	613	498
NSW	Wagga Wagga	1857	570	Jan	(150)124	630	489
Vic	Mildura	2161	280	Jan	(179)151	1079	896
Qld	Kingaroy	1619	778	Sep	(66)50	202	151
NT	Alice Springs	3054	272	Oct	(219)186	1674	1411
WA	Perth	1765	830	Jan	(153)131	658	542
WA	Geraldton	2474	465	Jan	(207)179	1150	971
Tas	Launceston	1324	687	Jan	(88)70	306	221
California	Fresno	1616	269	Jul	(154)133	817	692

Reference:

Goldhamer DA, Dunai J, Ferguson L (1993). *Irrigation requirements of olive trees and responses to sustained deficit irrigation.* **Acta Horticulturae** 356: 172-175

Assumptions:

- soil store 60 mm/m
- olive root depth 40 cm
- Irrigation distribution uniformity 85%
- Irrigation water salinity 2.6 dS/m (1560 mg/L) so leaching 10%
- Crop Coefficients (for use with reference crop ETo):
- maximum size (table olives) Kc=0.75
- maximum oil Kc=0.65 (Goldhamer)
- Annual irrigation mm can be reduced on mature (7 year old) olives by (25 to 40)% by correct use of Regulated Deficit Irrigation (RDI)

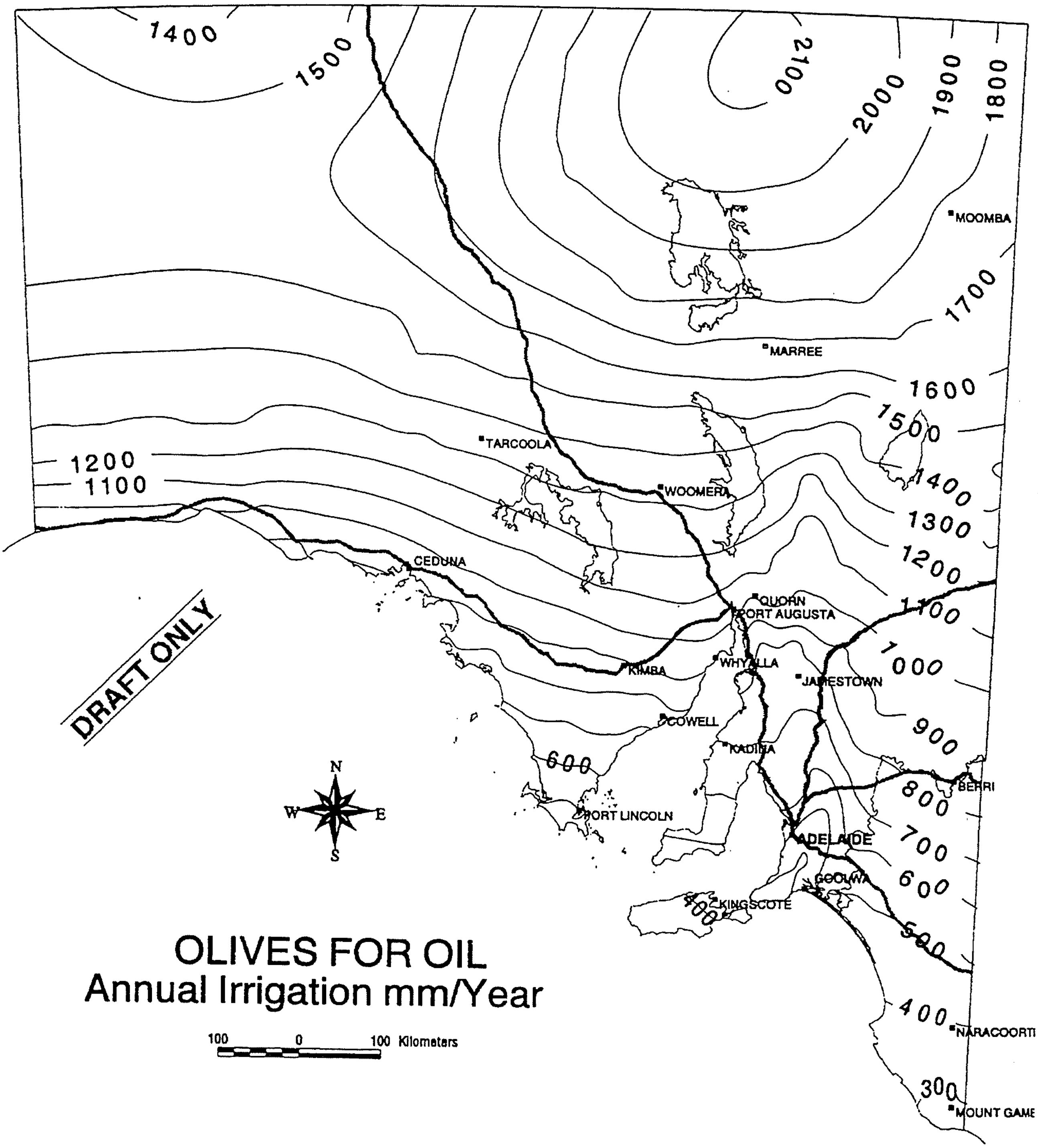

Figure 6: Olive tree annual irrigation requirements (draft)

A report *The new rural industries – financial indicators* was released by the Rural Industries Research and Development Corporation at Outlook 99 Confernece [Ed]

Allocation of underground water resources following Proclamation

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Summary: The process for the management of water resources in South Australia has resulted in non-sustainable, significant over-allocation and over-use of limited underground water resources. Proclamation under the *Water Resources Act* is typically too late and intensive data collection to determine allocations is required, creating scope for rorting and inequity. Three methods for determining water allocations are discussed, each with merit regarding simplicity, equity and robustness. Much can be done to improve water use efficiency, although factors affecting crop yield and quality in relation to water application need better understanding.

1 UNSUSTAINABLE WATER ALLOCATIONS

The process for management of water resources in South Australia has resulted in non-sustainable, significant over-allocation and over-use of limited underground water resources.

For example, the Northern Adelaide Plains (Virginia) was Proclaimed 28 years ago

- in 1967 the volume sustainably available was 7.0 GL/y;
- the total allocation in 94-95 was 27.9 GL/y which is 4 times the sustainably available and 1.5 times the metered use in 93-94,
- metered use in 93-4 was 18.9 GL/y, which is 2.7 times that sustainably available.

The picture for the Angas-Bremer (Langhorne Creek) area is similar, as shown in Table 1.

In the Barossa the total volume of water allocated does match annual recharge. However, because the Barossa was not proclaimed soon enough, the match between recharge and allocation has been achieved by giving a low allocation to grapes of only 100 mm/y which is well below their requirement and will limit grape yield (t/ha) and is expected to cause increasing problems of salt accumulation in the root-zones.

In the Southern Vales, if the normal process of Proclamation had been followed, the availability of 7.6 GL/y and metered use of 6.6 GL in 93-94 would have compared with a total allocation of 11.2 GL/y.

In both the Upper and the Lower South East, if the normal procedure of applying theoretical crop water use figures is used to convert from area licences to volumetric, the allocations will, again, far exceed actual use by the irrigators.

In Clare Valley, which has recently been proclaimed, the water resource available is unlikely to support the expanded area of grapes which has been planted.

With the existing process it is likely that the Marne River will be over-committed before it is proclaimed.

Large areas of inefficient flood irrigation are being developed each year near Kingston South-East by growers determined to secure a large share of the water resource before Proclamation.

The following pages summarise the existing process of Proclamation and suggest ways to improve the process.

2 PROCLAMATION PROCESS

The existing process and some suggestions for improvement, eg Clare, Marne, Lower South East.

2.1 The existing process:

1. Proclamation is typically too late, see table 1;
2. PIRSA (Groundwater Section) require time to quantify volume available;
3. "Land use survey" (area irrigated) of irrigators and other water users;
4. Total area licensed, including that allowed due to "financial commitment" and other criteria (eg "hardship"), far exceeds the area being irrigated, eg. Southern Vales: 3400 ha irrigated increased to 4200 ha licensed;
5. Convert from area to volumetric licences, 3 options:

- theoretical calculated crop target irrigation needs;
- historical water use (eg. water meter data);
- equal kL/ha.

Table 1: Water in Proclaimed Areas: recharge, allocations, use, salinity

		Groundwater resource						
		Barossa	**Angas Bremer**	**Northern Adelaide Plains**	**Southern Vales**	**Mid North**	**Coonawarra**	**Padthaway**
	Town Unit	Nuriootpa	Langhorne Creek	Virginia	McLaren Vale	Clare	Penola	Naracoorte
Year Proclaimed		1989	1980	1967	1990	? 1995		
Year first metered		90-91	86-87	70-71	92-93			
Recharge	GL	4.5	4.5	7.0	7.6	?		
Allocation at Proclamation	GL	4.3	29	36	plan 7.6	not pro-claimed	area	area
Used 1st metered	GL	3.1	12.1	20.5	3.71			
Use 93-94	GL	3.6	6.5	18.9	6.33 water depth in bores falling			
Allocation 94-95	GL	4.3	13.8[a]	27.9				
Salinity 93-94	µS/cm		3000 to 4200		1300 to 2200	?2200		?2200+

a After conversions of groundwater licences to licences from Lake Alexandrina 13.8 will become 6.0 GL

The theoretical option typically has been used. This option increases allocation above metered use, eg Southern Vales

6. Reduce allocations to match available. Angas Bremer and Northern Adelaide still have not balanced use with availability.

2.2 Suggestions for improvement

1. Early Proclamation eg when "use" is only about 1/4 of "available";
2. Volumetric "water use survey";
3. Immediately allocate a water volume, each individual allocation based on water use survey;
4. Auction any additional available water;
5. Annual charge per kL of licence even if not used; plus annual charge for each kL used;
6. See *Dividing the water resource after Proclamation.*

3 DIVIDING THE WATER RESOURCE AFTER PROCLAMATION

The options for determining the allocation to each licence are variations on, or combinations of, the following:

a. Theoretical crop need;
b. Fraction being used by each licensee at Proclamation;
c. Equal division between the irrigated hectares.

3.1 Option a: theoretical crop need

In locations which have been proclaimed to date (except Barossa) the local committees have:

- used theoretical crop water use values (except Northern Adelaide Plains);
- allocated a much larger volume than was being used; and
- allocated a much larger volume than was available;
- then attempted to cancel unused allocations;
- then, progressively over many years, incrementally reduced all licences by the same %, targeting to match the total of all allocations to the total volume available.

This process was readily accepted by licensees as no one is initially disadvantaged, but extra water (which has not been used and is not available!) is allocated and becomes "sleeper" water. When allocations are reduced to match the total allocated to the total available each individual is affected very differently and the process has been extremely unfair.

In most locations, the total of allocations still dramatically exceeds both:

- the volume available and
- the annual volume of water being used

(See table 1).

3.2 Option b: fraction being used by each licensee at Proclamation

Water meters can be used to estimate the fraction of water being used by each licensee at the time of Proclamation. The fraction metered as used by each licensee in the years after Proclamation is likely to be quite different from the relative use before Proclamation.

Option b rewards both high and inefficient water users and penalises both low and efficient water users. It rewards any irrigators who have deliberately inflated their water meter readings and penalises those whose water meters have stuck.

If the local Water Resource Committee gave an undertaking to the community that the committee would base allocations on individual metered water use it is unlikely that water meter readings would accurately or fairly reflect irrigation practices.

A method to determine the irrigation volume that was being used by each licensee BEFORE Proclamation is needed.

Arguments against allocations based on water use surveys:

- rewards wasters: solve with upper limits and charges;
- penalises developers: solve with "applications to increase";
- complex and time consuming to assess "applications to increase".

However, there are more arguments against allocations based on water meters:

- do not reflect pre-Proclamation: solve with water use survey;
- deliberate inflation of meter readings: solve with water use survey;
- jammed meters: solve with water use survey;
- need to assure licensees that water meter data will not be used to set individual allocations.

Allocation based on a "Volumetric Water Use Survey" can be used to estimate the volume that was being used by each licence before Proclamation.

Water meter values after Proclamation are unlikely to accurately reflect the actual use before Proclamation because some licensees will anticipate that the meters may be used to determine the amount of water which can be pumped in the future and hence the capital value of an individual licence.

Questions answered at the time of Proclamation during the "Land Use Survey" can be used to estimate volumetric water use before Proclamation. The total of these estimates would more accurately reflect total water use than the total of the theoretical water use figures that have been used to date. It would also more accurately indicate the proportion used by each licensee than would the water meter readings collected in subsequent years if licensees know that high water meter readings will give them a high final allocation.

In locations that are not yet proclaimed, a volumetric allocation could be introduced immediately after a "Volumetric water use survey". The following questions could be used to determine the historical volume of irrigation water used before Proclamation:

1. Obtain a copy of the pump curve from the irrigator or ask the name and phone of the pump installer/supplier, the name of the pump manufacturer, pump model, impeller size, motor kW and obtain the pump curve from the pump manufacturer;
2. Determine the pump flow rate. Measure to check that the figure is correct using one or more of a sonic flow meter (eg Fuji, Bais instruments and control equipment \$13 000), a manometer flow meter (eg Cox, Hydrological Services \$2 000), or a Pelton wheel flow meter (eg Quadrina, Tempress Controls \$5 100) and measure the average emitter flow and multiply by the number of emitters;
3. Measure the pump pressure to locate the pump operating point on the pump curve and record each of the components of pump pressure (see PIRSA sheet *Investigation of irrigation pumps*) which can also be used to measure the pump flow rate;
4. Calculate annual pumping hours. Ask a sequence of questions to ensure accurate figures: ask for hourmeter on pump, hourmeter on electric motor or hourmeter on diesel engine, date irrigation season starts, hours per irrigation, number of irrigations per week, number of irrigations per season, date irrigation season stops and compare with expected 2000 hours.
5. Confirm flow rate and annual hours. For electric pumps ascertain annual electricity (kWh) used for pumping from electricity account records and use this kWh figure and the formula:

$$W = \frac{PQT}{102\eta\varsigma}$$

where:

W = annual power use in kWh

P = pump pressure in m

Q = flow in L/s

η = pump efficiency say 0.7 and

ς = electric motor efficiency say 0.9;

to confirm flow rate and annual hours.

For diesel pumps, ascertain annual fuel consumption (L) used for pumping. Use this figure and the kWh formula above to confirm flow rate and annual hours assuming that a typical diesel engine consumes 1L diesel for 2.74 kWh and motor efficiency = 1.0.

Obtain electricity or diesel use records for 3 or so previous years.

If this "Volumetric Water Use Survey" method were used there would be no need for an expensive program spanning several years of crop monitoring to determine existing irrigation practices.

Theoretical maximum crop water use calculations would only be needed to set an "Upper Limit" for each crop.

Analysis of water meter data may be needed to compare metered use with the allocation calculated from the "Volumetric Use Survey".

In locations that are not yet proclaimed, the preliminary issue of an area-based licence could be omitted and a volumetric allocation could be introduced immediately after a "Volumetric Water Use Survey".

In locations currently unmetered and using area-based licences a "Volumetric Water Use Survey", as described above, could be used to convert from area to volumetric licences.

3.2.1 Use of water meters to adjust allocations ("individual negotiation") under Option b.

Each licensee will be offered the average of his/her metered water use for the last three years - the "proposed allocation". Where metered use has exceeded any crop upper limit it will be reduced to the crop upper limit.

Any licensee unhappy with the proposed allocation may apply for an increased allocation, which will be assessed on the following attached "Points for assessment of applications for increased allocation". All the applications for increased allocation will be assessed and adjusted where accepted.

For every licensee the proposed allocation will then be further adjusted up or down by multiplying the initial adjusted allocation by the ratio:

$$\frac{\text{sustainable yield}}{\text{total initially adjusted allocation}}$$

to make the total of all the final allocations equal to the sustainable yield.

3.2.2 Points for assessment of "applications for increased allocation"

Each application will be assessed on how well it addresses each of the following 9 points.

1. Crop upper limits. No allocation may exceed the upper limit set for each crop. Proposed upper limits for the Southern Vales are:

Crop	irrigation mm/y
Grapes	275
Almonds	500
Pasture	702
Stonefruit high	810
Stonefruit Low	562
Melons	645
Recreation	462
Summer fodder	597
Strawberries	583
Apple, Cherry High	942
Apple, Cherry Low	657
Avocado	810
Olive high	408
Olive Low	108
Native flowers	150
Continuous plantings:	
vegetables	444
cut flowers	272
Pasture starter/finisher	100

2. The water volume available is restricted to the sustainable yield;
3. Hence, for permanent horticulture crops the proposed upper limits do not provide for summer cover crops or for sprinkler irrigation;
4. Pumping capacity upper limit. For all licences that were issued NOT on the basis of financial commitment, the allocation to a site may not

exceed the pumping capacity at that site (kL/month) before Proclamation;

5. Proof will be needed of:

- Bore capacity, eg bore flow test as tested when bore was drilled or subsequent flow tests;
- Pumping capability of the pump in the bore at the date of Proclamation, determined from pump manufacturer, pump model, pump curve, operating pressure and operating flow rate, record of pumping hours during peak water use month (January) and record of pumping hours. For licences that WERE issued on the basis of financial commitment, no allocation may exceed the average irrigation depth allocated to that crop.

6. Larger crop requirement. The application must show:

EITHER

That the average annual water use has exceeded the proposed allocation: For Southern Vales the following methods could apply: 92-95 from water meters, 91-92 from water meters where available, 89-91 from land use survey, 87-88 from pump records, fuel consumption or irrigation depth;

OR

Reasons why water use metered in any year was artificially low: eg equipment not functioning due to breakdown, young plantings, or area being developed and hence not yet planted.

7. It will need to be demonstrated that the level of use applied for will not affect neighbouring bores; the water level in the bore is not falling, and the salinity in the bore is not increasing;

8. The following information will support applications:

a. Proof that irrigation water is not being wasted to drainage, eg irrigation record of irrigation depth vs date, soil moisture data plotted against date;

b. Demonstration of understanding and application of irrigation principles eg attachment of an irrigation management plan, or evaluation of irrigation system performance (pressures, flow rates, distribution uniformity, pump efficiency, evaluation of irrigation management and proof of attendance at Irrigation Workshops); Demonstration that yield per kL above district average and/or $ gross margin/kL exceeds Australian Bureau Statistics value.

3.3 Option c: Equal division between the irrigated hectares

Fairness can be argued for this method.
The monetary value of the right to water was reflected in the capital value paid for the land. High water use by the larger users has hastened the date of Proclamation of the resource. High water users have already received a larger benefit from their previous high use of the resource. Why should historically high water users continue to receive both a larger share of the capital value of the resource and a larger allocation each year?

If accepted, and incorporated into legislation that overrides common law legislation, "equal division" would dramatically simplify the process of allocation:

- less need for theoretical calculations;
- no need for crop monitoring;
- less need for analysis of meter data;
- less need for lengthy committee debates.

An auction among licensees only is one method by which the available resource could be divided between all the irrigated area according to water need. The total proceeds from the auction could be divided by the number of irrigated hectares and returned to all the licensees in proportion to the number of irrigated hectares held by each licensee.

<u>3.3. 1 Arguments against all same irrigation depth:</u>

- At Proclamation non-irrigators do not get a licence. Equal division would be to every hectare in the proclaimed area. Small volume to every hectare. These allocations would have to be bulked for irrigation use. Not practical;
- Each licensee has a different number of hectares, hence different volume, ie why not argue for division of allocation volume by number of licences;
- Different crops need different irrigation depth;
- Committee and community feeling that some individuals are hard done by;
- Creates sleeper water;
- Transfers water from more profitable to less profitable;
- Contrary to common law;
- Has been rejected by Tribunal.

Southern Vales different:

- historical average of all crops is equal irrigation depth to every crop;

- promise was given not to use water meter readings;
- Water use survey data collected with land use survey at time of Proclamation (May 1990) is incomplete.

4 VAST VARIATION IN IRRIGATION PRACTICES

When individuals in a group of irrigators record and compare their own data they discover that their irrigation practices differ dramatically between individuals. The irrigation practices used by many irrigators also differ from irrigation principles.

Data indicates that there is a need for many irrigators to dramatically change their irrigation practices. The changes needed are not just "fine-tuning": Many irrigators need to halve or double their annual irrigation application.

Opportunities exist to significantly increase both yield quantity and yield quality by improving irrigation system performance and improving irrigation management practices.

Significant benefits are available from recent technological advances in soil moisture monitoring equipment. These include:

- increased yield quantity;
- increased yield quality;
- maximising the benefit to the crop from applied fertiliser;
- minimising pollution of underground waters with chemicals and fertilisers;
- control of soil salinity.

These benefits cannot be realised where irrigation systems do not distribute water evenly and where management of the irrigation system is not applying basic irrigation principles.

4.1 Southern Vales grape irrigation practices 91-94

There was a large variation in the annual irrigation depth applied to grapes. In 93-94 and 92-93 respectively the application on grapes varied from 0 to 820 mm and from 0 to 460 mm.

The pattern with which the annual irrigation depth was applied varied widely. Within the Landcare Group there was a variation of 2 to 70 mm per irrigation. On six trial sites the number of irrigations varied from 1 to 123 per year.

Soil moisture records showed that some large water users, and also some small water users, wasted water to drainage. Soil moisture records also showed that some large water users did not waste water to drainage.
Irrigators changed the volume of irrigation water that they used from one year to the next. After adjusting for weather differences between 92-93 (wet) and 93-94 (near average) about half the irrigators increased their water use, many by up to 100% while about half decreased their water use also by up to 100%. From one year to the next the irrigators did not vary their annual irrigation depth by as much as the theoretical variation calculated from the weather variation. The summer of 91-92 was very dry (target irrigation was 128% of an average year), 92-93 was very wet (target irrigation was 48% of average and 93-94 was wetter than average (target 78% of average).

There was a wide variation in yield for a given annual irrigation depth. Below 125 mm/y the yield of shiraz recorded by the Landcare Group in 93-94 ranged from 9.4 to 25.5 t/ha. The highest shiraz grape yield recorded by the Landcare Group was 27.1 t/ha using 353 mm but 25.4 t/ha of shiraz was grown using 122 mm.

In 92-93 grape average yields in the Southern Vales were 8.5 t/ha or 5.2 kg/kL. This compares with 7.0 t/ha Barossa, 16.4 t/ha Riverland, 7.3 t/ha Angas Bremer, 10.9 t/ha for South Australia and 12.6 t/ha for Australia.

The theoretical irrigation needs for grapes in average weather in the Southern Vales (153 mm) are less than the needs in Northern Adelaide Plains (236 mm), Clare (228 mm), Barossa (221 mm), Angas Bremer (164 mm) but more than Padthaway (112 mm) and Coonawarra (84 mm).

4.2 Potato irrigation practices in 94-95 in the Adelaide Hills, Northern Adelaide Plains and at Bordertown:

The total irrigation applied to Adelaide Hills potato crops planted in November 94 (dry season) ranged from 187 to 720 mm. This compares with target irrigation requirements in a year with average weather ranging from a minimum of 311 mm for a potato crop planted in February at Mount Barker to a maximum of 680 mm for a crop planted in September at Virginia.

The irrigation depth applied per irrigation ranged from 10 to 38 mm. Assuming an active root depth for potato of 0.3 m, the irrigation depth required at each irrigation can be estimated as:

$$0.3 \text{ m} \times 60 \text{ mm/m} = 20 \text{ mm}$$

After this depth is increased for leaching (say leaching factor LF = 10%) and increased to compensate for distribution uniformity (say DU = 85%) the pumping requirement is:

$$20/[(1-LF)DU] = 20/[0.9 \times 0.85] = 24 \text{ mm}$$

The application rate ranged from 0.4 to 12 mm/h. A clay-loam soil can uptake water at 2 mm/h, a sand can uptake water at 10 mm/h.

The variation in flow from every emitter should not exceed ±5%.

Those few irrigators who measured sprinkler pattern distribution uniformity (DU) reported values ranging from 51 to 84%. For annual crops DU should exceed 85%. For permanent horticulture crops DU should exceed 75%. A DU of 67% is unacceptable.

This article was submitted to HYDSOC in 1996 [Ed]

NEWS

Commonwealth Parliamentary inquiry into catchment management by House of Representatives Standing Committee on Environment and Heritage. Submissions close 30 July 1999 at The Secretary, House of Representatives Standing Committee on Environment and Heritage, Parliament House Canberra ACT 2600, email Environment.Reps@aph.gov.au

Further information www.aph.gov.au/house/committee/environ tel (02) 6277 4580; fax (02) 6277 4424.

South Australian Parliamentary inquiry into EPA (SA)
The Australian Democrats have moved in the Legislative Council of the South Australian Parliament to set up an inquiry into the Environment Protection Authority by the Environment, Resources and Development Committee, following the oil spill at Port Stanvac. The HYDSOC Committee sees this as an opportunity to make a submission on the fragmentation of data collection and the use of water quality data archiving systems which are not compatible with interstate agencies, since the corporatisation of EWS and the transfer of Water Resources Group to DEHAA and EPA.

Australia's largest geothermal airconditioning at AGSO offices
New Canberra offices for the Australian Geological Survey Organisation (AGSO), formerly known as the Bureau of Mineral Resources, Geology and Geophysics, incorporate 220 geothermal heat pumps to pump water through loops of pipe in 350 boreholes up to 100 m deep to exchange heat with rocks at shallow depth. Energy savings are expected to be $1 million over 25 years. Some photos and a description of the new building can be viewed at www.agso.gov.au/information/newbuilding1.html

Extracted from IAH newsletter vol 15 no 1

Government budgets 99/00

Commonwealth Government hydrology budget
$ 20 m has been allocated to regional flood mitigation over 3 years – mainly for levees, channel improvements, flood warning systems and voluntary purchase of property with matching grants from State Governments and contributions from local Government.

Adelaide Advertiser May 1999.

The Federal budget has allocated an additional $ 4.8 million to upgrade weather forecasting services.

Crosscurrent 14/6/99

State Government hydrology budget
The water budget for DEHAA includes:

- $11.6m to Murray Darling basin works;
- $4m to Murray Darling 2001 initiative;
- $1.4m to initiate water resource management programs, including the establishment of the Arid Areas Catchment Water Management Board.
- Overall there is a reduction of $14.5m in the DEHAA budget.

Full text Budget Papers are available at www.treasury.sa.gov.au/budg2k/

Copyright changes to computer software.
Commonwealth Government legislation before the Senate will allow software developers to decompile programs, if the information is not readily provided by its originators, in order to facilitate error correction (including Y2K bug), inter-operability with other software and enhance computer security.

Extracted from the newsletter of the Institution of Engineers, Australia, South Australian Division 6/99.

Australian Rainfall and Runoff (ARR) update
As process of continous updating ARR 1987, the 14 chapters have been published in 8 booklets. Contact EAIBooks on tel (02) 9438 5355; fax (02) 9438 5343. Book VI (Chapter 13) *Estimation of large and extreme floods* is the first chapter to be revised. A copy of the draft is accessible from www.skm.com.au/news/papers.htm. Book IV Part 1 (Chapter 10) *Flood frequency analysis* and Book VIII (Chapter 14) *Urban Stormwater Drainage* are next to be revised and it is proposed to have a new chapter *Australian Runoff Quality*, so that both quantity and quality could be successfully integrated. For updates see www.ieaust.org.au/colleges/civil/np/waterengin.htm

Extracted from Civil Engineers Australia 3/99

Roof gardens as runoff mitigation
In Europe, use is being made of roof gardens comprising layered, prevegetated mats of coir fibre that absorbs rainfall, a mineral-based substrate that provides plant nutrients, and, below, a synthetic matrix that allows drainage. These are claimed to be able to reduce runoff by 2/3, low-maintenance except for occasional fertilising and annual weeding, and require no irrigation. Other claimed benefits are improved aesthetics and amenity; improved air quality by trapping dust; noise barrier; habitat; prolonging roof life by protection from wind erosion and ultraviolet light; thermal insulation; and city-wide evaporative cooling. Saturated weight varies from 25-100 kg/m^2. Germany has financial incentives for residential owners, and allows roof gardens as an option for its legislated offset to increasing impervious areas in industrial areas. In Germany in 1995, 8-10 km^2 of roof garden was anticipated to be constructed. One German manufacturer is Bon Terra Weilland GmbH, Nideggen.

Extracted from Stormwater Industry Bulletins 24 (December 1995) & 60 (December 1998)

Water efficient housing, Figtree Place, Newcastle
Roof runoff and stormwater will meet up to 60% of domestic consumption in a new development in Newcastle. Infrastructure includes underground tanks, gravel filled trenches for rainwater tank overflow, and recharge of impervious area runoff with diversion to conventional drainage in case of failure.

Extracted from Stormwater Industry Bulletin 63 (March 1999)

Cost cutting on safety
Preliminary information from the Royal Commission into the Longford (Victoria) gas explosion in October 1998 indicates that an essential safety assessment planned for 1995 was not carried out, there were staff cuts and no engineers on the site to diagnose and rectify problems, as they had been transferred to head office in Melbourne. All this raises questions about infrastructure maintenance for a company providing a public good...... Increasingly in the Australian water industry we need to ask these questions.

Bill Rees' Byline in CrossCurrent 10/5/99, Australian Water and Wastewater Association.

Catchment management cost cutting jeopardises safety
Responsibility for the management of Sydney's drinking water catchments will be transferred from Sydney Water to a new Authority, and an independent laboratory established. The proposed changes are recommendations from the McClennan Inquiry interim finding that the health of Sydney's drinking water has been seriously compromised by decades of piecemeal planning and the 'fragmented responsibilities' of various agencies. 'A modern treatment plant is not a substitute for proper catchment management' according to McClennan. A new Environment Planning Policy will limit development and regulate activity in the catchments.

Extracted from CrossCurrent 14/12/98 (Australian Water and Wastewater Association)

Record warm year for Australia in 1998 - Bureau of Meteorology
Australia recorded its highest-ever annual mean temperature in 1998 since high quality data records began in 1910. The Australian mean temperature for 1998 was 22.54°C, 0.73°C higher than the average for the 1961-1990 reference period.

Despite the new Australian record, it is unlikely that many people will remember 1998 as being particularly warm. Annual mean temperature departures are small because they are averaged over all of Australia, for all of the year. Within this overall average there is a lot of variability, both in time and throughout Australia. The largest contribution to the record

Australian mean temperature came from significantly warmer than usual minimum temperatures throughout the northern half of the continent. Some southern parts were actually slightly cooler than normal during 1998.

Warmer land temperatures in 1998 were partly due to significantly above average ocean temperatures around Australia.

The Bureau of Meteorology's National Climate Centre calculated the annual mean temperature from data from 130 non-urban observing stations throughout Australia. Many of the sites form part of Australia's Reference Climate Station network--a network established to monitor climate change.

The record annual mean temperature for Australia is consistent with global trends, in showing continued warming throughout this century. According to a statement, released by the WMO in December 1998, preliminary data indicated that 1998 had the highest global mean temperature in the instrumental record since 1860. Last year was the 20th consecutive year with an above global mean temperature.

Extracted from Climate Change Newsletter No 11(11) 1999.

Australia wetter

Parts of Australia have become wetter with more rainy days and more heavy rainfall. So concludes a CSIRO study of daily rainfall at over 300 Australian sites from 1910 to 1995. Annual total rainfall has risen by about 15% in New South Wales, South Australia, Victoria and the Northern Territory, with little change in the other states. Southwest Western Australia has become 25% drier in winter.

"There has also been a significant 10% rise in the Australian-average number of rainy days," said the author of the study, Kevin Hennessy of CSIRO Atmospheric Research.

The heaviest daily rainfall has become 8% more intense in summer with little change in the other seasons.

The observations over Australia during the past century are consistent with climate change model results but there may be other factors causing the observed changes, such as landuse change, burning of vegetation, ozone depletion, sunspot activity and long-term natural variability.

Extracted from CrossCurrent 14/6/99

World Climate Research Programme (WCRP) laments declining state of global climate observing systems

It is likely that, within a short time, observing systems will be unable to provide a reliable assessment of the state of global climate or detect any change in climate. The adequacy of global monitoring systems in meeting the needs of the Climate Change Convention is reviewed in the final report of the Global Climate Observing System (GCOS) Secretariat at ftp://www.wmo.ch/Documents/gcos/SBSTA/fullreport.pdf

The report received strong support from the World Meteorological Organisation (WMO), the International Oceanographic Commission (IOC) and the United Nations Environment Program (UNEP) and from an overwhelming number of countries. The decision of the Conference of Parties (COP4) set up under the United Nations Framework Convention on Climate Change is accessible at www/unfccc.de. Elements of the decision are:

- A mandate to the agencies participating in the Climate Agenda IWMO, UNESCO, IOC, UNEP, World Health Organisation. Food and Agriculture Organisation, International Council of Scientific Unions) to initiate an intergovernmental process to establish the priorities for action to improve global observing systems for climate;
- Parties are urged to support and implement meteorological, oceanographic and terrestrial monitoring systems within the framework of the various global observing systems and to develop national observing plans;
- A direction to parties for free and unrestricted exchange of data.

Extracted from Climate Change Newsletter 11(1) 1999.

UNEP calls for desertification action

United Nations Environment Program has launched the 2nd edition of its World Atlas of Desertification with estimates of people at risk and a study on migration and refugees. Nine issues have been identified in implementing the UN Convention to Combat Desertification.

Extracted from WQI Nov/Dec 1997

Water Associations Worldwide (WAW) is proposed to connect national and international associations worldwide, to share information about conferences, legislation and developments and to proffer advice to international bodies such as the World Bank. Australian convenor Chris Davis: email cdavis@awwa.asn.au

National Land and Water Audit
Contracts have been let with the States for projects on:

- Characterising Australia's water resources. particularly flow and quantity
- Water allocation, use and efficiency;
- Categorising water resources: effectiveness of current management and further needs;
- Value of use: case studies on costs of water and value of product.

In addition, projects are proposed on waterway health, including waterway condition, water quality, sediment transport and impacts, estuary health, landscape health and cost of degradation.

$29.4 million ($2.5 million for dryland salinity) has been allocated under the Natural Heritage Trust to provide nationwide assessment of Australia's land, vegetation and water resources. Progressive information at www.nlwra.gov.au

Contact: Janice Oliver tel (02) 6257 9516; fax (02) 6257 9518; email info@nlwra.gov.au

(Extracted from WATERways, March 1999)

$ 100 000 River Prize offered by River*festival* Brisbane
The prize is for outstanding achievement in river management, presented to an individual, organisation, agency, or group of organisations. Deadline for the 1999 prize has closed, but another prize will be awarded in 2000. The winner will be announced during the River*symposium* in Brisbane 29/9/99 to 1/10/99.
Details Chairperson, River*prize* Panel, River*festival*, PO Box 5696, West End Qld 4101; tel (07) 3846 7444; fax (07) 3846 7660; email belinda@riverfestival.com.au

Report warns of global water crisis
The John Hopkins University School of Public Health warns that nearly 0.5 billion people rising to 2.8 billion by 2025 face shortages of fresh water, and recommends reducing demand, slowing population growth, conserving water and better management. Water stress is defined as less than 1700 kL/y.person and water scarcity less than 1000 kL/y.p. In the USA groundwater is being used at 25% more than its replenishment rate. Globally over 20% of freshwater fish species are endangered, vulnerable or have recently become extinct.

Extracted from Engineering Technology Review (Institution of Engineers, Australia) September 1998.

World Bank and World Water Vision
The World Water Council, co-sponsored by FAO, UNEP, UNDP, UNESCO, WHO, WMO and the World Bank, has established a *World Commission on Water for the 21st Century*. The Commission is chaired by Dr Ismail Serageldin, who is also Chairman of the Global Water Partnership and Vice-President of the World Bank. The main task of the Commission is to guide the development of the *Long Term Vision on Water, Life and the Environment for the 21st Century (or World Water Vision)* that the Council is preparing.

The main objective of the project is to develop a widely shared vision on the actions required for tackling water issues globally and regionally. The project will be characterised by a participatory approach with extensive consultation and innovative "out-of-the-box" or futurist thinking and will emphasise communication with groups outside the water sector. The Vision will be truly global, including both developed and developing regions, but with special attention given to the needs of developing countries and of the poor.

The interim results of the World Water Vision project will be discussed at Stockholm Water Symposium (8/99) and the final results will be presented at The 2nd World Water Forum and Ministerial Conference, 17-22 March 2000, The Hague, The Netherlands.

Active contributions to the World Water Vision process are invited. Contact World Water Vision Unit, William J Cosgrove, Director (wjcosgrove@compuserve.com) or Frank R Rijsberman, Deputy Director (f.rijsberman@unesco.org), c/o UNESCO, Division of Water Sciences, 1 rue Miollis, 75352 Paris Cedex 15, France; tel +33 1 4568 3904; fax +33 1 4568 5811.

For details of The Vision contact World Water Council Secretariat, Les Docks de la Joliette, Atrium I03, 10 place de la Joliette 13304, Marseille Cedex 2, France; tel +33 4 9199 4100; fax +33 4 9199 4101; email: wwc@worldwatercounci1.org

French water utilities object to pollution tax
Only 20 % (down from initially proposed 100 %) of water taxes collected by water agencies will now go into the new general tax to fund control of water pollution (TGAP), after heavy criticism from water authorities. The tax will subsume existing funds from environmental agencies, plus a new indirect tax on polluters. Further taxes are contemplated including ones on:

- modification of the flow regime; and
- agricultural products.

Extracted from WQI January/February 1999.

European sewerage charges
Germany has the highest sewerage charge of Western Europe, but also the highest connection rate. Annual charges, adjusted to a common basis to allow for subsidies, taxes and rainwater collection, vary from DM 117/person (Italy) to DM 305/p (Germany), or 0.38-0.77 % of GNP. (1 DM ≅ 1 $A). Information from Professor Rudolph email rudolph@uni-wh.de

Research funded by UK Water Industry Research concluded from a literature review that costs of the most severe water-based illnesses in the region were 10-40% of GDP, and that 60-80% of these are avoidable through water and sanitation improvements. The economic burden in Eastern Europe is estimated at Euro 25/p (1AUD ≈ 0.63 Euro). Refer www.who.dk/London99.

Extracted from WQI April 1999

European water research to change focus
A report by the World Health Organisation concludes that water research needs to become more multidisciplinary and proactive in preventing deterioration of water resources, including emphasis on: resource conservation and quality/quantity interactions, legislation, social and market based conflicts; behavioural change, closed systems, and international cooperation.

The report can be obtained from Jamie Bartran, WHO European Centre for Environment and Health, fax +39 6 4877599; email jba@who.it.

A background report of a Task Force of the European Commission, planning to invest £ 200 m (1AUD ≈ £0.41) over 5 years on water related research, is available from DGXII of the Commission, Contact European Commission Joint Interpreting And Conference Service, fax +32 2 2953736; email 5pc.essen@scic.cec.be

Extracted from WQI Nov/Dec 1997 and Nov/Dec 1998

A Danish consortium has set up the Agrovand Centre for integrated land and water management. Decisions tools software will be developed for:

- land and water resources information;
- planning tools for water resources management in larger river basins;
- agrochemical modelling;
- watershed development and management; and
- remote sensing.

OECD sustainable agricultural water management policy
The Organisation for Economic Cooperation and Development (OECD) has published a report on policy directions for sustainable agricultural irrigation. The summary article in WQI (Nov/Dec 1998) indicates a similarity with Australian COAG "reforms", emphasising pricing reform, transparency of subsidies, water rights, institutional reforms and preparation of state/pressure/ response environmental indicators. The need for data collection, social considerations or economic distortions through speculation were not covered in the summary. The report is available at www.oecd.org/search.

Extracted from WQI May/June 1999

US EPA to conduct National Beach Surveys
As part of forcing implementation of changes by which beach quality is measured, using E Coli rather than faecal or total coliforms, the US EPA will produce guidance documents, including an assessment of tools for predicting health risks, incorporating exposure factors. A national survey of water quality and improvement measures will be undertaken and the BEACHWatch website is to become a real-time electronic database. However, the EPA will unlikely have the resources to carry out large-scale epidemiological studies to calibrate the models. See www.epa.gov/OST/beaches

Extracted from WQI May/June 1999

WORKING GROUPS

International Association of Hydrogeologists (IAH) Commissions and Working Groups

(from IAH Australian Chapter newsletter vol 15 number 2)

IAH has Commissions, which are focus groups of special hydrogeological interest determined by the members. Sometimes Commission activities are carried out jointly with other organisations such as UNESCO. Eight commissions and 3 working groups are:

- Commission on hydrogeological maps: Dr Wilhelm Struckmeier, email: w.struckmeir@bgr.de
- Commission on hydrogeology of karst: Prof Dr Heinz Hoetzl, email: heinz.hoetzl@bio-geo.uni-karlsruhe.de
- Commission on mineral and thermal waters: Prof. Dr Jan DOWGIALLO, Filtrowa 67 M5, Warszawa 7, 02942, POLAND
- Commission on groundwater protection: Dr. Jaroslav VRBA, Korandova 32, 14700 Prague 4, CZECH REPUBLIC
- Working group on groundwater vulnerability mapping: Dr Jaroslav VRBA - address as above.
- Commission on hydrogeology in developing nations (Burdon Commission): David Ball, email: davidbal@indigo.ie
- Commission on education and training: Dr. John E Moore, 1730 Grape Street, Denver CO 80220, USA.
- Commission on hydrogeology in urban areas: Prof. Ken Howard, email gwater@scar.utoronto.ca
- Commission on computers in hydrogeology: Gary Moore, email: gary_dw_moore@email.msn.com
- Working group on hydrogeology of hard rocks: Jiri Krasny, email krasny @prfdec.natur.cuni.cz
- Working group on artificial recharge: A Ivan Johnson, 7474 Upham Court, Arvada CO 80003, USA

International Association of Water Quality Working Groups

International Working Group on Data and Models (IWGDM) (Chairman: Prof C Maksimovic, EWRE - Environmental and Water Resources Section, Department of Civil Engineering, Imperial College of Science, Technology and Medicine, Imperial College Road, London SW7 2BU, UK; tel +44 171 594 6013; fax +44 171 225 2716; email: c.maksimovic@ic.ac.uk.

Real-Time Control of Urban Drainage Systems (RTCUDS) Working Group
Chairman: Dr. A. Khelil, Institute for Water Quality Control and Waste Management, Technical University of Munich, Am Coulombwall, D-85748 Garching, Germany; tel +49 89 2892 5278; fax +49 89 2892 2799; email: khelil@wga.bauwessen.tu-muenchen.de.

Sewer Systems and Processes Working Group
Chairman: Prof Richard Ashley, Wastewater Technology Centre, University of Abertay Dundee, Bell Street, Dundee DD1 IHG, UK; tel +44 1382 308 160; fax +44 1382 308 117; email r.ashley@tay.ac.uk; Group homepage www.sspwg.civil.auc.dk

Working Group on Source Control for Stormwater Management
Chairman: Govert Geldof, Tauw Civiel en Bouw by, P.O. Box 830, 7400 A V Deventer, The Netherlands; fax +31 570 699 333; email gdg@tauw.nl.

Working Group on Urban Rainfall
Chairman: Dr Thomas Einfalt, Hydrotec Environmental Engineers, Bachstr 62-64, D-52066 Aachen, Germany; tel +49 241 946 8940; fax. +49 241 506 889; email t.einfalt@hydrotec.de. Group homepage http://iswws3.bau-verm.uni-karlsruhe.de/GUR/.

Technology Exchange, Transfer and Training Working Group
Chairman: Jozsef Gayer, Vikuti Rt, PO Box 27, Budapest H-1453, Hungary; tel 361 215 61 40; fax 361 216 15 14; email jgayer@attmail.com. Group homepage: www.datanet.hu/hydroinfo/vituki/int/tett.htm

Urban Drainage in Cold Climate
Contact Dr. Maria Viklander, Div of Sanitary Engineering, Luleå University of Technology, SE-971 57 Luleå, Sweden; tel 46 920 91634; fax 46 920 91493; email maria.viklander@sb.luth.se.

Extracted from newsletter no 12 of the IAHR/IAWQ Joint Committee on Urban Drainage, November 1998

WEB DIRECTORY

Stormwater drainage Best Management Practice database/survey initiated by the Ontario Environmental Office of the Ministry of Transportation, Canada www.chi.on.ca, more specifically http://www2.chi.on.ca/bmpstructural.html and http://www2.chi.on.ca/bmpsurvey.html; email info@chi.on.ca; fax +1 519 767 2770. The manual has been updated and information can be obtained from Jonathan P'ng at Province of Ontario at pngjo@ene.gov.on.ca

Texas University site has an interactive selection for a pollution control BMP, where one types in what is known about water quality, and an optimised solution is suggested www.txnpsbook.org more specifically http://www.txnpsbook.org/BMPs/URBMPS.htm

Urban Drainage Modelling conference 98*: summary at* http://ewre-www.cv.ic.uk/udm98.htm#summary

(Abstracted from IAHR/IAWQ Joint Committee on Urban Drainage Newsletter no 12 November 1998)

Bibliography of urban hydrogeology

An online database of references to literature relating to urban hydrogeology is currently maintained at www.lib.chalmers.se/extern/CGUA

Areas of interest include:

- urban hydrogeology in general;
- stormwater treatment;
- hydrogeological properties of urban geology;
- geochemical properties of urban waters, as related to pollution, effects on constructions etc;
- clean-up of polluted waters in urban areas;
- urban expansion effects on hydrogeology.

The database custodians from the Chalmers University of Technology, Sweden (Per Thernquist, per@lib.chalmers.se and Chester Svensson, chester@geo.chalmers.se) would appreciate any contributions of references. Online forms are available for direct data input as well as for querying the database.

Urban groundwater database

Brief descriptions of cities and their groundwater issues, contacts and references can be accessed at www.clw.csiro.au/UGD. The database relies on user contributions, and has facilities for you to input data. The database is looking for more data entries, especially from Australia.

Joint Universities Masters Program in Hydrology (JUMP)

The JUMP program combines the hydrological expertise of the three major tertiary educational institutions in South Australia, www.scieng.flinders.edu.au/teaching/Hydrology/Hydrology.htm

Government environment agencies

NSW. Department of Land and Water Conservation: offices, community-based programs, fact sheets and media releases www.dlwc.nsw.giv.au

Northern Territory. Water Resources Division, Department of Lands, Planning and Environment www.nt.gov.au

Queensland. Department of Natural Resources (includes site for Great Artesian Basin) www.dnr.qld.gov.au

Victoria. Department of Natural Resources and Environment. Downloadable borehole data on 1:250 000 map sheet basis. www.nre.vic.gov.au

AusGEO News, newsletter of the Australian Geological Survey Organisation: www.agso.gov.au/information/ausgeonews

Database on Australian geological nomenclature and classifications (including groundwater). http://agso/gov.au/information/structure/isd/database/lookups.html

LAWNads email newsletter covering advertisements in land and water management. Free to subscribers by sending a blank email to lawnads-list-subscribe@webmedia.com.au. To place an advertisement contact Chris Duigan tel 8388 5608; fax 8388 5372, email LAWNads@webmedia.com.au

Hydrologic sites

KESAB Watercare Club

Dead fish game www.cwmb.sa.gov.a/kwc/coastalenvironments/game

Institute for Sustainable Futures. Includes programs on water efficiency and least cost urban systems *www.isf.uts.edu.au*

CSIRO including urban water systems program *www.dcbe.csiro.au*

CRC Catchment Hydrology publications and videos include salinity, waterway management, forest hydrology, urban hydrology, flood hydrology, technology transfer and *Field measurement techniques in hydrology.* Free newsletter. www.catchment.crc.org.au

International Association of Hydrogeologists-Working group on hydrogeology of hard rocks www.natur.cuni.cz/IAH

Stockholm Water Institute www.siwi.org

British Hydrological Society www.salford.ac.uk/civils/BHS

Institute for hydrology *(United Kingdom)* www.nwl.ac.uk/ih

German Rainwater Institute www.behaelterverband.de/regenwasser.html

Environmental sites, including extensive listings of organisations, education, reference and software www.lycos.com/wguide/network/net_484491.html

Environment Australia's EnviroNET is a network of databases which has information on industry expertise, environmental technologies, education, research and development. www.environment.gov.au/net/environet.html

International Environmental Technology Centre (IETC) under the United Nations Education Program: Environmentally sound technologies for sustainable development of cities and of freshwater basins www.unep.or.jp

Climate change newsletter of the Bureau of Rural Sciences (Commonwealth Government) www.brs.gov.au/brs/ccs/ccn.html

Australian Greenhouse Strategy www.greenhouse.gov.au/pubs/ngs/ngs.html *with reference to* ***National Carbon Accounting System*** workshop at www.greenhouse.govc.au/au/ncas

Climate change and water management in the Macquarie River Region *at* *www.environment.gov.au/portfolio/esd/climate/fs_macq.html*

Climate of 1998: Annual Review from National Climate Data Center, National Oceanic and Atmospheric Administration www.ncdc.noaa.gov/ol/climate/research/1998/ann/ann98.html#overvie. From UK www.meto.gov.uk/sec1/MOPR/PR19981217.html

CSIRO Atmospheric Research Fine resolution climate change scenarios *for New South Wales* www.dar.csiro.au/res/cm/nsw98long12.pdf

Local land cover change *('hotspots') affecting global climate* www.lucc.es/

Miscellaneous sites:

Australian Bureau of Statistics www.abs.gov.au Basic statistics for each State, key national indicators ABS product release details and general information.

Performance of ***government trading enterprises*** www.pc.gov.au/

Database of research on water conservation and efficient use www.detr.gov.uk

Watergame for children by WaterAid charity www.wateraid.org.uk/game

World Water Council www.worldwatercouncil.org

Sulabh International Museum of Toilets www.sulabhtoiletmuseum.org

CSIRO urban water project to identify achievement of more sustainable urban water systems, whilst reducing costs. Useful models at www.dbce.csiro.au/=urbanwater

Regulations for more efficient water systems, including dual flush toilets, in United Kingdom www.global-utilities.com/

More efficient agricultural systems promoted by New South Wales Department of Agriculture through incentives, training and loans at http://agric.nsw.gov.au/waterwise

Australian spatial data directory www.environment.gov.au/net/asdd/

Institution of Engineers, Australia www.ieaust.org.au

Universities water information network: links to many water related organisations and list of events www2.unwin.siu.edu/watersites/browse.html

Australia Institute www.tai.org.au

Elsevier publications

Advances in Water Resources. Free until 1/9/99 then to individuals whose institutions subscribe to the print edition at www.elsevier.nl/locate/advwatres or www.elsevier.com/locate/advwatres

Computers and geosciences online www.elsevier.nl/locate/cgonline (free demo sample for non-subscribers)

Contents Direct free alerting service of Elsevier journal contents by email at www.elsevier.nl/locate/ContentsDirect
Journal of agricultural water management www.elsevier.com/locate/agwat
Journal of contaminant hydrology www.elsevier.nl/locate/jconhyd
Journal of hydrology www.elsevier.nl/locate/jhydrol or www.elsevier.com.locate/jhydrol Individuals at institutes that subscribe to the Journal of Hydrology have free access once they have registered. Authors have access for 6 months – see homepage.
Journal of science and technology www.elsevier.nl/locate/jnlnr/00464
ScienceChannel free news, views, hot topics and daily updates www.sciencechannel.nl
www.elsevier.nl/locate/agrformet

Journal of urban technology *www.carfax.co.uk/jut-ad.htm*

Mailbases
Low cost sewerage discussion forum to promote collaborative working icsewerage@mailbase.ac.uk
Waste stabilisation ponds: to promote ponds as part of the greening of rural wastewater treatment works and safe reuse for crops: wsponds@mailbase.ac.uuk
Sustainable water management including appropriate and affordable collection, treatment and disposal, particularly those which encourage recycling and reuse, and planning and regulation wastewater-management@mailbase.ac.uk
Further details www.mailbase.ac.uk

International groundwater chat line GROUNDWATER@ias.champlain.edu

Urban drainage electronic mail discussion list: www.mailbase.ac.uk/lists/urban-drainage

Mount Lofty Ranges Catchment Program projects, events, staff and interactive maps at www.mlrcp.sa.gov.au

SOFTWARE

Drains: for designing stormwater piping. Download 5 conduit demonstration model at www.watercom.com.au

Dry/wet computer model that predicts ecological changes caused by water diversions from arid zone rivers. It shows how fish and other aquatic animals respond to changes in patterns of flow. Jim Puckridge, CRC for Freshwater Ecology, Department of Zoology, University of Adelaide SA 5005; tel 8303 5689; fax 8303 4364; email jpuckridge@zoology.adelaide.edu.au

Rainman: extensive historical Australian rainfall data, as well statistical predictive tools for rainfall based on the Southern Oscillation Index. www.dpi.qld.gov.au

Hydrogeologic software from Waterloo Hydrogeologic. Demonstration programs at www.flowpath.com

HYDROKIT 98 Groundwater and surface water software on 2 CDs ($US 230 for 2 or $US 140 for groundwater), Includes MODFLOW and linked programs. Contact International Association for Environmental Hydrology (IAEH), PO Box 35324, San Antonio, Texas 78235, USA; fax +1 210 344 9941, email hydroweb@mail.org; web www.hydroweb.com

Internet Café: six modules each dedicated to a particular industry sector outlining typical production process and its potential impacts on air, water, land, energy and worker health and safety. Industries covered include metal finishing, pulp and paper production, mining, municipal solid waste management, leather processing, sugar processing.
Yellow pages on Environmentally Sound Technologies (ESTs): A resource guide to international directories and trade shows dealing with air pollution control, water treatment, waste management, recycling, energy, land and water remediation, noise and vibration control, monitoring, services. See UNEP IE website or contact Laura Williamson at UNEP IE.

Modifications to MODFLOW to include density variations in groundwater *(with particular reference to the River Murray).* AGSO Record 1997/37. Ross Brodie, AGSO, tel (02) 6249 9396; fax (02) 6249 9985; email rbrodie@agso.gov.au

Rainwater tank/infiltration demonstration program (in German) from Professor Sieker at the University of Hannover at www.sieker.de/natrwbew.htm

HARDWARE

Information about report on ***The role of publicly-funded research and publicly-owned technologies in the transfer and diffusion of environmentally sound technologies*** produced by the UNCTAD, UNEP and the UN Division for Sustainable Development – Division of Economic and Social Affairs. Contact Mr Rae-kwon Chung, Counsellor, Permanent Mission of the Republic of Korea in the United Nations, tel +1 212 715 2229; fax +1 212 371 8873

South Australian reclaimed water use guidelines now available from South Australian Environment Protection Agency. Contact Ms Alverna Ballard tel 8204 2009; fax 8204 9393; email aballard@dehaa.sa.gov.au

National Water Quality Management Strategy
Two more documents, of particular interest to South Australia, have been released, bring the total to 21. These are:

- ***Implementation Guidelines***: describing the steps to manage fresh and coastal waters, from preparation of water quality management plans and community communication (free).
- ***Effluent management guidelines for Australian wineries and distilleries*** ($18)

They are produced by the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), and Australian and New Zealand Environment and Conservation Council (ANZECC).

Copies are available from AFFA Shopfront, GPO Box 858, Canberra ACT 2601; tel 1800 020 157 or Commonwealth Government Bookshops

Revised ANZECC guidelines for fresh and marine waters draft www.affa.gov.au/nwqms

Sediment management industry seminar video: lessons from the Tarago Reservoir Catchment Study. CRC for Catchment Hydrology, tel (03) 9905 2704; fax (03) 9905 5033; email virginia.verrelli@eng.monash.edu.au

Stream rehabilitation manual for Australian streams (Program Leader Peter Hairsine) and video *Rehabilitating streams in your catchment – priorities and possibilities* (Dr Ian Rutherford, Prof Sam Lake and Dr Peter Breen): www.lwrdcc.gov.au or Virginia Verrelli at Cooperative Research Centre for Catchment Hydrology tel (03) 9905 2704

Water quality – guidance on sampling from Standards Australia Standards AS/NZ 5667:1998 www.standards.com.au

Interactive GIS database on River Murray disposal basins. $15 +pp from Ross Brodie, AGSO, tel (02) 6249 9396; fax (02) 6249 9985; email rbrodie@agso.gov.au

Remote sensing to discover potential water sources in arid areas (case study in Northern Territory) by AGSO: Record 1997/45. $60+pp. Contact Gerry Jacobson tel (02) 6249 9758; email gjacobso@agso.gov.au

Sydney Water's quarterly report on water quality, measuring 70 parameters from catchment to tap daily compiled for three month period is now available at www.sydneywater.com.au. The site has a postcode search facility that indicates the source water for that area and a tracking of water quality changes.

Loving and loathing
Why are engineers so unloved? Samuel Florman, an American civil engineer, has come up with some answers in *The Existential Pleasures of Engineering* (Souvenir Press, £10·99, ISBN 0 285 63287 6). The engineer, he says, is seen as the archetypal technologist in an era when "technology" is a word of evil implication, identified with weaponry, greed and environmental degradation. Nothing new there. But Florman's response, first published in 1976 and now reissued, goes on to explore the challenging compromises, and compromising challenges, that confront the profession every day. Not bad thinking--for on engineer.

Extracted from New Scientist 30/9/95
[not bad thinking - for a science magazine (Ed.)]

SEMINARS

HYDSOC SEMINARS

All seminars are at the Charles Hawker Auditorium, Waite Institute, Waite Road, Urrbrae, commencing at 5.30 pm for 6.30 to 8.00 pm except as noted. The audience is invited to join the guest speaker at dinner afterwards.

Tentative program for 1998 is listed in the following table. Please take note of changes as advised by the flyer prior to the meeting.

Date 1999	Subject	Speaker
19 August (AGM)	Riparian zone management	Sharon Rixon, Department for Environment Heritage and Aboriginal Affairs
21 October (Waterweek) half day seminar	Living with water: supply, security, surplus, sustainability (to be held at Australian Mineral Foundation, Conyngham Street, Glenside)	various
21 October	Hydsoc Oration and dinner	

World Water Day 22 March 1999
5 June World Environment Day
National Water Week: Sunday 19/10/99 to Saturday 25/10/99
6 December Ocean Care Day

DEPARTMENT FOR ENVIRONMENT, HERITAGE AND ABORIGINAL AFFAIRS 1999 ENVIRONMENT POLICY TECHNICAL SEMINAR SERIES

In the South Australian Water Corporation "Australia-Asia Centre", Level 4, Australis House, 77 Grenfell Street, Adelaide 10.15 am for 10.30 am to 11.45 am. Please verify the program prior to the date as it is subject to change without notice. Please verify the program prior to the date as it is subject to change without notice. Telephone (08) 8204 9129, email bvanderwel@dehaa.sa.gov.au

18 August	National Environment Protection Measures (NEPM)	*Leanne Burch/Jo Bishop*
15 September	Local Agenda 21	*Maggie Hine*
20 October	Murray-Darling Basin update	*Claus Schonfeldt*
17 November	Anti-fouling paints and ballast water: environmental dilemmas	*Ian Kirkegaard*
15 December	Landscape evaluation	*Andrew Lothian*

AUSTRALIAN WATER QUALITY CENTRE, BOLIVAR.

Tuesdays at 10.30 am at Bolivar Wastewater Treatment Plant, Hodgson Road, Bolivar

Attendance from people outside of the Australian Water Quality Centre is welcomed. Please advise the AWQC If you are interested in coming to give an idea of numbers and to ensure that you are informed of any adjustments that may have been made to the program.

CONFERENCES and WORKSHOPS

An electronic version of this newsletter is available for easier access to email addresses and web sites.

Date	Title	Organiser	Location	Abstracts close	Contact
to be decided	Dryland salinity	Centre for Groundwater Studies	Adelaide and Perth	na	
03 8 99	Australian Standard/NNZS 4020:1999 and HB131-1999: Products in contact with drinking water	Standards Association of Australia	Adelaide (seminars in other locations on other dates)		Seminar Services, Locked Bag 802; South Melbourne Vic 3205; tel (03) 9693 3502; fax (03) 9696 1319
03 04 8 99	Pumps 99 – pumps, systems and controls expo		Melbourne Vic		Michael Percy, Exhibitor Services, tel (02) 9894 8911; fax (02) 9894 8533; email Exhibition@exhibitorservices.com.au; web www.exhibitorservices.com.au
06 -11 8 99	Decision support systems in water engineering				Hawkesbury Technologies, tel (02) 4570 1690; fax (02) 4570 1520
09 -12 8 99	9th Stockholm water symposium: urban stability through integrated water-related management		Stockholm, Sweden		Symposium secretariat, Stockholm Water Symposium, SE-106 36, Sweden; tel +46 8 736 2021; fax +46 8 736 2022; email sympos@siwi.org
9 -15 8 99	ECSA-Climate impacts on coast and estuaries		Hamburg, Germany		Prof Jürgen Sündermann, ZMK, Bundestraße 55, 20146 Hamburg, Germany; email suendermann@ifm.uni-hamburg.de
12 8 99	Urban drainage modelling for design and analysis – XP-UDD workshop	XP Software	Sydney NSW	na	XP Software Pty Ltd, tel (02) 6235 1844; fax (02) 6235 1847; email sales@xpsoftware.com.au
18 -21 8 99 23 -24 8 99	Water resources modelling 1 Water resources modelling 2	UNSW School of Civil and Environmental Engineering	Sydney NSW	na	Gillian Phillips, UNSW School of Civil and Environmental Engineering, tel (02) 9385 5091; fax (02) 9385 6139; email gphillips@unsw.edu.au
18 -20 8 99	Physical aspects of contaminated groundwater	UNSW School of Civil and Environmental Engineering	Sydney NSW	na	Gillian Phillips, UNSW School of Civil and Environmental Engineering, tel (02) 9385 5091; fax (02) 9385 6139; email gphillips@unsw.edu.au
22 -24 8 99	First European Seminar on Environmental Engineering Education		Zurich, Switzerland		Professor Willi Gujer; tel +41 1 6333067; fax +41 1 6331061; email eee99:eawag.ch
22 -26 8 99	The International Congress on Local Government Engineering and Public Works incorporating the 10th National Local Government Engineering Conference	Institute of Municipal Engineering Australia, Institution of Engineers, Australia, International Public Works Federation	Sydney NSW	closed	Congress Secretariat, ICMS Australasia Pty Ltd, GPO Box 2609, Sydney NSW, tel (02) 9241 1478; fax (02) 9251 3552; email imea@icmsaust.com.au; web site www.imea.asn.au/national/conference/
23 -25 8 99	Chemical and biological aspects of contaminated groundwater	UNSW School of Civil and Environmental Engineering	Sydney NSW	na	Gillian Phillips, UNSW School of Civil and Environmental Engineering, tel (02) 9385 5091; fax (02) 9385 6139; email gphillips@unsw.edu.au
23 -27 8 99	28th IAHR Congress	IAHR	Graz, Austria		Christa Spanner, Joanneum Research, XXVIII IAHR Congress, Steyrergasse 17, A-8010 Graz, Austria; tel 43 316 876 1100; fax +43 316 876 1404; email iahr@joanneum.ac.at
24 -27 08 99	High altitude and sensitive ecological environmental geotechnology		Nanjing, China		Eleanor Nothfelfer, Fritz Engineering Laboratory, Lehigh University, 13E packer Avenue, Bethlehem, PA 18015-3176, USA; tel +1 610 758 3520; fax +1 610 758 6405; email esn0@lehigh.edu

Date	Title	Organiser	Location	Abstracts close	Contact
26 -28 8 99 (tentative)	Training workshop on rainfall	International Association of Water Quality	Kuala Lumpur, Malaysia		Dr. Hj. Mohd. Nor bin Hj. Mohd. Desa, Director, The Regional Humid Tropics Hydrology and Water Resources Centre for Southeast Asia and the Pacific, c/o Department of Irrigation and Drainage Malaysia, Km. 7, Jalan Ampang, 68000 Ampang, Kuala Lumpur, MALAYSIA, Tel: 603 4566852/ 4562657/ 4561894; Fax: 603 4561894, E-mail: ips33@pop.moa.my
30 8 99 03 9 99	8th International conference on Stormwater Drainage and Trade Exhibition	International Association of Water Quality	Sydney NSW		BICUSD Conference Secretariat, The Organising Group, Suite 1, 470 Sydney Road, Balgowlah, NSW 2093; tel (02) 9949 4933; fax (02) 9949 3905; email orggroup@orgroup.aust.com
30 8 99 03 9 99	25th WEDC Conference: Integrated development for water supply and sanitation		Addis Ababa, Ethiopia		Dr John Pickford, WEDC, Loughborough University, Leicestershire LE11 4TU, United Kingdom; tel +44 1509 222390; fax +44 1509 211079; email j.a.pickford@lboro.ac.uk
9 99	Control and prevention of odours in the water industry	The Chartered Institution of Water and Environmental Management and IAWQ	London, United Kingdom	closed	Erica Hammond, Terence Dalton Events, 47 Water Street, Lavenham, Suffolk CO10 9RN, United Kingdom; tel 01787 248097; fax 01787 248267; email erica@lavpress.demon.co.uk
01 -03 9 99	2nd Inter-Regional conference on environment and water		Lausanne, Switzerland		Ecole Polytechnique Federale de Lausanne, IATE-HYDRAm, 1015 Lausanne, Switzerland
05 10 9 99	Infrastructure 99		Hong Kong, China		Secretariat, Infrastructure99, tel (03) 9647 9799; fax (03) 9646 3427; web www.infraconf.com.au
6 -10 09 99	XXIX congress of IAH: hydrogeology and land use management	International Association of Hydrogeologists	Bratislava, Slovakia,		Marian Fendek, Geological Survey of Slovak Republic, Mlynska dolina 1, 81704 Bratislava, Slovakia; tel +421 7 370 5355; fax +421 7 371 940; email iahcongr@gssr.sk; web petra.fns. uniba.sk/iah99
07 -10 9 99	Exposure assessment: its role in ecotoxicology		Cardiff, United Kingdom		Mrs J Goodwin, Unilever Research Laboratory, Port Sunlight Laboratory, Quarry Road East, Bebington, Wirral, Merseyside L63 3JW, United Kingdom; tel +44 151 641 3208; fax +44 151 6411853
08 -10 9 99	Floodplains. Risks and rewards. Victoria's inaugural flood management conference		Wangaratta		Roel von't Steen, North East CMA; tel (02) 6055 6133; fax (02) 6055 6119; email necma@albury.net.au
08 -10 9 99	Estuarine processes	UNSW School of Civil and Environmental Engineering	Sydney NSW	na	Gillian Phillips, UNSW School of Civil and Environmental Engineering, tel (02) 9385 5091; fax (02) 9385 6139; email gphillips@unsw.edu.au
08 -10 9 99	Applied groundwater modelling	UNSW School of Civil and Environmental Engineering	Sydney NSW	na	Gillian Phillips, UNSW School of Civil and Environmental Engineering, tel (02) 9385 5091; fax (02) 9385 6139; email gphillips@unsw.edu.au
9 -10 9 99	International conference on environmental engineering		Cartagena, Spain		99-ICEE Secretariat, Department of Chemical Engineering Cartagena, 44 Paseo de Alfonso XIII, 30203 Cartagena, Murcia, Spain; tel +34 968 325562; fax +34 968 325433; email joriia@plc.um.es
11 -19 9 99	Water and agriculture in the next millennium		Granada, Spain		ICID-CIID 48 Nyaya Marg, Chanakyapuri, New Delhi 110021, India; tel +91 11 611 5679; fax +91 11 611 5962; email icoiad@giasd101.vsnl.net.in

Date	Title	Organiser	Location	Abstracts close	Contact
11 9 99	Advances in environmental engineering: a symposium in honour of Professor David Jenkins		Berkeley, CA, USA		Professor Slav Hermanowicz, Department of Civil and Environmental Engineering #1710, University of California, Berkeley, CA 94720-1710, USA; fax +1 510 642 7483; email hermanowicz@ce.berkeley.edu
13 -15 9 99	CCWI'99 - Computing and control for the water industry		Exeter, United Kingdom		Dr Dragan Savic, The Centre fro Water Systems, School of Engineering, University of Exeter, Harrison Building, North Park Road, Exeter EX4 4QF, United Kingdom; tel +44 1392 263 637; fax =44 1392 217 965; email CCWI99@exeter.ac.uk
13 -15 09 99	Catchment surface modelling	UNSW School of Civil and Environmental Engineering	Sydney NSW	na	Gillian Phillips, UNSW School of Civil and Environmental Engineering, tel (02) 9385 5091; fax (02) 9385 6139; email gphillips@unsw.edu.au
14 -16 09 99	Murray-Darling Basin groundwater workshop 99		Griffith, NSW	na	Ms Anne Vince, Country Conferences Pty Ltd, PO Box 1365, Armidale NSW 2350; fax (02) 6722 8330
14 -17 09 99	Irrigation expo China '99		Beijing, China		Monica Blume, EJ Krause and Associates Inc Germany, Morsenbroicherweg 191, D-40470 Düsseldorf, Germany; tel +49 211 610 730; fax +49 211 610 7337; email 10635.1040@compuserve.com
15 -17 9 99	Characterisation and treatment of sediments		Antwerp, Belgium		Ms Rita Peys – CATS4 Secretariat, c/- Technologisch Instituut vzw, Desguinlei 214, 2018 Antwerpen, Belgium; tel +32 3 216 0996; fax +32 216 0689; email cats@conferences.ti.kviv.be
17 -20 9 99	WATSAN Vietnam 99		Hanoi, Vietnam		TSC International Exhibition Services, 33 Batrieu str, Hanoi, Vietnam; tel +84 4 9431 264; fax +84 4 8266 649; email vcci.expo@hn.vnn.vn
18 -24 9 99	22nd World water congress	IWSA	Buenos Aires Argentina		AIDIS Argentina, Av. Belgrano I580-3° PISO, 1093 Buenos Aires, Argentina; tel +54 11 3815832; fax +54 11 3815903; email aidisar@aidisar.org.ar
20 -23 09 99	ModelCARE99. International conference on calibration and reliability in groundwater modelling		Zurich, Switzerland		Conference Secretariat ModelCare'99, ETH, Institute of Hydromechanics and Water Resources Management, ETH Hoenggerberg, CH-8093 Zurich, Switzerland; tel +41 1 633 3075; fax +41 1 633 1061; email stauffer@ihw.baum.ethz.ch; web www.baum.ethz.ch/ihw/modelcare/program.html
20 -22 09 99	Integrated drought management – lessons for sub-Saharan Africa		Pretoria, South Africa		Drought Management Conference Planners, PO Box 82, Irene 0062, South Africa
21 -24 9 99	WasteTECH '99 international exhibition and conference on waste management		Moscow, Russia		SIBICO International Ltd. PO Box 173, Moscow 107078, Russia; tel/Fax: +7 095 9753423; email waste-tech@sibico.com
22 -24 9 99	Sustainable groundwater management: groundwater for managers and planners	Centre for Groundwater Studies	Barron Town House Adelaide	na	
22 -24 9 99	Valuing our environment: Dollars and sense. 41st annual conference and expo	NZWWA	Christchurch, New Zealand		1999 NZWWA Conference, PO Box 13880, Onehunga, Auckland, New Zealand; tel +64 9 6363636; fax +64 9 6361234; email water@nzwwa.org.nz
23 -24 09 99	Sustainable groundwater management: groundwater for managers and planners	Centre for Groundwater Studies	Barron Townhouse Adelaide	na	Trevor Pillar or Glenys Jackson. Tel (08) 8303 8700; fax (08) 8303 8730; email cgs.national@clw.csiro.au; web www.clw.csiro.au/CGS

Date	Title	Organiser	Location	Abstracts close	Contact
22 -25 09 99	Landscapes futures. Advances in research for natural resource planning	UNESCO	Armidale, NSW		University of New England fax (02) 9810 6320
29 9 99 01 10 99	13th International conference on pipeline protection		Edinburgh, United Kingdom		Tracey Wheeler, Conference Manager, BHR Group Ltd, Fluid Engineering Centre, Cranfield, Bedfordshire MK43 OJA, United Kingdom; tel +44 1234 750422; fax +44 1234 750074; email twheeler@bhrgroup.co.uk
29 9 99 01 10 99	2nd River Symposium		Brisbane, Qld		www.riverfestival.com.au/symposium.html
08 -10 10 99	Development of innovative water and wastewater treatment technologies for the 21st century	Department of Civil Engineering, Hong Kong University of Science and Technology *et al*	Hong Kong, China		Dr GH Chen, Department of Civil Engineering, Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, China. Tel +852 2358 8752; fax +852 2358 1534; email ceghchen@ust.hk
9 -13 10 99	WEFTEC '99		New Orleans, USA		WEF, 601 Wythe Street, Alexandria VA 22314-1994, USA; tel +1 703 684 2452; fax +1 703 684 2471; email confinfo@wef.org
11 -13 10 99	NO-DIG '99		Budapest, Hungary		NO-DIG '99, Budapest, CCH-Congress Organisation, Matthias Rieger/Christine Vortische, St Petersburgerstr 1, D-20355 Hamburg, Germany; tel +49 40 3569 2244; fax +49 40 3569 2269; email nodig99@cch.de
12 -14 10 99	Pipes Wagga Wagga: A vested interest in pipes with an emphasis on pipeline renewal	Charles Sturt University	Wagga Wagga NSW		Ray Farnham, Pipes Wagga Wagga '99; Department of Residences and Catering, Locked Bag 699, Charles Sturt University, Wagga Wagga, NSW 2678; tel (02) 6933 3875; email rfarnham@csu.edu.au
13 -15 10 99	International conference on urban pollution control technology		Hong Kong		Conference Organiser (ICUPCT), Department of Civil Engineering, The Hong Kong Polytechnic University, Hung Hom, Hong Kong; fax +852 2334 6389; email cecspoon@poly.edu.hk
18 -20 10 99	Asian WATERQUAL'99 – 7th IAWQ Asia-Pacific Regional Conference		Taipei, Taiwan		Prof Shang-Lien Lo, Secretary General, Organising Committee, Graduate Institute of Environmental Engineering, National Taiwan University, 71 Chou Shan Road, Taipei, Taiwan; tel +886 2 362 5373; fax +886 392 28821; email t95070062@ccms.ntu.edu.tw
19 -21 10 99	IWEX '99		Birmingham, United Kingdom		Paul Tweedale tel +44 1895 454540
20 -23 10 99	Environment Japan '99	Japan External Trade Organisation	Osaka, Japan		Fax +81 3 3505 0450
21 10 99	**Living with water: security, sustainability, surplus and supply**	**Hydrological Society of South Australia**	**Adelaide**	**25/6/99**	**Dr David Walker, Department of Civil and Environmental Engineering, University of Adelaide SA 5005. Email dwalker@civeng.adelaide.edu.au**
22 -23 10 99	Water down the track	Australian Water and Wastewater Association	Albury NSW	21/5/99	Water down the track Secretariat, Joe Owzinsky, c/- AWWA, PO Box 1033, Caulfield North Vic 3161; tel (03) 9509 2748; fax (03) 9509 8243;
25 -28 10 99		Geological Society of America	Denver, USA		www.geosociety.org/calendar/1999meet.htm
27 -29 10 99	Aquifer storage and recovery	Centre for Groundwater Studies	Barron Town House Adelaide	na	Trevor Pillar or Glenys Jackson. Tel (08) 8303 8700; fax (08) 8303 8730; email cgs.national@clw.csiro.au; web www.clw.csiro.au/CGS

Date	Title	Organiser	Location	Abstracts close	Contact
02 -06 11 99	MEDCOAST 99 –EMECS 99 Joint Conference		Antalya, Turkey		MEDCOST Secretariat (MEDCOAST 99 –EMECS Joint Conference), Middle East Technical University, 06531 Ankara, Turkey; tel +90 312 210 5429; fax +90 312 210 1412; email medcoast@rorqual.cc.metu.edu.tr
08 -12 11 99	International congress on biometeorology and international conference on urban climatology		Sydney NSW		fax (02) 9262 3135
08 -12 11 99	Civil and environmental engineering conference – new frontiers and challenges		Bangkok, Thailand		Dr AS Balasubramaniam, School of Civil Engineering, Asian Institute of Technology, PO Box 4, Klong Luang, Pathumthani 12120, Thailand; tel +66 2 254 5519; fax +66 2 516 2126; email bala@ait.ac.th
09 -10 11 99	Water reuse and water treatment plant operation		Toulouse, France		Hubert Debellefontaine, Institut National des Sciences Appliquées, GPI-LIPE, Complexe Scientifique de Raguil, 31077 Toulouse Cédex4, France; tel +33 5 6155 9761; fax +33 5 6155 9760; email
09 -12 11 99	European conference on desalination and the environment	European Desalination society and IWSA	Las Palmas, Gran Canaria	closed	European Desalination Society, Miriam Balaban, Science and Technology Park of Abruzzo, Via Antica Arischia, 1, 67100 L'Aquila, Italy; tel +39 0862 3475308; fax +39 0862 3475213; email balaban@sgol.it
10 -13 11 99	Pumps & systems Philippines '99		Manilla, Philippines		HQ Link Pte Ltd, 150 South Bridge Road, #13-01 Fook Hai Building, Singapore 058727; tel +65 53 43588; fax +65 53 42330; email hqlink@singnet.com.sg
12 -15 11 99	Water Expo CHINA L99		Beijing, China		Gloria Li, EJ Krause & Associates Beijing, Room 5207, Zi Yu Hotel, 55 Zeng Guang Road, Hai Dian District, Beijing, 100037 China; tel +86 10 6841 5250; fax +86 10 6841 1728; email ejk@public3.bta.net.cn
16 -17 11 99	Wetlands and remediation		Utah, USA		Battelle fax +1 614 488 5747
18 -19 11 99	CEDA Dredging days		Amsterdam, The Netherlands		CEDA Dredging Association, PO Box 3168, 2601 DD Delft, The Netherlands; tel +31 15 278 3145; fax +31 15 278 7104; email ceda@wbmt.tudelft.nl
20 23 11 99	Hydro 2000: 3rd international hydrology and water resources symposium. Interactive hydrology: interactions between hydrology and climate, environment, economics and society	IE Aust et al	Perth WA		Congress West Pty Ltd, PO Box 1248, West Perth WA 6872; tel (08) 9322 6906; fax (08) 9322 1734; email conwes@congresswest.com.au; web www.ieaust.org.au/hydro2000
22 -24 11 99	1st international congress on Integrating sustainable development into environmental health practice	Queensland University of Technology	Brisbane, Qld		Melissa Stoneham, email mstoneham@qut.edu.au
28 11 99 08 12 99	18th Australian Groundwater School: fundamentals of groundwater; GIS	Centre for Groundwater Studies	Brisbane Qld	na	Trevor Pillar, Centre for Groundwater Studies, Private Bag 2, Glen Osmond SA 5064; tel 8303 8700; fax 8303 8730; email cgs.training@adl.clw.csiro.au; web www.clw.csiro.au/CGS
29 11 99 02 12 99	Sustainable freshwater ecosystems: the new millennium	New Zealand Limnological Society and Australian Society of Limnology	Wairakei, Taupo, New Zealand		Dr IKG Boothroyd, NZLS/ASL Limnology Conference, c/- NIWA, PO Box 11-115, Hamilton, New Zealand; tel +64 7 856 1737; fax +64 7 856 0151; email i.boothroyd@niwa.cri.nz; web rsnz.govt.nz/clan/limsoc/
01 12 99	Water Management Asia 99		Singapore		Regional Institute of Environmental Technology, fax +65 339 5651

Date	Title	Organiser	Location	Abstracts close	Contact
06 -07 12 99	Strategies for treatment for coastal discharges in small communities		Edinburgh, United Kingdom		Zena Hickinson, AE Technology Transfer, School of Civil Engineering, University of Leeds, Leeds LS2 9JT, United Kingdom; tel +44 113 233 2308; fax +44 113 233 2243; email z.hickinson@leeds.ac.uk
13 -17 12 99	Fall meeting	American Geophysical Union	San Fransisco USA		www.agu.org
16 -20 01 00	4^{th} International conference on diffuse pollution		Bangkok, Thailand	15/11/99	Ms Nitayaporn Tonmanee, Department Land Development, Phaholyothin Road, Chatuchak, Bangkok 10900, Thailand. Tel +66 579 0111, ext 1386; fax +662 562 0732; email ldd@mozart.inet.co.th
23 -27 01 00	Water Desalination	Arab school of Science and Technology and the Academy of Scientific Research and Technology (Egypt)	Cairo, Egypt	12/6/99	Prof. Hisham El-Dessouky, Department of Chemical Engineering, Kuwait University; email eldessouky@kuc01.kuniv.edu.kw; fax 965 483 9498; web http://kuc01.kuniv.edu.kw/~hisham/doc1.gif http://kuc01.kuniv.edu.kw/~hisham/doc2.gif http://kuc01.kuniv.edu.kw/~hisham/doc3.gif http://kuc01.kuniv.edu.kw/~hisham/doc4.gif
30 01 00 02 02 00	Water reuse 2000	American WWA			American WWA fax +1 303 794 7310
16 -18 02 00	Particle removal from dams and reservoirs	IAWQ/IWSA Joint Specialist Group on Particle Separation	Durban, South Africa		Prof KJ Ives, IAWQ, Duchess House, 20 Mason's Yard, Duke Street, St James's, London SW1 6BU, United Kingdom. Tel +44 171 839 8390; fax +44 171 839 8299; email d-taylor@iawq.org.uk
19 -25 02 00	10^{th} Congress UAWS/UADE		Durban, South Africa		Fax +27 226 242629
22 -25 02 00	Congress of the Union of African Water Suppliers				
03 00	First World Water Forum	World Water Council	The Hague, The Netherlands		World Water Council Secretariat, Les Docks de la Joliette, Atrium 103, 10 place de la Joliette, 13304 Marseille Cedex 2, France; tel +334 91 994100; fax +334 91 994101; email wwc@worldwatercouncil.org; web www.worldwatercouncil.org
02 -05 03 00	International Landcare 2000 conference		Melbourne, Vic		Fax (03) 9690 7155
11 -17 03 00	Xth World Water Congress	International Water Resources Association	Melbourne, Vic		ICMS Pty Ltd, 84 Queensbridge Street, Southbank Vic 3006; tel (03) 9682 0244; fax (03) 9682 0288; email worldwater@icms.com.au. Web www.icms.com.au/worldwater/
17 -25 03 00	Water 2000	WEF, NZWWA, IPENZ, RSNZ	Auckland, New Zealand		New Zealand Water & Wastes Association, PO Box 15-974, New Lynn, Auckland New Zealand; tel +64 9 827 5757; fax +64 9 9827 20003; email water@nzwwa.org.nz
04 -07 04 00	Wastewater treatment: standards and technologies to meet the challenges of the 21^{st} century (CIWEM Millennium Conference)		Leeds, United Kingdom		Zena Hickinson, AE Technology Transfer, School of Civil Engineering, University of Leeds, Leeds LS2 9JT, United Kingdom; tel +44 113 233 2308; fax +44 113 233 2243; email z.hickinson@leeds.ac.uk
04 09 04 00	AQUA-EXPO: Water, the source of life		Paris, France		OREXPO, 2 bis rue Jules Breton, 75103 Paris, France; tel +33 1 4535 7681; fax +33 1 4327 5009; email aqua-expo.ja@wanadoo.fr

Date	Title	Organiser	Location	Abstracts close	Contact
09 -13 04 00	WaterTECH: Greater expectations; Greenhouse: sustainable environmental management; Fifth Australian waste convention	Australian Water and Wastewater Association. Waste Management Association of Australia et al	Sydney NSW	27/8/99 6/9/99 17/9/99 ?	Quitz Pty Ltd, PO Box 632, Willoughby, NSW 2068; email: quitz@dot.net.au; fax (02) 9415 1599
07 -11 05 00	Salt 2000, 8th world salt symposium		The Hague, The Netherlands		Secretariat 8th World Salt Symposium, PO Box 25, 7550 GC Hengelo Ov, The Netherlands; tel: +31 74 2443908; fax: +31 74 2443272; email: Salt.2000@inter.NL.net
08 -10 05 00	The international symposium on groundwater 2000 –IAHR		Omiya, Japan		c/o Hydroscience and Geotechnology Laboratory, Saitama University, 255 Shim-okubo, Urawa 338-8570, Japan; tel +81 48 855 3568; fax +81 48 855 1378; email iahr@hql.saitama-u.ac.jp; web www.hql. saitama-u.ac.jp/iahr-saitama/index.html
23 -25 05 00	TraM'2000 international conference on tracers and modelling in contaminant hydrology		Liège, Belgium		TraM'2000, LGIH, University of Liège, B19 Sart-Tilman, 40000 Liège, Belgium; tel +32 4 366 2216; fax +32 4 366 2817; email adassarg@lgih.ulg.ac.be
23 -26 05 00	Managing water and wastewater in the new millennium		Johannesburg, South Africa	31/8/99	Roelein-M Bakkar, IWA Conference, PO Box 6011, Halfway House 1685, South Africa; tel +27 11 05 6368; fax +27 11 315 1258; email conference@wisa.co.za; web www.iawq.org,uk/conpage.htm
24 -27 05 00	H2O Accuduco – International exhibition on water technology		Ferrara, Italy		Ferrara Fiere SRL; via Bologna 534, 44040 Chiesuol del Fosso (Ferrara), Italy; tel +39 532 900713; fax +39 532 976 997; email fefiere@sestantenet.it
28 05 00 01 06 00	WISA 2000 Biennial Conference		Sun City, South Africa		Roelein-M Bakkar, IWA Conference, PO Box 6011, Halfway House 1685, South Africa; tel +27 11 05 6368; fax +27 11 315 1258; email conference@wisa.co.za; web www.iawq.org,uk/conpage.htm
06 -08 06 00	Groundwater 2000 – international conference on groundwater research		Copenhagen, Denmark		Groundwater 2000, MiaCon Meeting and Conference Services, Heksingevej 23, DK-2830 Virum, Denmark; tel +45 45 859727; fax +45 839727; email: gw2000@isva.dtu.dk; web www.isva.dtu.dk/grc/lgw2000
25 -29 06 00	8th international conference on flow .analysis		Warsaw. Poland		Professor Marek Trojanowicz, Department of Chemistry, University of Warsaw. Pasteura 1, 02-093 Warsaw, Poland; tel/fax +48 22 822 3532; email trojan@chem.uw.edu.pl
03 -07 07 00	Paris 2000: 1st World Congress of the International Water Association, including the 3rd International symposium on wastewater reclamation, recycling and reuse and health-related water microbiology symposium	IAWQ	Paris, France	1/9/99 (full paper required) 15/1/00 poster	Addresses vary according to theme and oral or poster presentation. See web page www.aghtm.org or www.iawq.org.uk email aghtm@aghtm.org or Alan Click email aclick@iawq.org.uk
03 07 07 00	IWSA World Congress 2000		Paris, France		AGHTM, 83 Avenue Foch, BP 3916, 75761 Paris cedex 16, France; tel +33 1 3570 1353; fax +33 1 5370 1340; email aghtm@aghtm.org
04 -6 07 00	URBAN 21		Berlin. Germany		Federal Office for Building and Regional Planning, URBAN 21, Am Michaelshof 8, D-53177 Bonn. Germany; tel +49 228 826 315; email info@urban21.de
31 07 00 04 08 00	Joint meeting ALHSUD-ABAS-IAH		Forteleza, Brazil		ABAS Ceara Chapter, Avienda Santos Dumont, 7700 Papicu, Forteleza, CEP 60 150-163, Brazil; tel +55 85 2651288; fax. +55 85 2652212; web www.abasce. com.br

Date	Title	Organiser	Location	Abstracts close	Contact
06 -16 08 00	31st international geological congress. Geology and sustainable development: challenge for the third millennium		Rio de Janeiro, Brazil		Sec. del 31 IGC, Av. Pasteur, 404, Urca, Rio de Janeiro, CP22.290-240, Brazil; tel +55 21 295 5847; fax +55 21 295 8094; email 3ligc@3ligc.org.br; web: www.3ligc.org.br
?? 08 00	Hydrogeology 2000 – Workshop on the latest developments of methods and techniques in hydrogeology		Amsterdam, The Netherlands		IAH Netherlands National Committee, Erik Romijn, Mariënbergweg 1, 6862ZL. Oosterbeek, The Netherlands; tel +31 26 339 06 40; fax +31 26 339 06 41
17 -21 08 00	Environmental geotechnology and global sustainable development		Belo Horizonte, Brazil		Symposium Secretary, 5th International Conference on Environmental Geotechnology, Departamento de Engenharia de Transportes e Geotecnia, Escola de Engenharia da Universidade Federal de Minas Gerais, Avenida do Contorno, 842 sala 104, Belo Horizonte, Minas Gerais, CEP 30 110 –060, Brazil; tel +55 31 238 1793; fax +55 31 238 1742; email cassia@etg.ufmg.br
17 -27 09 00	Karst 2000, 6th international symposium and field seminar		Marmaris, Turkey		Dr Gültekin Günay, UKAM, Hacettepe University, Beytepe Campus, Ankara, 06532 Turkey; tel +90 312 235 2543; +90 312 235 2862; web www.karst.hun.edu.tr
18 -20 09 00	WATERMATEX 2000 - systems analysis and computing in water quality management	International Association on Water Quality	Gent, Belgium	1/2/2000	Professor Peter Vanrolleghem, BIOMATH Department, University of Gent, Coupure Links 653, B-9000 Gent, Belgium; tel +32 9 264 5932; fax +32 9 223 4941; email Peter.Vanrolleghem @ rug.ac.be
25 -28 09 00	Pumps and systems Asia 2000		Singapore		HQ Link Pte Ltd, 150 South Bridge Road, #13-01 Fook Hai Building, Singapore 058727; tel +65 53 43588; fax +65 53 42330; email hqlink@singnet.com.sg
23 -27 10 00	XXXth congress of hydrogeologists	International Association of Hydrogeologists	CapeTown, South Africa		Christine Colvin, email ccolvin@csir.co.za; tel +27 21 887 5101; fax: +27 21 883 3086
19 -24 11 00	GeoEng 2000 - international conference on geotechnical and geological engineering		Melbourne, Vic		Conference Secretariat GeoEng 2000, c/- ICMS Pty Ltd, 84 Queensbridge Street, Southbank, Vic 3006; tel: (03) 9682 0244; fax (03) 9682 0288; email geoeng2000@icms.com.au; web www.eng.monash.edu.au/discipln/mgg/geo2000.htm
25 -29 02 01	2nd international conference in interactions between sewers, treatment plants and receiving water in urban areas (INTERURBA II)		Lisbon, Portugal		INTER URBA II Conference Secretariat, Instituto Superior Técnico, Departamanto de Engeharia Civil, Av. Rovisco Pais, 1096 Lisboa Codex, Portugal; rel +351 1 841 7650; fax +351 1 849 7650; email gaby@civil.ist.utl.pt; web www.iawq.org.uk/conpage.htm
06 -08 06 01	3rd Black Sea conference		Varna, Bulgaria		Dr Atanas Pakalev, 22 "Maria Luiza str, floor 3, room 23, 1505 Sofia, Bulgaria; tel/fax +359 2 980 3547; email watergl@ttm.bg; web www.iawq.org.uk/conpage.htm

Ian Laing prize

The 1998 Ian Laing prize was presented to Mr Ian Burns from the University of Adelaide, who was then in his 4th year at Civil Engineering.

The Ian Laing prize is a cash award by HYDSOC in honour of Ian Laing, an engineer with the Water Resources Group of the Engineering and Water Supply Department (now SA Water) and outstanding student in Civil Engineering at the University of Adelaide, who died prematurely in the mid 80s.

Submissions are being reviewed for the 1999 Ian Laing Prize. Contact Paul Pavelic, telephone 8303 8741 (work) or 8410 0096 (home).

Update on the Constitution by Bill Lipp

Following the review and subsequent membership approval of amendments to the constitution, which all took place some time back, the final steps have now been taken and the updated constitution registered with the Corporate Affairs Commission.

The significant changes of interest are

- There is now provision for associates of full members (ordinary and life) to join the Society. These members carry no voting rights and it is intended for partners etc who may wish to join and participate in the activities of the Society.
- The procedures for elections to the Committee have been clarified and greater flexibility provided to the Committee to fill vacant positions on the Committee.
- Simplifies the meeting procedures of the Society. The only formal meeting of the Society every year is the Annual General Meeting unless another General Meeting is called. The normal bi-monthly technical meeting is not a General Meeting in terms of the Associations Incorporation Act and hence there is no need to keep minutes etc.
- Any General Meetings, whether the Annual General Meeting, a General Meeting called by the Committee or a General Meeting called by the membership are all placed on an equal basis as regards quorums and the requirement of a simple majority to pass all resolutions, including amendments to the Constitution.
- Allows for the establishment of Regional Groups if there is sufficient interest in any particular regional area to form such a group.

A full copy of the constitution is available to any interested member. Please contact me on 8343 2508 to obtain a copy.

HYDSOC accounts 97/98

HYDSOC made a profit of $ 2258 in the financial year ending 1998, substantially from the proceeds of the seminar *Stormwater in the next millennium*. Total revenue was $ 9336, of which $ 2430 was from membership subscriptions. Total accumulated funds year-end 98 were $ 12 250.

Biographical publications

A request for the membership list of HYDSOC has been received by, and declined to be provided to, International Biographical Centre, Melrose Press Ltd, St Thomas Place, Ely, Cambridgeshire CB7 4GG, United Kingdom; fax +44 1353 646601; email info@melrosepress.co.uk for publication in their Who's Who free of charge. Any members wishing to avail themselves of a listing, please contact the publishers direct.

HYDSOC submission on review of water-related legislation

HYDSOC made a submission on discussion papers prepared by the South Australian Government on existing water-related legislation, which sought to identify where the legislation might be considered anti-competitive in accordance with COAG water reform agenda.

HYDSOC considered that competitiveness was not necessarily beneficial with regard to a resource as vital to human survival and well being as water. There is no substitute for water. However, if water use continued to be managed by a government authority, it had to be adequately funded to protect the resource, have adequate information, be innovative to provide the community with choice and advance community interest in other areas such as environmental protection and economic development. A holistic approach to the management of all water resources, including rural runoff, urban runoff (stormwater); sewage and septic tank effluent, groundwater and seawater was advocated.

It is a misconception that SA Water has a monopoly on water harvesting or distribution, particularly outside designated reticulation areas. Harvesting by farm dams, rainwater tanks or groundwater bores are common, as are sales of bottled water. Where the monopoly is entrenched is in the powers of SA Water, including power to compulsory acquire land, control catchment landuse, require compulsory payment for its services whether used or not, and set a charges which do not reflect external environmental and social costs and is not structured as pay for resource use (particularly for sewers).

These factors also apply to local government stormwater and septic tank effluent schemes. HYDSOC recommended that consideration be given to:

- the role of government in water services provision, including security of the water supply, mitigating social and environmental impacts; and ensuring public health;
- requiring environmental and social impact assesments for water harvesting and waste discharge strategies and the Competition Policy;
- reviewing the pricing structure of water services (including sewage and stormwater drainage) to better allocate cost factors such as peak flows, pay for resource use, separation of provision for firefighting, and external environmental and social costs; removal of the compulsory access charge; competitiveness in the provision of community service obligations;
- adequate data collection and analysis and information provision which will not be shrouded behind commercial confidentiality, including design standards, climatic variables, consumption, costs, and environmental and social impacts, to be operated by a regulatory agency;
- establishing a regulator of water supply, sewage and stormwater standards;
- establishing an authority which undertakes work of State-wide applicability;
- establishing a suitable structure for a water supply authority to encourage a holistic outlook to water (including sewage and urban runoff) including demand management;
- funding the trialing of alternative methods of water/sewage/urban runoff (re)use;
- third party access to pipes carrying all the water resources, including sewage, stormwater runoff and (treated) rural runoff.

98-19 EXECUTIVE COMMITTEE OF THE HYDROLOGICAL SOCIETY OF SOUTH AUSTRALIA Inc.

Name/Position	Work	Home	Fax	Email
Chairman: Chris Burton	8272 3299	8297 3905	8271 4811	ccburton@a011.aone.net.au
Vice Chairman: Geoff Fisher	8299 9411	8339 6545		
Treasurer: Bill Lipp	8343 2508	8277 5802	8343 2747	lipp@transport.sa.gov.au
Secretary: Chris Purton	8223 5583	8339 3112	8223 5237	chris.purton@bctonkin.com.au
Ordinary Committee Members elected 1998 for 2 years				
Alex Smith				asmith@maths.adelaide.edu.au
Paul Pavelic	8303 8741	8410 0096	8303 8750	paul.pavelic@adl.dwr.csiro.au
Bart van der Wel	8204 9129	8267 5112	8204 9144	bvanderwel@dehaa.sa.gov.au
Ordinary Committee Members elected 1997 for 2 years				
David Walker	8303 4319	8376 0457	8303 4359	dwalker@civeng.adelaide.edu.au
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