# REMOVAL OF SUSPENDED SOLIDS AND ASSOCIATED POLLUTANTS BY A CDS GROSS POLLUTANT TRAP

**T. A. Walker**
**R. A. Allison**
**T. H. F. Wong**
**R. M. Wootton**

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# PREFACE

This report describes an extensive monitoring program to assess the efficiency of a CDS gross pollutant trap in removing suspended solids and nutrients. Monitoring was undertaken during real storm events and dry weather flow conditions at a CDS unit installed at Coburg, an inner suburb of Melbourne, Australia. Over the past few years, there has been a continuing research effort undertaken in the Coburg catchment by the Cooperative Research Centre for Catchment Hydrology as part of its Urban Hydrology Program. These projects have been directed at estimating gross pollutant loads generated from an urban catchment and assessing the performance of a number of gross pollutant traps. Results of these and other research efforts in the Urban Hydrology Program have been published by the CRC in a number of reports. These include the Technical Reports entitled ‘From Roads to Rivers, Gross Pollutant Removal from Urban Waterways’ and ‘A Decision Support System for Determining Effective Trapping Strategies for Gross Pollutants’ and Industry Reports entitled ‘Urban Stormwater Pollution’ and ‘Stormwater Gross Pollutants’.

The focus of this project is not directed at gross pollutants but rather at the suspended solids and nutrients conveyed in urban stormwater. The project was initiated to take advantage of the research infrastructure established in the Coburg catchment and to gain a better insight into the performance of the CDS unit, found to be highly efficient in trapping gross pollutants, on the removal of suspended solids and associated pollutants.

Tom McMahon
Program Leader, Urban Hydrology
Cooperative Research Centre for Catchment Hydrology

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# ABSTRACT

Pollutants carried by urban stormwater runoff are considered a significant contributor to the degradation of receiving waters. Gross pollutants are often targeted first for removal and many structural measures have been applied with varying results. In a previous CRC study, Continuous Deflective Separation (CDS) units were found to be an effective gross pollutant trap. However, the removal of pollutants <5 mm is less well understood although field observations suggest the CDS unit does retain a portion of this material. This report investigates the performance of a CDS unit installed at Coburg in Melbourne, Australia. The removal efficiencies for Total Suspended Solids (TSS), Total Phosphorus (TP) and Total Nitrogen (TN) were estimated for storm and dry weather flow conditions.

During storm flow conditions, water samples were collected using automated samplers and inflow TSS, TP and TN concentrations from the Coburg catchment were observed to be as high as 570 mg/L, 4.3 mg/L and 6.0 mg/L respectively. In the case of TSS, the CDS unit effectively reduced concentration levels above 75 mg/L, with a mean removal efficiency of approximately 70%. For concentration levels below 75 mg/L TSS removal was highly variable. This is thought to be due to flow turbulence maintaining a larger fraction of the inflow particles in suspension. Removal rates for TP were found to be approximately 30%, although there were occasions when downstream concentrations were found to be higher than the inflows. Removal rates for TN were found to be highly erratic.

During dry weather flow conditions, the data suggest that the CDS unit has a small effect on the TSS, TP and TN concentrations. The CDS unit was found to have consistently removed TN under dry weather flow conditions. However, statistical analysis of dry weather samples show a consistently higher concentration of TP at the outflow compared to inflow, in contrast to TN which showed the reverse trend. TSS showed no significant trend although there is a tendency for the unit to slightly increase TSS concentrations at the outflow. During dry weather flows, it is possible that a high proportion of TP discharged from the CDS unit is in the soluble form resulting from sediment desorption in the CDS separation chamber.

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# 1. INTRODUCTION

Pollution carried by urban stormwater is considered a significant contributor to the degradation of receiving waters and is perceived by government and the public as requiring remedial action. Urban stormwater pollutants include gross pollutants, trace metals and nutrients that are associated with sediments, and dissolved pollutants. Catchment management authorities and local municipalities in Australia are undertaking a major public awareness campaign to reduce the gross pollutant problem, particularly litter, and to encourage environmental awareness of the effects of urban community behaviour. In addition to this initiative, structural measures are used to remove urban stormwater pollutants.

Gross pollutants are often the first type of stormwater pollutants targeted in urban catchment management for water quality improvement. Many structural measures for the removal of gross pollutants have been developed to improve the quality of urban receiving waters. The costs associated with these measures vary across a wide range, both in design and construction, and in ongoing maintenance requirements. Trapping efficiencies also vary widely and are an important consideration when selecting gross pollutant traps (GPT).

An earlier study investigated the performance of a continuous deflective separation (CDS) unit and estimated litter and gross pollutant loads from a suburban catchment in Coburg, Melbourne. The CDS unit was found to have a high gross pollutant (material larger than five millimetres) trapping efficiency during the 12 month monitoring period (Allison et al., 1998). However, the trapping performance for material less than five millimetres was not estimated.

This report investigates the trapping performance of a CDS unit for material less than five millimetres. Removal of this fine material is regarded as a secondary benefit of this gross pollutant trap. The performance of the CDS unit in removing suspended particles, particularly sediment and associated contaminants was assessed during stormwater runoff events and dry weather flow conditions at the same installation as the previous study. Over a 22 month period, 15 storms were monitored and dry weather samples were taken at least every two weeks. Water samples collected by automatic water samplers during storm events and manually collected samples in dry weather are used to assess the effect of the CDS unit.

# 2. BACKGROUND

Stormwater pollutants are generated from urban land-use activities and are transported from street surfaces by stormwater runoff before discharging into receiving waters. Community awareness of the environmental effects of urban stormwater pollution and their expectation that urban aquatic ecosystems are protected from environmental degradation has resulted in an increased emphasis on urban stormwater quality. Many local authorities have implemented stormwater management strategies for the protection of receiving waters. These include major public awareness campaigns to encourage environmental sensitivity and structural methods to physically remove pollutants from stormwater. Such initiatives are essentially focused on visible pollutant impacts and concerned with reducing gross pollutants, particularly litter. However, urban stormwater transports a variety of material ranging from large gross pollutants to fine particulates, all of which impact urban receiving waters and therefore require management.

Road surface runoff has been identified in a number of studies as a significant source of suspended solids, dissolved solids, nutrients and toxicants transported as sediment-bound contaminants in stormwater. A CDS unit, that has been found to have a high gross pollutant trapping efficiency may produce secondary benefits by further removing stormwater pollutants such as suspended particles and associated contaminants. This section discusses contaminants associated with suspended particles (particularly sediment) in stormwater and also describes the operation of a CDS unit for the removal of stormwater pollutants.

## *2.1 Suspended Solids and Associated Contaminants in Urban Stormwater*

It is well recognised that a significant amount of pollutants are transported by stormwater as sediment-bound contaminants. Results from an investigation by Mann and Hammerschmid (1989) on urban runoff from two Australian catchments in the Hawkesbury/Nepean basin showed high correlations between total suspended solids (TSS) and total phosphorus (TP), total Kjeldahl Nitrogen (TKN) and Chemical Oxygen Demand (COD). Ball et al. (1995) similarly demonstrated a high correlation between TSS and TP. These Australian studies are consistent with numerous overseas studies showing similar correlations and characteristics of road and street runoff.

Many investigations have found the concentration of sediment-bound contaminants in street dirt to be associated with the fine particle size fraction. Pitt and Amy (1973), NCDNRCD (1993) and Woodward-Clyde (1994) have all shown that higher concentrations of pollutants such as heavy metals are associated with the smallest particle size fraction of urban dust and dirt. These data indicate that almost half of the heavy metals (represented by copper, lead and zinc) found on street sediments are associated with particles of 60 to 200 μm in size and 75% are associated with particles finer than 500 μm in size. Dempsey et al. (1993) undertook a particle size distribution analysis for urban dust and dirt, and partitioned contaminants into a number of size fractions to determine the concentrations of contaminants in each particle size range. Results show that the highest recorded concentrations of Copper, Zinc and Phosphorous are associated with particles between 74 μm and 250 μm in size.

Colwill et al. (1994) found 70% of oil and approximately 85% of polycyclic aromatic hydrocarbon (PAH) to be associated with solids in the stormwater. That study subsequently demonstrated that, over a period of dry weather conditions, increasing concentrations of oil become associated with particulates with the highest oil content found in the sediment range of 200 μm to 400 μm.

Sansalone et al. (1997), Fergusson and Ryan (1984), Baker (1980) and Wilber and Hunter (1979) all reported that heavy metal concentrations increase with decreasing particle size. Results presented by Sansalone et al. (1997) from particle size distribution and metal analyses indicate that Zinc, Copper, and Lead concentrations increase with decreasing particle size or equivalent specific surface area. The absorption of contaminants to particles is often regarded as being directly related to the surface area per unit mass available for ion absorption. Measured specific surface area results presented by Sansalone et al. (1997) indicated that the assumption of smooth spherical particles to estimate available surface area for ion absorption grossly underestimated available surface areas. Specific surface area values were found to deviate from the monotonic pattern expected for spherical particles with the greatest surface area being recorded for the particle size range of 425 to 850 µm.

The sediment binding behaviour of other toxins such as polychlorinated biphenyls (PCBs) and polycyclic aromatic hyrdrocarbons (PAHs) can be different to that of heavy metals. Schorer (1997) reported PCBs and PAHs to have no correlation with particle size distribution or surface area but rather with the abundance of organic material. Results indicate that the organic material content in different particle size fractions was bimodally distributed with maximum measurements recorded for fine silt (2-6.3 µm) and fine sand fractions (63-200 µm).

The particle size distributions for sediment transported in runoff have a direct influence on the effectiveness of stormwater treatment measures in removing nutrients, metals and hydrocarbons. The selection and sizing of treatment measures is often based on the particle size distribution of the suspended solids conveyed in the runoff. Figure 1 presents a collection of 20 particle size distribution curves derived from sampling solids from street surfaces and of street runoff from a number of overseas and Australian catchments.

It is evident from Figure 1 that despite the overseas data being collected from a variety of sources, locations and various methods they show a consistent distribution ranging from approximately 10 µm to approximately 10,000 µm. The particle size distributions derived from sampled road runoff from two Australian sites, one as part of an ongoing CRC project and the other Ball and Abustan (1995), are also presented and appear to fall outside the range of the particle size distribution curves of the overseas catchments. The Australian data range from 2 µm to approximately 500 µm. There may be a number of possible explanations for this observed finer particle size distribution including differences in sampling and analysis techniques. However, it should be noted that the particle size distributions derived from overseas catchments were based on a variety of sampling and analysis techniques. Adjustments (Lloyd et al., 1999) to the overseas data to eliminate particles larger than 600 µm still showed the Australian data sets to exhibit finer particle size characteristics. The significantly different particle size distribution of the Australian catchments may indicate differences in catchment geological characteristics.

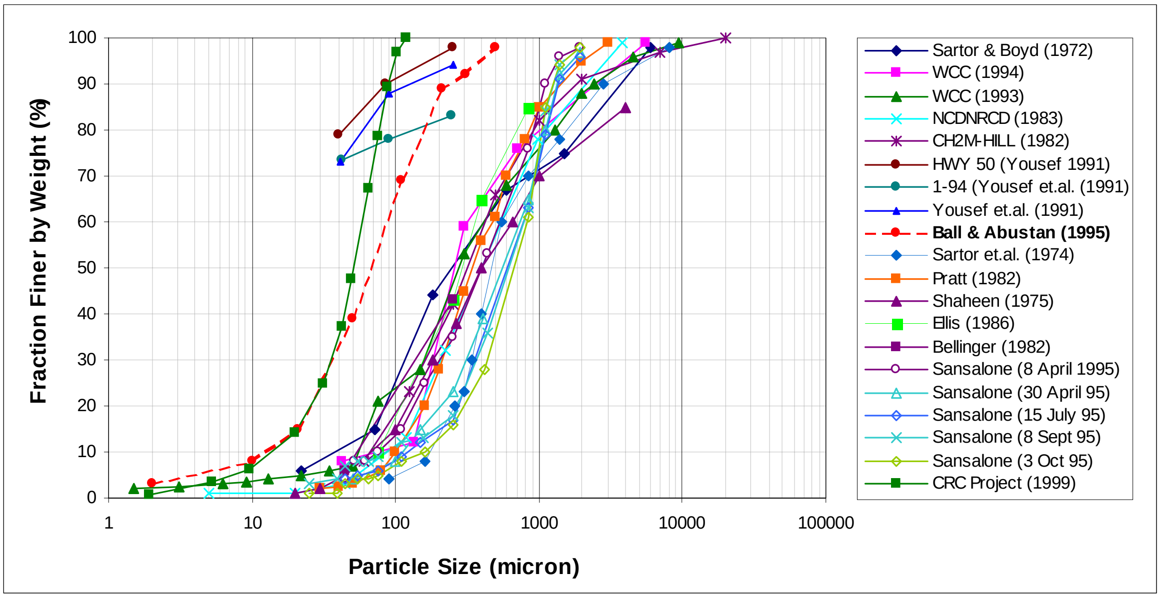

Figure 1: Particle Size Distribution of Solids Found on Streets and Suspended in Road Runoff.

Coarse sediments transported from urban areas have a physical impact on the receiving aquatic environment by smothering aquatic habitats and silting waterways leading to a reduction in the waterway discharge capacity. Fine suspended particles carried by stormwater flows may not necessarily be considered to have significant physical impacts on the environment. However, they lead to elevated turbidity levels and it is generally understood that the highest concentrations of pollutants (such as nutrients, heavy metals, and organics) are attached to the finer fractions of suspended sediments in urban stormwater. The removal of fine sediments and associated contaminants are therefore an important stormwater management objective and often other treatment methods (such as wetlands and swales) involving a significantly longer detention period will be required in addition to GPTs to allow settling of these finer particles.

### *2.2 Operation of a CDS Unit*

CDS devices are gross pollutant traps designed to capture trash and debris and have been found to efficiently trap gross pollutants in urban stormwater. The unit is typically installed below ground requiring an area of between 10 $m^2$ and 20 $m^2$, depending on the design operational flow. Maintenance requirements for the device have been reported to be lower than conventional devices that block because of the self cleansing screen which is a result of the continuous deflective separation mechanism.

The mechanism by which the CDS technology separates and retains gross pollutants is by first diverting flow and associated pollutants in a stormwater drainage system away from the main flow stream of the pipe or channel into a pollutant separation chamber as shown in Figure 2.

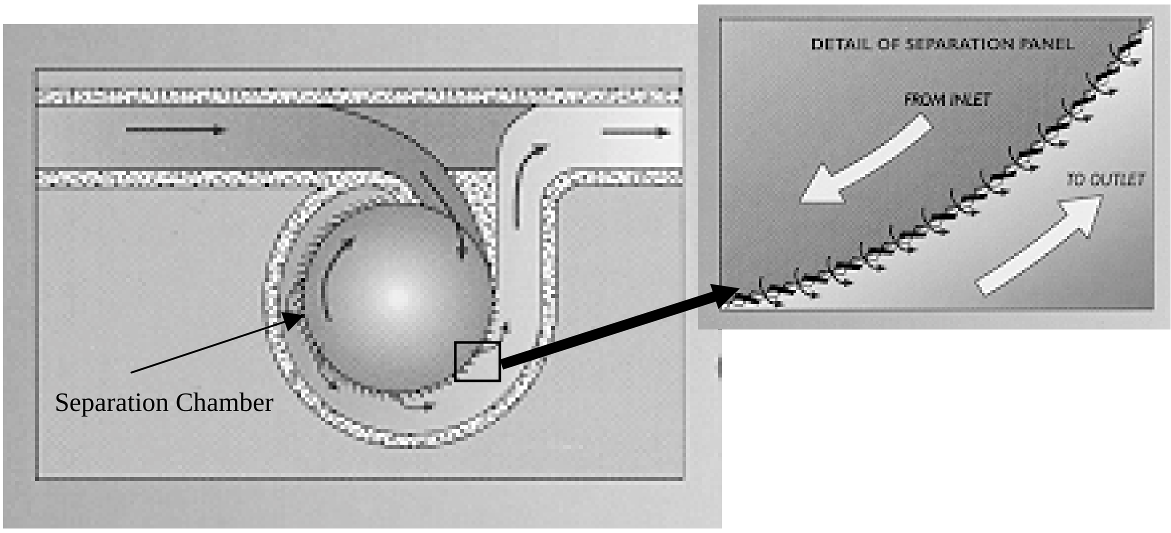

Figure 2: Schematic Plan View Representation of the CDS System

The separation chamber consists of a containment sump in the lower section and an upper separation section as shown in Figure 3. Gross pollutants are retained within the chamber by a perforated plate that allows water to pass through to the outlet pipe. The water and associated pollutants contained within the separation chamber are kept in continuous motion by the energy generated by the incoming flow. This has the effect of preventing the separation plate from becoming blocked by the gross solids retained from the inflow. Heavier solids settle into the containment sump and much of the neutrally buoyant material eventually sinks while floating material accumulates at the water surface.

Diverting stormwater and associated pollutants into a separation chamber overcomes problems associated with the direct filtration systems used in conventional gross pollutant traps. The diversion weir is designed to divert all flows below the crest level of the diversion weir. During above-design flow conditions, when water levels exceed the crest of the diversion weir, some flow would by-pass the CDS system carrying pollutants downstream. The selection of the design crest level of the diversion weir can vary for different installations depending on site conditions and the capacity of the CDS unit. The by-pass system is designed to minimise upstream flood afflux for above design flow conditions. If the unit discharges directly to a watercourse, some type of outlet scour protection will be appropriate, such as gabions or riprap.

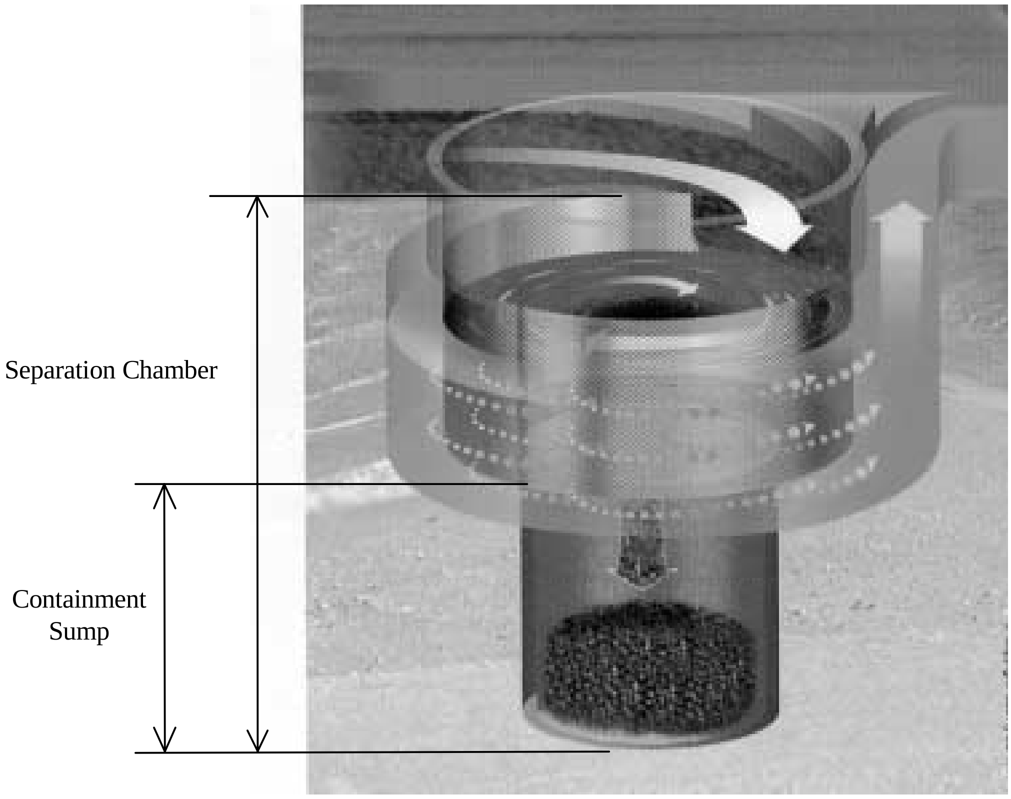

Figure 3: Isometric Representation of the CDS unit (CDS Technologies, 1998)

The solid separation system consists of a perforated stainless steel partition, which acts as a filter screen with a perimeter volute outlet passage. The perforations in the separation screen are typically elongated in shape and are aligned with the longer axis in the vertical direction. The size of the elliptical perforations can be specified according to performance requirements and typical perforation size for use in urban stormwater systems is 4.7 mm by 10 mm however finer screens have been used. The separation screen is installed with the leading edge of each perforation extending into the flow.

Trapped materials in the containment sump of a CDS unit can be removed in three ways, in a containment basket that can be lifted out of the unit, suction from within the sump; and removal by an excavator. For small CDS units, containment baskets are often used. The basket is placed in the containment sump and cleaned by a truck-mounted hydraulic crane used to lift the basket out of the sump. Vacuuming the trapped material with a large truck mounted suction hose is also an effective method that is commonly used in Australia.

### *2.3 Previous Monitoring of a CDS Unit*

Gross Pollutant Traps (GPTs) commonly employ a screen to trap material larger than the screen aperture size. A trap will operate effectively provided the screen does not become blocked. In the case of the Continuous Deflective Separation (CDS) Technology design (Wong et al., 1997) there has been no evidence of screen blockage due to the continuous deflective separation mechanism incorporated in the design. It is good design practice to limit excessive energy losses through a GPT during above design flow conditions (flows approaching the discharge capacity of the pipe drainage system). Often a by-pass weir is employed and the selection of the operating characteristics of the by-pass system is dependent on the hydraulic interaction between the GPT and the pipe system.

For the CDS trap under review, flow records collected over a 12 month period, during an earlier investigation (Allison et al., 1998) suggest infrequent operation of the by-pass weir and therefore a high gross pollutant trapping efficiency for material larger than the 4.7 mm screen aperture. It was found that practically all material greater than the screen size (5 mm) was retained in the separation chamber during the monitoring period. In the study by Allison et al. (1998), the trapping efficiency of the CDS unit was calculated by measuring the proportion of discharge volume bypassing the separation chamber of the unit. Pressure sensors installed across the top of the diversion weir recorded depth data, which was used to estimate the amount of discharge overflowing the weir. Measurements indicated that less than 1% of stormwater flowed over the weir during the 12 months of monitoring. In computing the trapping efficiency, it has been assumed that gross pollutants are uniformly distributed across the water column and that entrained material which by-passed the separation chamber would be of the same concentration as the flow entering the separation chamber. This is a conservative assumption and is therefore likely to underestimate the trapping efficiency for gross pollutants by this unit.

The capture rate for material entering the separation chamber larger than the screen size was 100% as no damage to the separation screen was observed during the monitoring period. From this research the CDS trap was estimated to be 99% efficient for the removal of gross pollutants (ie. material >5 mm) during the 12 months of monitoring.

Evidence from laboratory studies (Wong et al., 1997) and field data (Allison et al., 1998) suggest that the device is capable of providing further benefits to stormwater quality by trapping a significant proportion of material that is finer than the screen aperture size (typically 4.7 mm). Allison et al. (1998) indicated that 90% of the sediment collected (ie. excluding other trapped material) in the containment sump of the Coburg CDS unit was less than the 4.7 mm screen size as shown in Figure 4. Analysis of sediment contained in the CDS unit was carried out by sieve analysis down to 45 μm. Of the sediments collected, approximately 70% were found to be less than 400 μm in size.

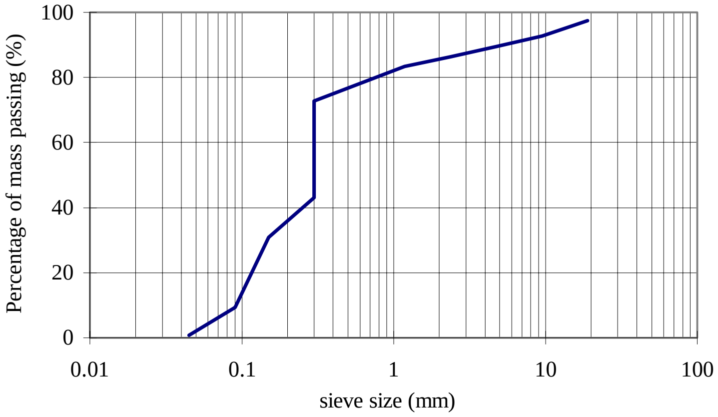

Figure 4: Sediment Size gradings collected from the CDS containment sump (Allison et al., 1998)

The particle size distribution of sediment trapped by the CDS unit provides an indication of the size range the unit is capable of trapping. The quantity of material less than the screen aperture size passing through the device is however unknown and thus a trapping efficiency for fine material cannot be determined. Nevertheless, the data suggest a significant secondary benefit is gained in terms of sediment removal in addition to the performance of the unit in its primary task of gross pollutant removal.

# 3. COBURG RESEARCH CATCHMENT

The Coburg research catchment is situated approximately eight kilometres north of Melbourne's central business district. The research catchment covers an area of approximately 50 hectares of the inner city suburb of Coburg, which consists of 35% commercial and 65% residential land-use as shown in Figure 5. The stormwater outlet from the catchment is a 1200 mm diameter pipe in which a CDS gross pollutant trap has been installed. The catchment has an average annual rainfall of approximately 660mm and the mean period between storm events is calculated to be 2.6 days with a skewed probability distribution and a standard deviation of 3.2 days. Rainfall for the catchment was recorded using an automatic rain gauge installed approximately 500 metres from the catchment outlet and six minute rainfall data were collected from this gauge.

The CDS unit in this catchment has been the site of numerous CRC and associated industry studies described by Allison et al. (1998). The Moreland City Council has continued to carry out typical municipal street litter management and stormwater system maintenance practices in the research catchment during the monitoring period. These management practices include daily and two weekly street sweeping, six monthly drainage pit cleaning and the employment of a litter officer in the busy commercial area.

Figure 5:  Coburg Research Catchment

# 4. MONITORING PROGRAM

## *4.1 Monitoring System*

Monitoring involved measuring stormwater flows and collecting water samples from locations upstream and downstream of the CDS unit (Figure 6, locations A & C). Two acoustic flowmeters that measure water depth and velocity were used to determine the discharge hydrograph. They were located 8m upstream and 7m downstream of the CDS unit. Water samples were collected at the same two locations, by automatic water samplers during storm events and by manual grab sampling during dry weather periods. Dry weather water samples were also collected from within the CDS collection chamber at various depths.

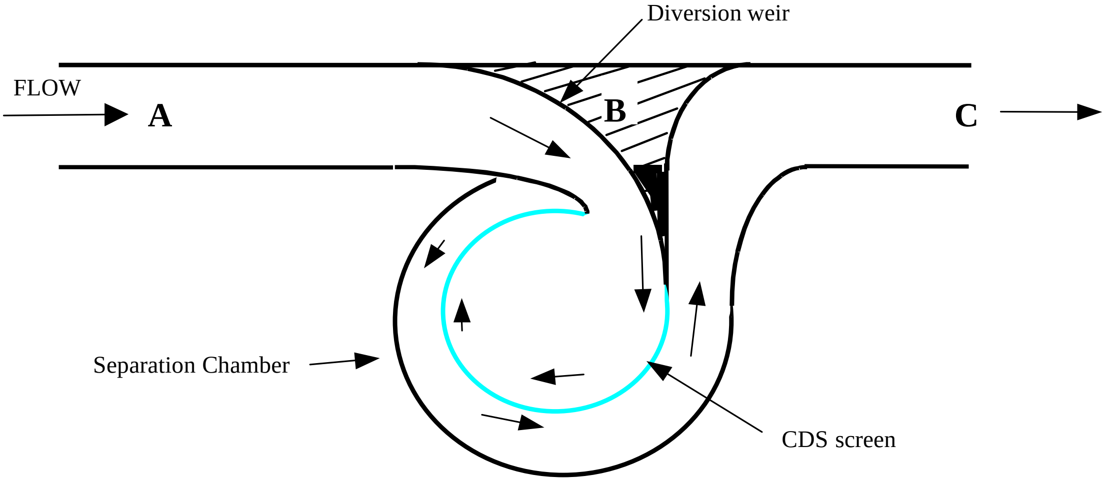

Figure 6: Location of instrumentation at the CDS unit in Coburg (Allison et al., 1998)

Site maintenance involved equipment checks, battery changes and data retrieval at least every two weeks. Dry weather sampling was undertaken during site maintenance visits. Two automatic water samplers collected storm event samples, each with the capacity for extracting 24 discrete water samples. The sample bottles were removed and dispatched to a laboratory for analysis after each rainfall event. Laboratory calibration of the acoustic flowmeters was performed before installation in the field and continuous checks were conducted over the monitoring period. Data retrieved from the upstream and downstream acoustic flowmeters was checked for missing or spurious data and if inconsistencies were found the instruments were checked, and if necessary replaced. Water samples collected from the monitoring sites were refrigerated and later analysed for Total Suspended Solids (TSS), Total Phosphorous (TP) and Total Nitrogen (TN) using Standard Methods, (1996).

## *4.2 Sampling Protocol*

Storm Event

Storm event water samples were collected between November 1996 and February 1998. In total, water samples were collected from fifteen storm events and were tested for TSS. Eight events of varying storm magnitudes were selected for additional laboratory analysis of TP and TN. This selection was dependent on storm magnitude and the number of samples taken. Flow depth and velocity measurements were recorded every two minutes at the two monitoring sites throughout the 16 month monitoring period. The automatic water samplers are triggered by the downstream acoustic flow meter when water depths exceed 100 mm. Once triggered water is pumped, every ten minutes, via a suction hose fixed to the drainage pipe into 500 mL bottles. The inlet filter through which stormwater samples were drawn was installed slightly above the pipe invert (approx.

20 mm) to avoid blockage by bed load sediment. The ISCO automatic water samplers are commonly used throughout Australia for water quality monitoring. The extracted samples are limited to particles less than the 5 mm aperture of the intake hose and may also be affected by the velocity of the flow in the drain, the alignment and position of the intake hose and the length, height and velocity within the hose.

Flow velocities in the pipe are generally of the order of 1.0 m/s to 2.5 m/s during sampling and it has been assumed that suspended solids are reasonably well-mixed in the water column under these conditions. The samples of suspended solids were thus assumed to be representative of particles transported in the stormwater. However, given the limitations with the sampler it is anticipated that sediment particles larger than 1mm are unlikely to reach the sample bottles during storm sampling. Samples contained in the automatic samplers were collected immediately after each storm event and refrigerated for later laboratory analysis. Sample bottles were then replaced with clean ones and the automatic water samplers reset for sampling when next triggered by a rainfall event.

Dry Weather

Dry weather samples were routinely collected manually from the inlet and outlet and at three depths within the CDS separation chamber. Water samples were taken from 1 m, 2.5 m below the water surface and from the bottom of the sump in the separation chamber (see Figure 3). This data set extends from May 1996 to February 1998 with samples collected either weekly or every two weeks. A minimum of 3 days gap following storm events was adopted to define the commencement of dry weather flow conditions. Typically dry weather flows were less than one litre per second.

### *4.3 Analysis of Samples*

The collected water samples were analysed for TSS, TP and TN using standard method analyses (Standard Methods, 1996). TSS concentrations were measured as the material remaining after filtration of the water sample through a millipore filter of pore size of 0.45 µm. Analysis for TP and TN in the water samples were undertaken with the Merck SQ 200 photometer and accompanying water quality testing kits. In addition to this testing method, some samples were duplicated and sent for analysis by Water Eco-science, a NATA certified laboratory to check the validity of the results obtained with the Merck instrument. The results of the duplicated water samples analysed for measured TP concentrations are shown in Figure 7 and indicate that the results of water analysis using the Merck device were comparable to the certified laboratory results and within the variations expected in sub-sampling stormwater samples for analysis.

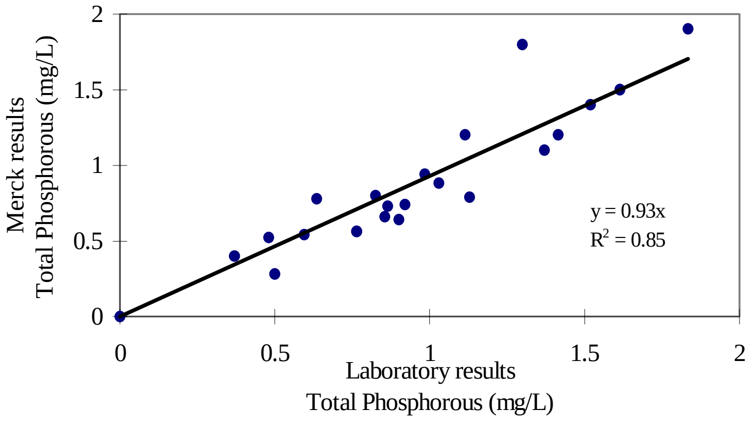

Figure 7: Plot of TP results using a Merck Photometer and a certified laboratory (Allison et al. 1998)

# 5. DATA ANALYSIS

## *5.1 Typical Observed Pollutographs*

To assess the influence of the CDS unit in removing suspended particles and associated contaminants during stormwater runoff events, rainfall, discharge and contaminant concentrations at the two monitoring stations located upstream and downstream of the CDS unit were recorded. A total of 15 storm events were monitored, however, only eight included sufficient inflow and outflow samples for an adequate assessment of the water quality effects of the CDS unit. The observed hydrographs and pollutographs for these eight events are presented in Figures 8 to 15. Inflow TSS concentrations reach a maximum of 570 mg/L with corresponding concentrations for TP and TN being 4.3 mg/L and 6.0 mg/L respectively. Apart from TP, the inflow pollutant concentrations were within the range expected from typical urban catchments. The observed peak inflow TP concentration of 4.3 mg/L is approximately 50% higher than the expected maximum for typical urban catchments.

Pollutographs of the eight storms show trends of higher inflow concentrations of TSS in the early parts of the storm indicating incidences of pollutant first flush although the maximum pollutant load in each case coincided with the period of maximum discharge. Comparison of observed pollutographs for inflow and outflow suggests a significant removal of TSS during the early stages of the runoff hydrographs. Inflows with TSS exceeding approximately 100 mg/L were effectively reduced to a baseline concentration level.

A similar trend was reported for total phosphorous, and less so for total nitrogen, consistent with the expectation of a higher correlation between TP and TSS. The results demonstrate the ability of the CDS unit to retain sediment smaller than the screen size, especially during the early stages of a storm event. This is consistent with results from laboratory studies (Wong, 1997) and analyses of sediment particle size of trapped materials obtained from a CDS installation in the field (Allison et al., 1998).

When TSS concentrations are less than 75 mg/L, there appears to be less influence by the CDS unit on TSS concentrations and consequently less variation was observed between the inflow and outflow concentrations. Generally, the monitored storm events indicate that the CDS unit has the potential to trap suspended particles, particularly sediment and associated contaminants (TP and TN) above some notional background concentrations and thus can be expected to have a beneficial effect on downstream water quality.

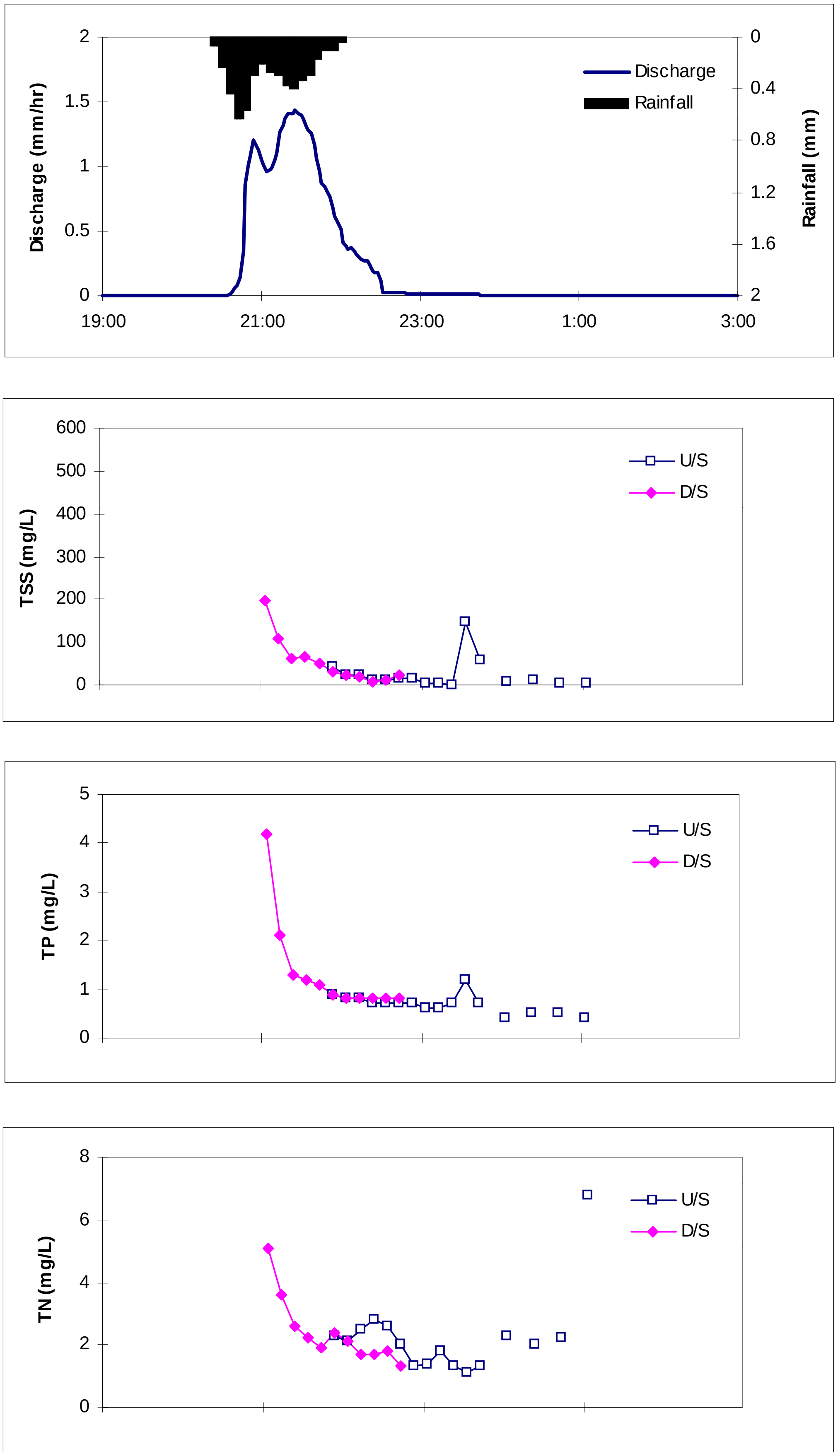

Figure 8: Rainfall, discharge and upstream/downstream water quality TP, TN and TSS concentrations 02 November 1996

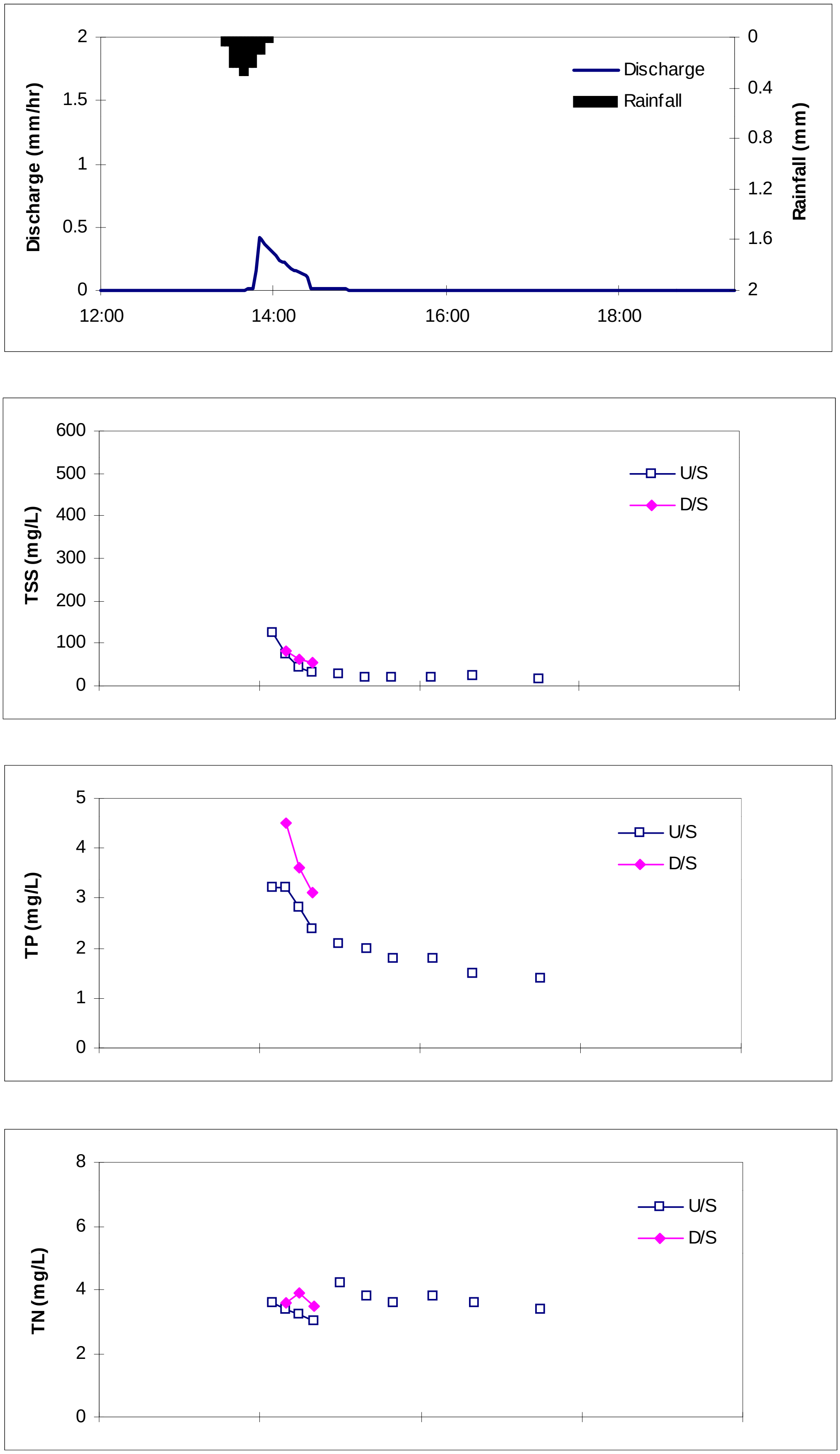

Figure 9: Rainfall, discharge and upstream/downstream water quality TP, TN and TSS concentrations 16 November 1996

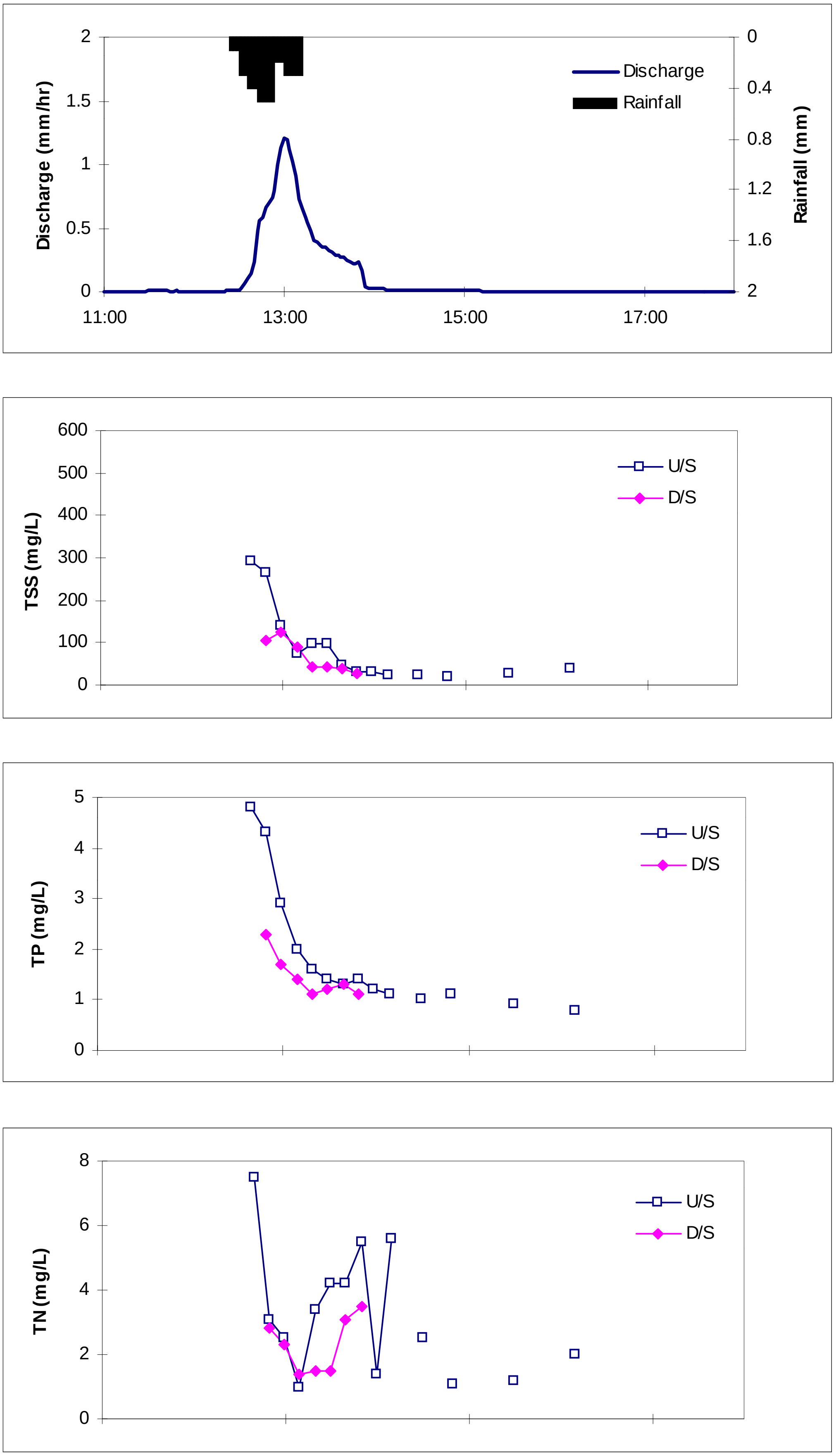

Figure 10: Rainfall, discharge and upstream/downstream water quality TP, TN and TSS concentrations 27 January 1997

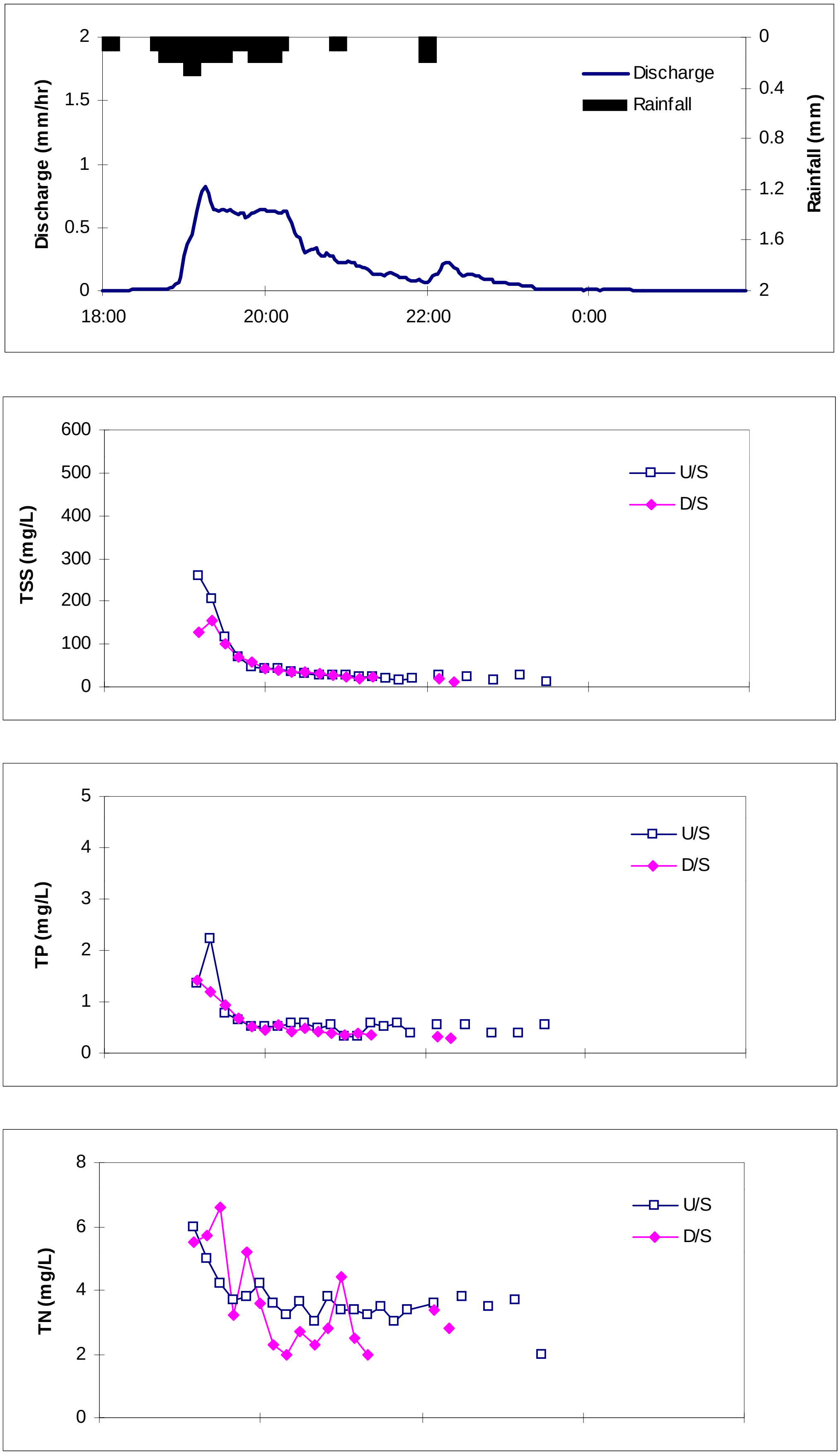

Figure 11: Rainfall, discharge and upstream/downstream water quality TP, TN and TSS concentrations 21 April 1997

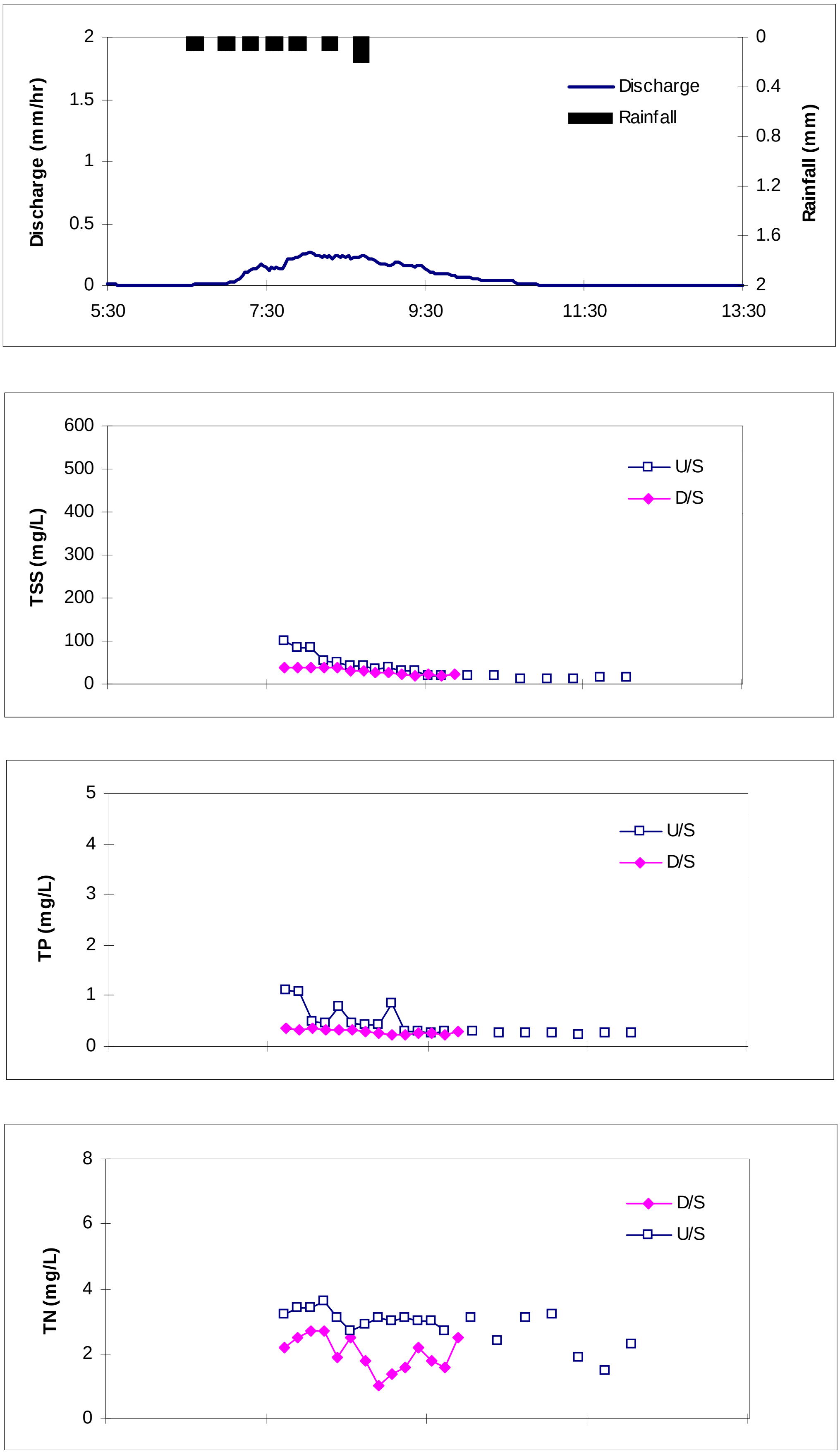

Figure 12: Rainfall, discharge and upstream/downstream water quality TP, TN and TSS concentrations 03 May 1997

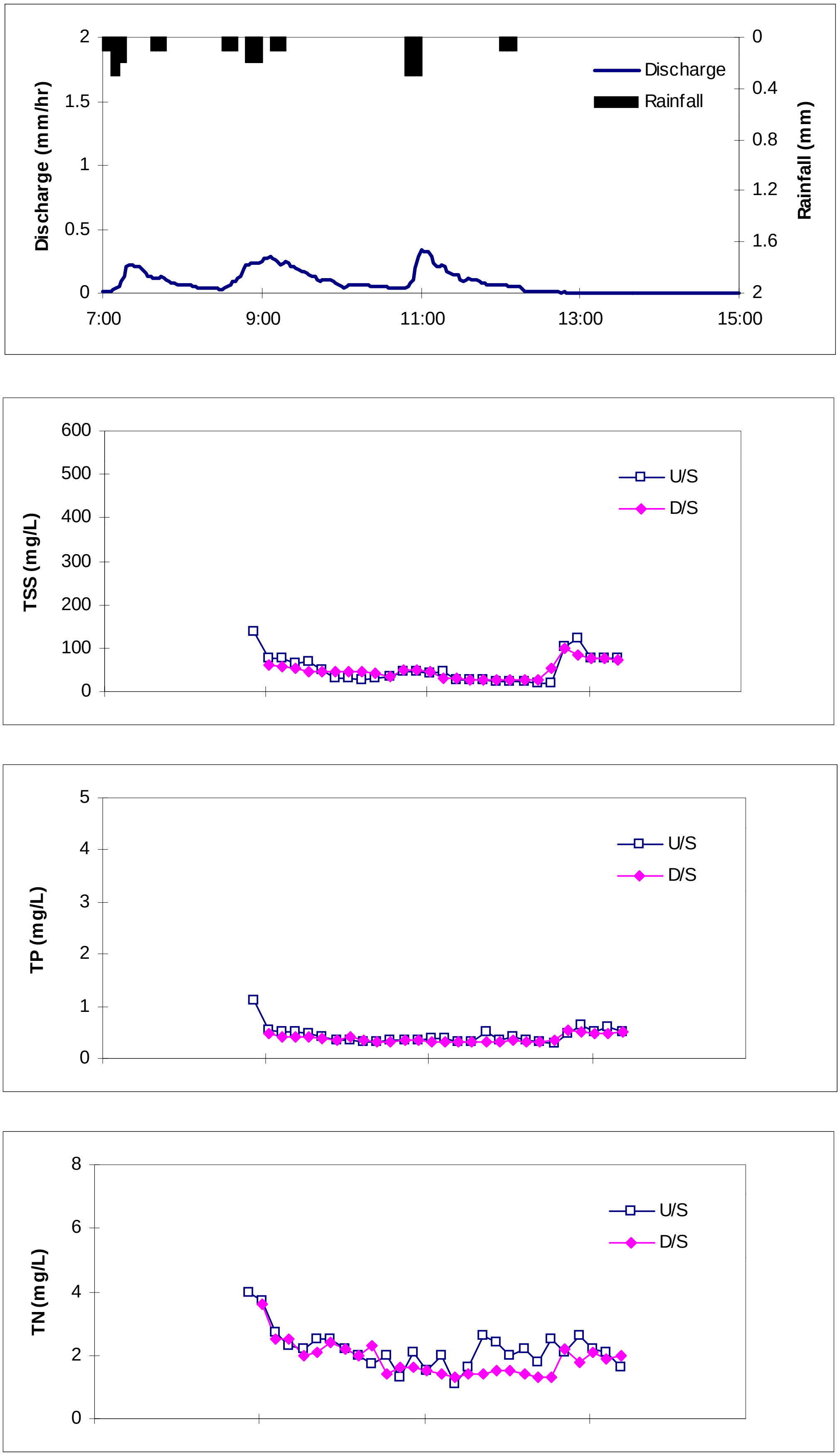

Figure 13: Rainfall, discharge and upstream/downstream water quality TP, TN and TSS concentrations 26 May 1997

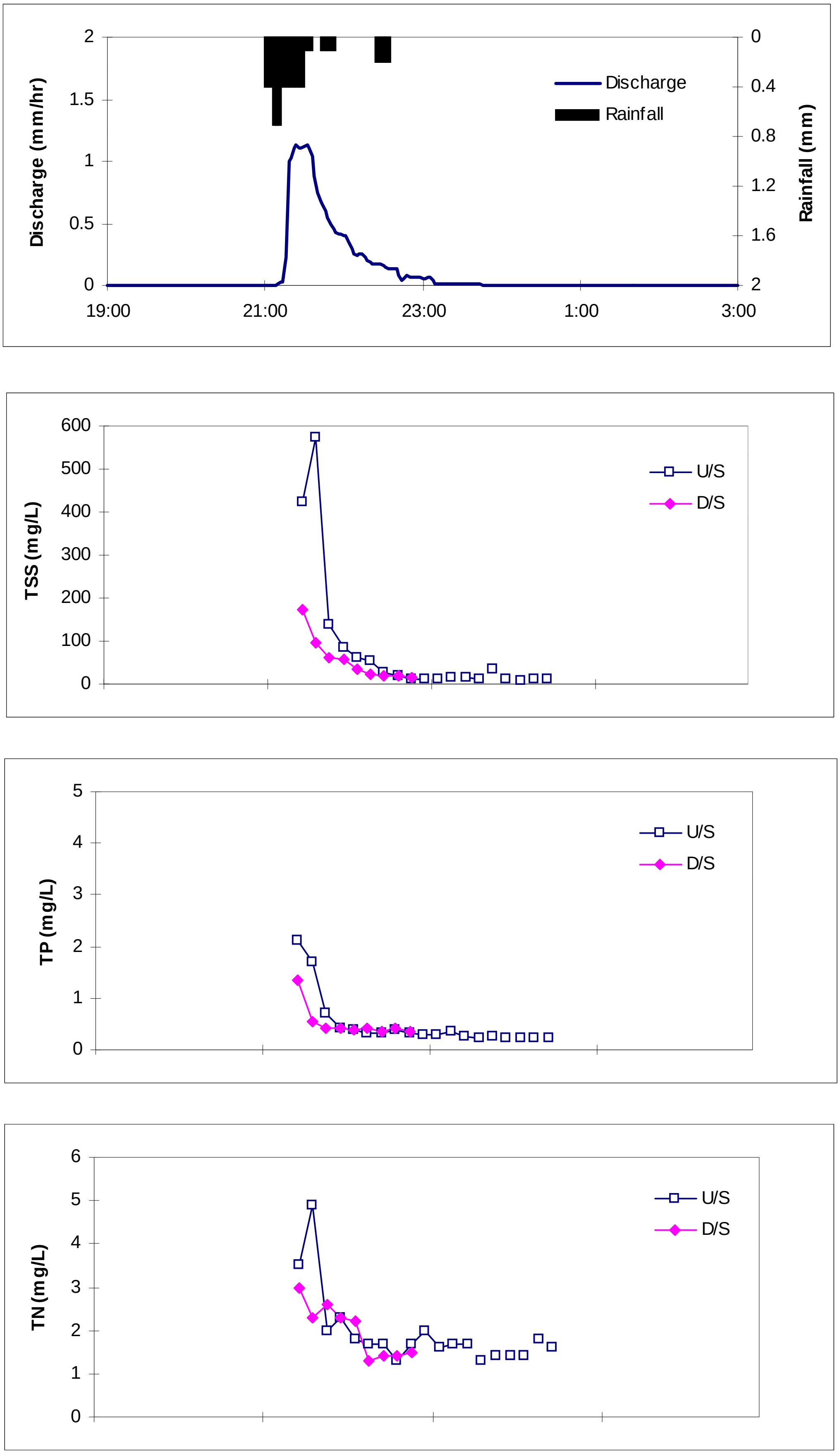

Figure 14: Rainfall, discharge and upstream/downstream water quality TP, TN and TSS concentrations 5-6 June 1997

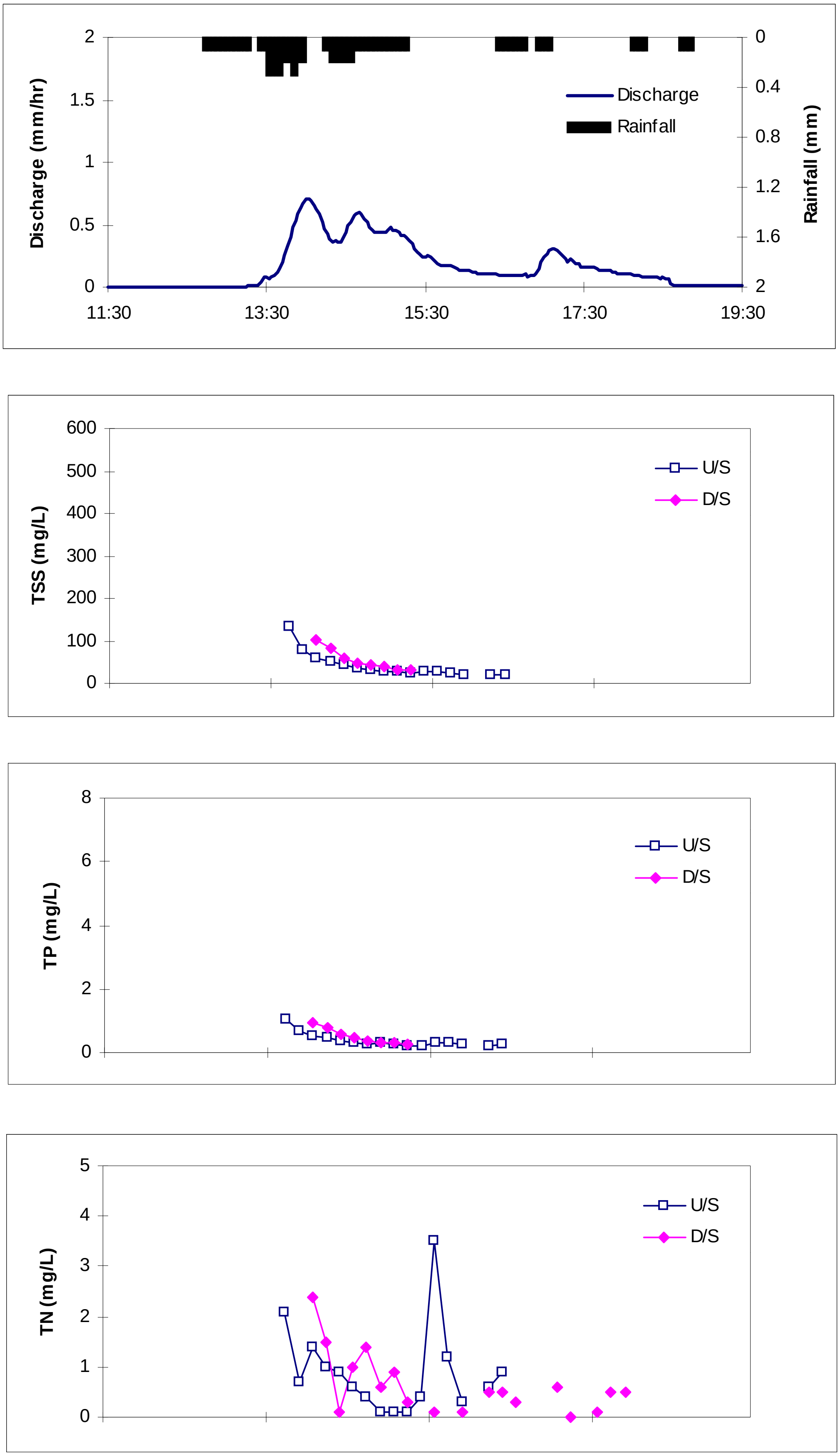

Figure 15: Rainfall, discharge and upstream/downstream water quality TP, TN and TSS concentrations 19 Sept 1997

### *5.2 Water Samples in the CDS Pollutant Separation Chamber*

Water samples were collected from upstream, downstream and within the CDS separation chamber (from water depths of 1.0 m, 2.5 m and at the bottom of the containment sump) during dry weather flow conditions. These samples were analysed to provide an insight into the breakdown of pollutants within the separation chamber as they are retained over long periods of time (up to three months between clean outs). Results of dry weather sampling are presented in Table 1. Time series plots of observed dry weather concentrations of TSS, TP and TN in the separation chamber are shown in Figures 16, 17 and 18. These time series plots are for data collected during 1997, as continuous points are required.

The results presented in Figures 16, 17 and 18 show that the water quality characteristics within the separation chamber of the CDS unit are stratified, particularly for TSS. Generally TSS, TP and TN concentrations in the water column within the separation chamber are highest at the bottom of the containment sump. These vertical profiles of pollutant concentrations are indicative of a number of physical and biochemical processes occurring in the separation chamber during dry weather including:-

- sedimentation (affecting predominantly TSS);
- organic material breakdown at the bottom (affecting predominantly TP and TN);
- biochemical transformation of nutrients contained in the trapped material (affecting predominantly TP and TN); and
- limited mixing (affecting pre-dominantly TSS).

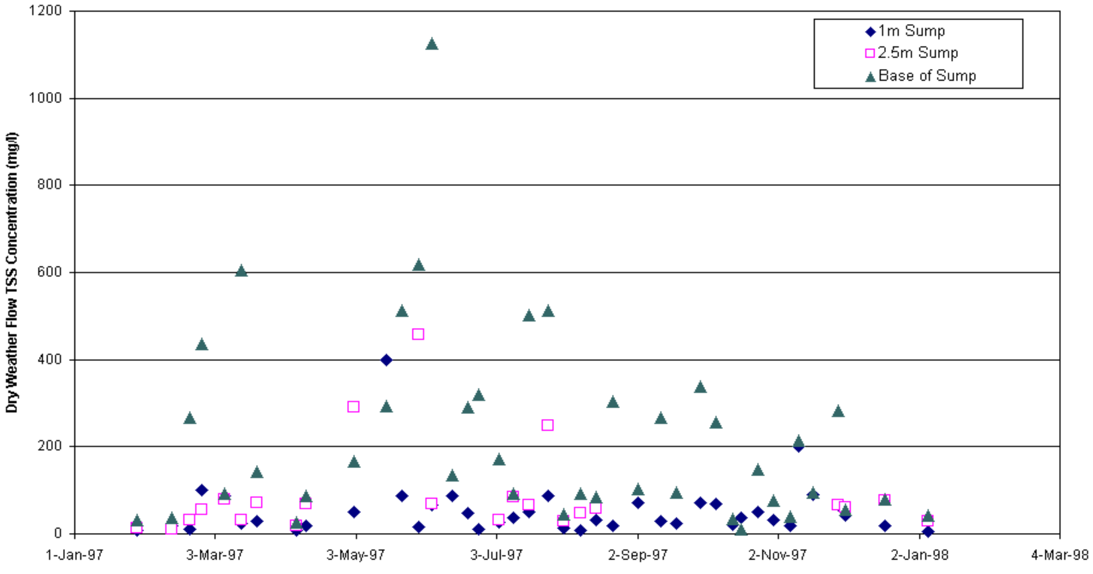

Figure 16: Time Series Plot of Dry Weather TSS Concentrations in the CDS Separation Chamber

Table 1: Dry Weather Flow Water Quality Results

| **Sample** | | | TP mg/L | | | | | TN mg/L | | | | | TSS mg/L | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Date** | **U/S** | **D/S** | **1m** | **2.5m** | **Sump** | **U/S** | **D/S** | **1m** | **2.5m** | **Sump** | **U/S** | **D/S** | **1m** | **2.5m** | **Sump** |
| | | | | | | | | | | | | | | | |
| 12-May-96 | 0.7 | 0.3 | n/a | n/a | n/a | 2.3 | 1.2 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 13-May-96 | 0.3 | 0.8 | 0.4 | n/a | 0.4 | 2.1 | 1.2 | 1.2 | n/a | 1.3 | 4 | 7 | 3 | n/a | n/a |
| 22-May-96 | 0.5 | 0.5 | 0.5 | n/a | 0.5 | 1.4 | 1.2 | <1.0 | n/a | 2 | 2 | 7 | 13 | n/a | 4 |
| 17-Jun-96 | 1.2 | 1.3 | 1.4 | n/a | 1.2 | 1.5 | 2 | 2.3 | n/a | 2.1 | 49 | 50 | n/a | n/a | n/a |
| 17-Jun-96 | 1.2 | 1.3 | 1.4 | n/a | 1.4 | 2.4 | 2.3 | 1.8 | n/a | 2.1 | 53 | 54 | n/a | n/a | n/a |
| 21-Jun-96 | 0.9 | 4.5 | 1.2 | n/a | 1.6 | 1.3 | 5 | 1.4 | n/a | 2.2 | 202 | n/a | 22 | n/a | 16 |
| 27-Jun-96 | 0.5 | 4.7 | 1.2 | n/a | n/a | n/a | 8.8 | 5.3 | n/a | n/a | n/a | 61 | 67 | n/a | n/a |
| 03-Jul-96 | 1.7 | 2.1 | 2 | n/a | 1.7 | 1.5 | 2.8 | 2 | n/a | 2.6 | 7 | 22 | 7 | n/a | 5 |
| 10-Jul-96 | 1.2 | 3.2 | 2.1 | n/a | 2.5 | 5.8 | 2.8 | 1.8 | n/a | 2.2 | 81 | 48 | 6 | n/a | 7 |
| 18-Jul-96 | 5 | <5.0 | 2.3 | n/a | 2.7 | 1.8 | 2.3 | 1.6 | n/a | 1.8 | 16 | 24 | 22 | n/a | 21 |
| 24-Jul-96 | 0.8 | 1.2 | 1.4 | n/a | 1.4 | 1.6 | 1.7 | 1.5 | n/a | 1.5 | 23 | 31 | n/a | n/a | 83 |
| | | | | | | | | | | | | | | | |
| 28-Jan-97 | 1.4 | 1.1 | 1.2 | 1.2 | 1.2 | 3.5 | 2.4 | 3.3 | 3.2 | 3.4 | 6 | 12 | 9 | 13 | 32 |
| 12-Feb-97 | 1.5 | 1.1 | 1.2 | 0.8 | 1 | 3.8 | 3.8 | 3.5 | 3.1 | 3.6 | 29 | 14 | 19 | 10 | 38 |
| 20-Feb-97 | 1.2 | 1.5 | 0.5 | 1.2 | 1.6 | 3.7 | 3.6 | 3.2 | 5.7 | 6.2 | 67 | 18 | 9 | 32 | 268 |
| 25-Feb-97 | 0.6 | 1.5 | 0.7 | 0.5 | 0.6 | 3.2 | 3.2 | 3.3 | 3 | 6.7 | 17 | 14 | 100 | 56 | 437 |
| 07-Mar-97 | 0.8 | 0.6 | 0.7 | 0.7 | 1.1 | 3.4 | 3.7 | 4.6 | 4.4 | 7 | 4 | 9 | 87 | 80 | 91 |
| 14-Mar-97 | 1.3 | 0.7 | 1.2 | 1 | 2.5 | 3.5 | 3.1 | 4.2 | 5.4 | 5.8 | 5 | 4 | 24 | 32 | 606 |
| 21-Mar-97 | 0.9 | 0.8 | 1.1 | 3.2 | 1.5 | 2.8 | 2.9 | 3.2 | 3.3 | 8.1 | 12 | 11 | 28 | 72 | 143 |
| 07-Apr-97 | 0.7 | 0.4 | 1.1 | 1 | 1.5 | 3.1 | 3 | 3.2 | 5.3 | 7.7 | 3 | 15 | 7 | 19 | 27 |
| 11-Apr-97 | 1.1 | 0.8 | 1.1 | 1.2 | 1.6 | 2.8 | 2.3 | 3.6 | 3.2 | 3.5 | 11 | 3 | 20 | 69 | 88 |
| 02-May-97 | 0.9 | 1.1 | 1.4 | 1.4 | 1.5 | 2 | 2.1 | 2.8 | 3.8 | 4.2 | 7 | 25 | 49 | 291 | 167 |
| 16-May-97 | >5.0 | >5.0 | >5.0 | n/a | >5.0 | 2.6 | 1.2 | 1.4 | n/a | 3.5 | 17 | 99 | 400 | n/a | 292 |
| 23-May-97 | 1.8 | 1.2 | 1.3 | n/a | 3.5 | 2.8 | 2.1 | 2.9 | 9.1 | 9.1 | 10 | 55 | 88 | n/a | 513 |
| 30-May-97 | 0.8 | 0.5 | 1.6 | 1.6 | 1.6 | 2.2 | 1 | 3.5 | 3.4 | 5 | 5 | 15 | 16 | 458 | 618 |
| 05-Jun-97 | 0.7 | 1.1 | 1.2 | 3.2 | 2.3 | 3 | 2.1 | 2.8 | 3.1 | 9.5 | 16 | 26 | 67 | 69 | 1125 |
| 13-Jun-97 | 0.9 | 2.1 | 1.3 | n/a | 1.4 | 1.7 | 2.3 | 2.7 | n/a | 2.1 | 22 | 14 | 88 | n/a | 134 |
| 20-Jun-97 | 1.1 | 1.6 | 2.4 | n/a | 3.2 | 3.2 | 3.2 | 1.6 | n/a | 2.6 | 13 | 23 | 48 | n/a | 292 |
| 25-Jun-97 | 1.9 | 0.8 | 2.2 | n/a | 0.9 | 3.7 | 2.7 | 4.2 | n/a | 5.4 | 16 | 15 | 11 | n/a | 320 |
| 04-Jul-97 | 1.2 | 1.5 | 1.2 | 1.4 | 2.5 | 1.5 | 2.3 | 2.3 | 2.4 | 2.2 | 65 | 23 | 27 | 32 | 172 |
| 10-Jul-97 | 0.3 | 0.2 | 1.4 | 1.4 | 1.6 | 1.5 | 2.8 | 1.8 | 1.6 | 1.8 | 12 | 31 | 37 | 85 | 93 |
| 17-Jul-97 | 1.4 | 1.2 | 2.1 | 2.2 | 1.5 | 2.4 | 1.7 | 1.6 | 1.8 | 1.7 | 18 | 20 | 49 | 67 | 503 |
| 25-Jul-97 | 1.2 | 3.2 | 2 | 2.7 | 2.7 | 1.3 | 2 | 2.3 | 2.2 | 2.9 | 9 | 24 | 87 | 249 | 512 |
| 01-Aug-97 | 0.7 | 1.1 | 1.2 | 1.6 | 1.5 | 2.1 | 1.8 | 1.7 | 3.8 | 6.7 | 4 | 10 | 13 | 28 | 46 |
| 08-Aug-97 | 0.9 | 1.5 | 1.2 | 3.2 | 1.5 | 3.1 | 4.4 | 1.6 | 4.2 | 5.4 | 14 | 13 | 8 | 47 | 92 |
| 15-Aug-97 | 0.7 | 1.4 | 1.8 | 0.8 | 1.7 | 3 | 1.2 | 2.7 | 3.2 | 3.8 | 5 | 15 | 32 | 58 | 85 |
| 22-Aug-97 | 0.3 | 0.8 | 1.1 | n/a | 1.6 | 2.8 | 1.8 | 2.8 | n/a | 2.9 | 11 | 7 | 19 | n/a | 304 |
| 02-Sep-97 | 0.7 | 0.4 | 1.2 | n/a | 2.5 | 3.4 | 3.1 | 4.2 | n/a | 5.4 | 15 | 4 | 72 | n/a | 104 |
| 12-Sep-97 | 1.5 | 1.3 | 1.2 | n/a | 3.2 | 4.9 | 2.5 | 4.9 | n/a | 15.9 | 7 | 9 | 30 | n/a | 266 |
| 19-Sep-97 | 0.8 | 1 | 1.3 | n/a | 2.8 | 2.6 | 2.4 | 5.7 | n/a | >20.0 | 3 | 7 | 24 | n/a | 96 |
| 29-Sep-97 | 0.6 | 0.8 | 0.9 | n/a | >5.0 | 4 | 1 | 9.6 | n/a | 5.8 | 5 | 9 | 72 | n/a | 338 |
| 06-Oct-97 | 0.3 | 1.2 | 1.5 | n/a | 1.6 | 3.3 | 3 | 2.9 | n/a | 4.4 | 36 | 29 | 70 | n/a | 257 |
| 13-Oct-97 | 1.4 | 1.1 | 1.2 | n/a | 1.2 | 2.9 | 2.8 | 3.2 | n/a | 7 | 8 | 12 | 22 | n/a | 35 |
| 17-Oct-97 | 0.6 | 1.3 | 1.2 | n/a | 1.6 | 1.6 | 2.4 | 3.2 | n/a | 3.6 | 6 | 8 | 36 | n/a | 10 |
| 24-Oct-97 | 1.7 | 1.5 | 1.2 | n/a | 1.5 | 2.8 | 2.3 | 2.8 | n/a | 3.4 | 17 | 11 | 49 | n/a | 148 |
| 31-Oct-97 | 0.8 | 0.5 | 0.7 | n/a | 2 | 2.2 | 3.1 | 3.3 | n/a | 3.3 | 13 | 10 | 31 | n/a | 76 |
| 07-Nov-97 | 1.3 | 2.1 | 2.2 | n/a | 1.6 | 3.5 | 3.2 | 4.6 | n/a | 5.7 | 28 | 16 | 19 | n/a | 40 |
| 11-Nov-97 | 1.5 | 1.2 | 1.1 | n/a | 1.5 | 1.8 | 2.1 | 4.4 | n/a | 5.8 | 19 | 88 | 200 | n/a | 213 |
| 17-Nov-97 | 1.5 | 1.3 | 0.8 | n/a | 3.2 | 2.8 | 2.4 | 3.2 | n/a | 3.4 | 41 | 53 | 90 | n/a | 94 |
| 28-Nov-97 | 0.7 | 0.4 | 1.2 | 1.4 | 1.6 | 3 | 2.3 | 3.6 | 3.5 | 5.3 | 5 | 12 | 65 | 67 | 284 |
| 01-Dec-97 | 1.4 | 0.9 | 1.5 | 1.6 | 1.8 | 2.8 | 2.1 | 2.8 | 3.2 | 3.6 | 16 | 22 | 43 | 60 | 55 |
| 18-Dec-97 | 1.2 | 1.3 | 1.6 | 2.8 | 2.7 | 3.6 | 2.4 | 3.6 | 3.4 | 4.2 | 52 | 25 | 18 | 77 | 80 |
| | | | | | | | | | | | | | | | |
| 06-Jan-98 | 0.7 | 1.3 | 1.2 | 1.6 | 1.5 | 3.5 | 3.8 | 3.6 | 4.2 | 3.6 | 7 | 8 | 6 | 28 | 42 |
| 28-Jan-98 | 0.8 | 1.2 | 0.9 | 1.2 | 1.6 | 11.9 | 1.2 | 2 | 3.3 | 3.4 | 36 | 9 | 5 | 11 | 9 |
| 17-Feb-98 | 1.2 | 1.3 | 2.1 | 2.6 | 2.5 | 2.6 | 1.7 | 1.5 | 1.7 | 1.8 | 19 | 4 | 9 | 22 | 28 |

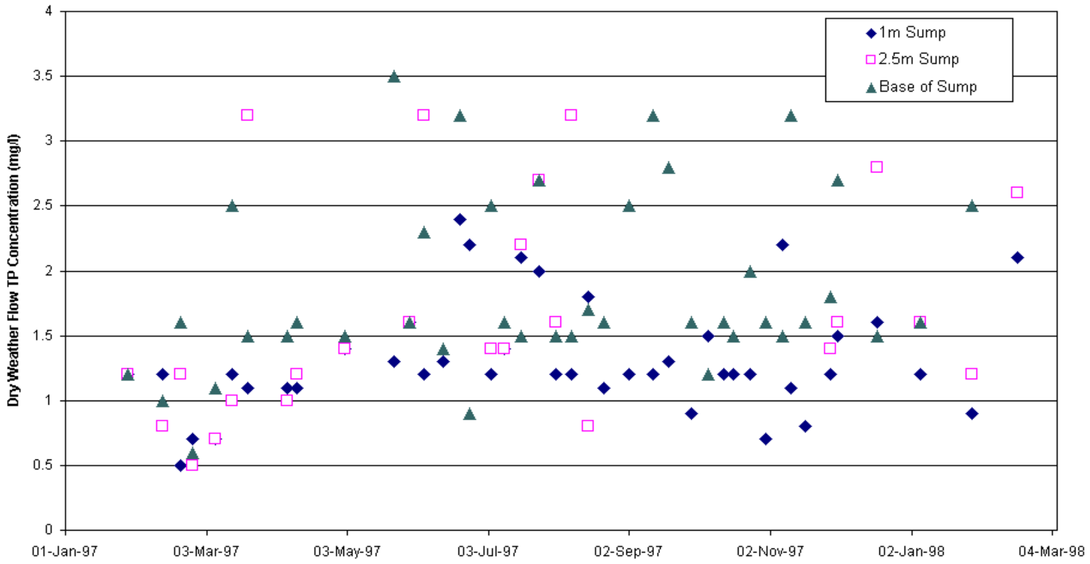

Figure 17: Time Series Plot of Dry Weather TP Concentrations in the CDS Separation Chamber

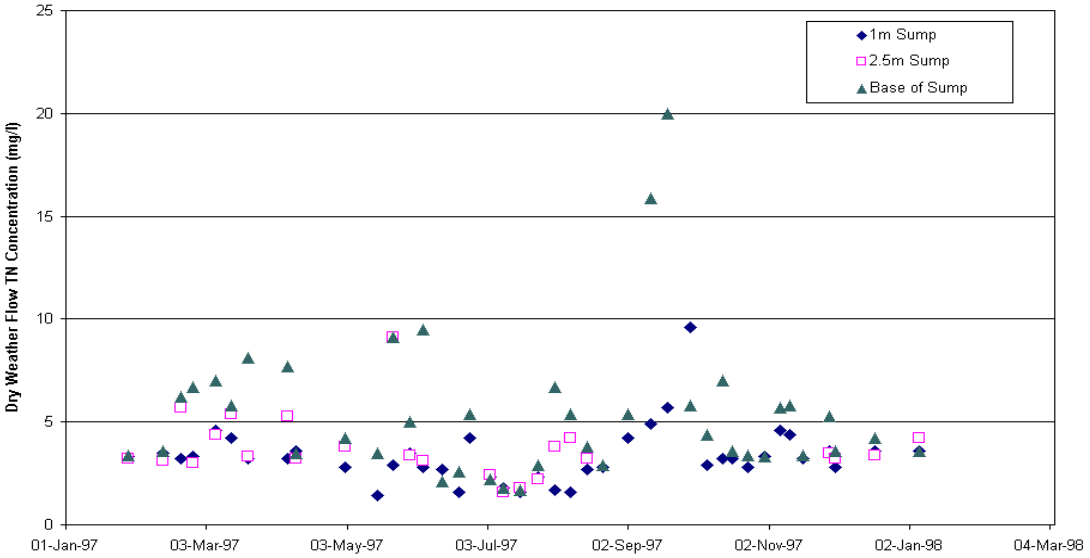

Figure 18: Time Series Plot of Dry Weather TN Concentrations in the CDS Separation Chamber

Correlation analyses of water quality recorded at the bottom of the separation chamber and at the sampling station downstream of the CDS unit were undertaken to examine the contribution of ambient water quality in the separation chamber to the receiving waters during dry weather flow conditions. The results of the correlation analysis are shown in Figures 19, 20 and 21. As evident from the plots, correlation between the water quality at the outflow of the CDS unit is highest with the water quality observed at 1 m below the water surface in the separation chamber, suggesting limited mixing during dry flow conditions.

Figure 19 shows that TSS concentrations at the outflow of the CDS unit are not influenced by TSS concentrations in the separation chamber under dry weather flow conditions. The outflow TSS concentration levels were significantly lower than that observed at the bottom of the containment sump. Concentrations in the sump were an order of magnitude larger than that observed at the sampling location downstream of the CDS unit. The data suggest flow conditions to be highly stratified during dry weather flow operation and very little vertical mixing in the separation chamber.

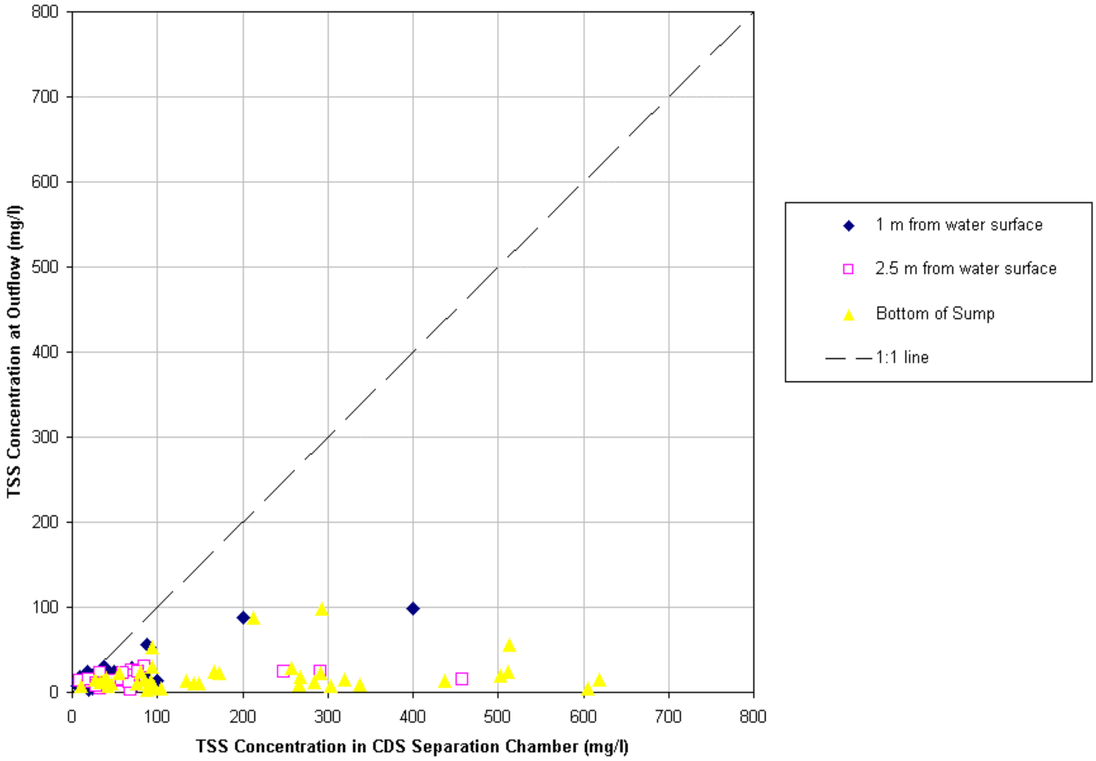

Figure 19: Correlation Scatter Plot between TSS Concentration at the Outflow and TSS Concentration in the CDS Separation Chamber

Figures 20 and 21 show a weak, but apparent correlation between TP and TN concentrations observed at 1 m from the water surface in the separation chamber and that observed at the sampling location downstream of the CDS unit with the data points plotting about the 1:1 line. To some extent, the TP and TN concentrations observed at 2.5 m below the water surface were also similarly correlated with the observed TP and TN concentrations at the outflow with concentrations of less than 2.0 mg/L and 4.0 mg/L respectively plotting about the 1:1 line.

It is possible that the proportion of the dissolved form of phosphorus and nitrogen in the separation chamber would be higher than that typical of the inflow because of phosphorus sediment desorption and nutrient biochemical transformation of organic material trapped. The soluble form of nutrients is expected to diffuse in the water column more readily (compared to suspended solids) and thus the tendency for water quality in the sump to have a higher influence on the quality of the outflow from the CDS unit. While the range of TP and TN concentrations within the separation chamber are comparable to outflows from the CDS unit, the observed nutrient concentrations at the bottom of the sump were found to be consistently higher than that observed discharging from the CDS unit. This indicates the combined effect of incomplete vertical mixing in the water column and the higher TSS concentration towards the bottom of the separation chamber, the former being attributed to quiescent flow conditions.

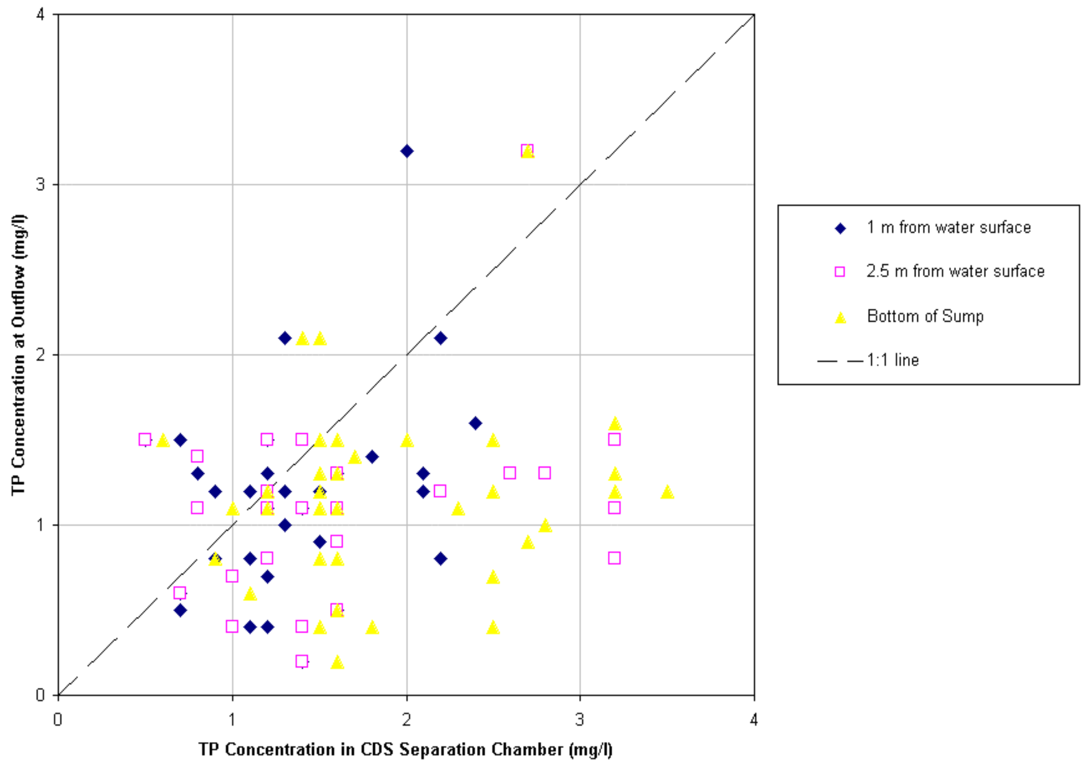

Figure 20: Correlation Scatter Plot between TP Concentration at the Outflow and TSS Concentration in the CDS Separation Chamber

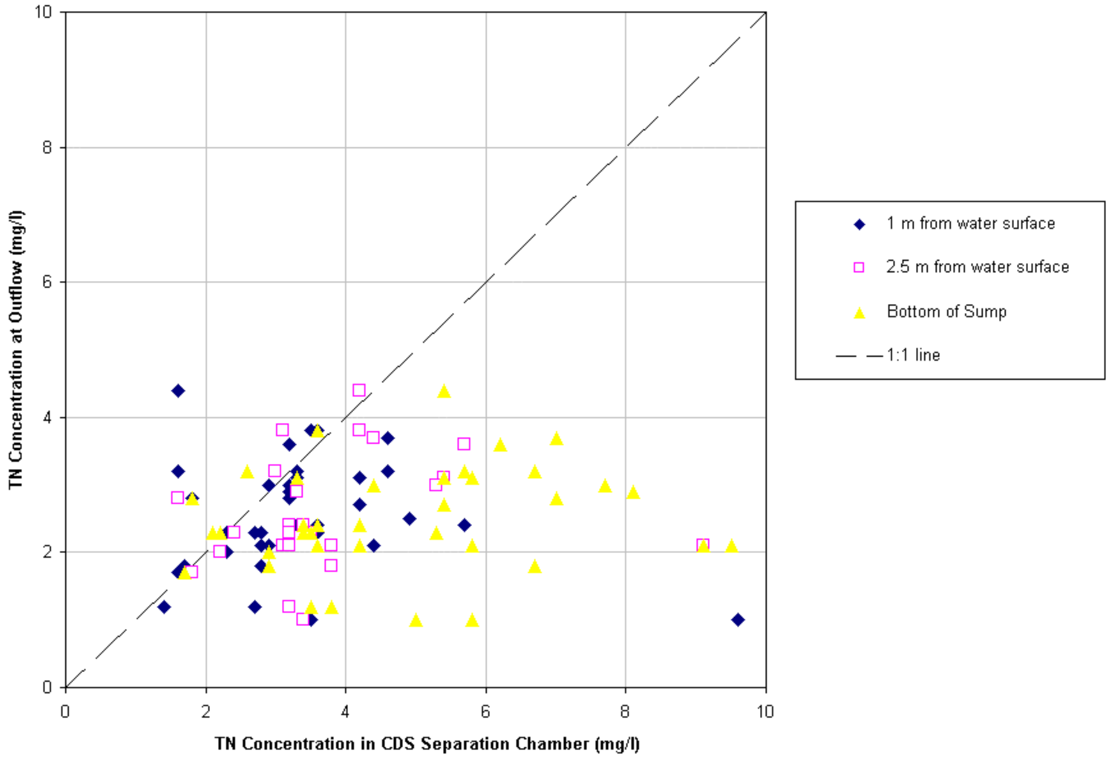

Figure 21: Correlation Scatter Plot between TN Concentration at the Outflow and TSS Concentration in the CDS Separation Chamber

### 5.3 Removal Efficiency Computation

Event Sample Analysis

Storm events sampled between November 1996 and February 1998 were analysed to investigate the removal performance of the CDS unit for suspended solids and associated contaminants during runoff events. Storm events monitored ranged from 1 mm to 5 mm in rainfall depth. TSS, TP and TN concentrations recorded at the upstream and downstream monitoring locations are plotted as scatter plots and presented in the following sections. Concentrations from a total of 15 storm events were used for the TSS analysis while concentrations for eight of these events were used to analyse TP and TN.

Analysis of pollutant reduction by means of scatter plots of instantaneous water quality concentrations were found to be an appropriate method for analysing storm events in the present investigation owing to the absence of water samples collected over the full hydrograph duration. With the very short detention period in the CDS unit, it is reasonable to compare instantaneous water quality for the inflow and outflow of the CDS unit as a basis for assessing its influence on stormwater quality.

Dry Weather Sample Analysis

Routinely collected samples were analysed to determine the influence of the CDS unit on water quality during dry weather conditions. Cumulative frequency analysis was used to assess the difference between dry weather flow concentrations at the inlet and outlet of the CDS unit. This approach was preferred for analysis of dry weather flow operation because of the significantly lower flow rate through the CDS unit and consequently a higher detention storage effect on the outflow. Cumulative frequency water quality distribution curves plot the percentage of time for which water quality falls below a given value during the monitoring period. These plots are useful in assessing the long-term effects of a treatment measure on the "exposure frequency" of the receiving waters to different levels of water pollutant concentrations. Testing water quality, at regular time intervals, at the inflow and outflow of the treatment measure enables this analysis to be carried out. Water quality levels are then ranked in descending order. The frequency of exceedence of each sample is estimated as the ratio of the sample ranking (m) to the total number of water quality samples (N) obtained at the site. The cumulative frequency of the water quality is computed as:

$$CF_r = 1 - P_r$$

where: $CF_r$ is the cumulative frequency or the percentage of time pollutant concentrations are below the specified level;
$P_r$ is the frequency of exceedence computed as m/N;
m is the ranking (in descending order of the magnitude of the pollutant concentration) of the water quality sample;
N is the total number of samples taken at regular time intervals at the site.

Concentrations of TSS, TP and TN were ranked and plotted to determine their respective cumulative frequency curves at the inflow and outflow of the CDS unit. (These are presented in Figures 24, 27 and 30).

### 5.4 *Total Suspended Solids*

Figure 22 shows a scatter plot and line of best fit of TSS concentration entering and leaving the CDS unit observed during fifteen storm events. The line of best fit has a slope of 0.28 and intercepts the 45° line (ie. inflow concentration is the same as outflow concentration) at approximately 38 mg/L indicating, statistically, a mean increase in TSS concentration when inflow concentrations fall below this value.

The plot indicates that the CDS unit is relatively effective in reducing TSS for concentrations above approximately 75 mg/L. For inflow TSS concentrations less than 75 mg/L, some reductions in the TSS concentrations were apparent in the outflow from the CDS unit. The reduction in TSS during periods of inflow concentrations less than 75 mg/L were however erratic, with some instances of higher TSS concentration at the outflow than the inflow. This is probably the result of a combination of low inflow TSS concentrations with turbulence in the separation chamber caused by high flow rates. In some instances, background concentrations can be influenced predominantly by the flow rate and are largely independent of the inflow concentration, leading to virtually no TSS removal by the unit when inflow concentrations fall below these background concentration levels.

The slope of the fitted line indicates the pollutant removal efficiency above the background TSS concentration and estimates a TSS removal efficiency of approximately 70% above the background concentration of 75 mg/l. The TSS removal efficiency of the CDS unit is thus expected to be low when the inflow TSS concentration is within the range of the background concentrations and the efficiency is approximately 70% with higher concentrations.

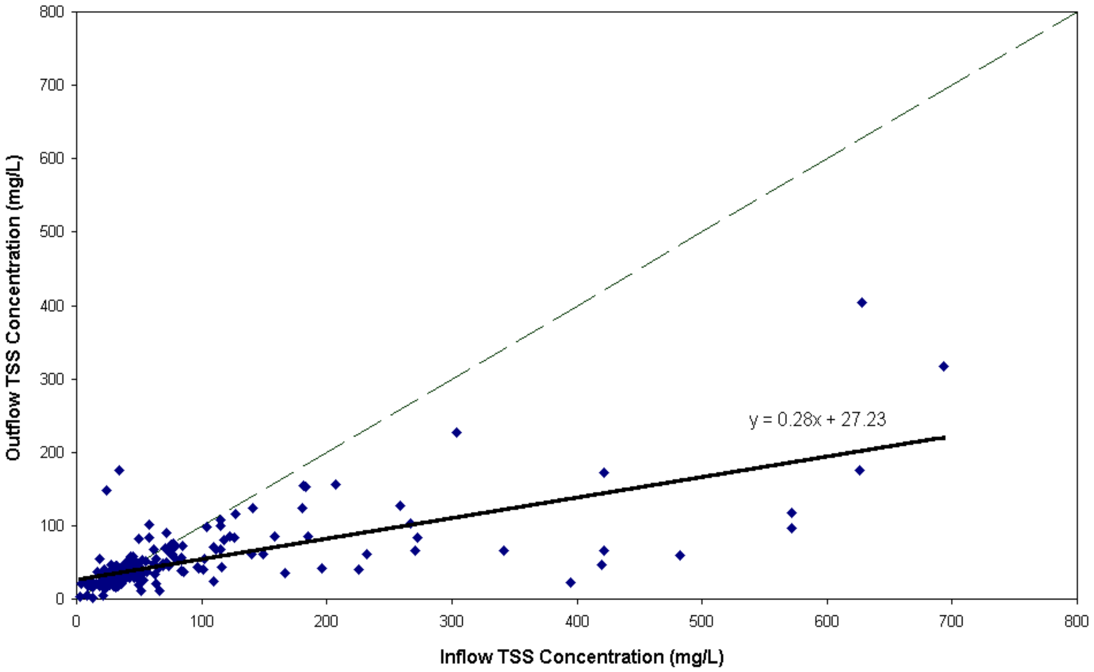

Figure 22: Event – TSS Concentrations at the Inflow and Outflow of the CDS Unit

Figure 23 shows a time series plot of dry weather flow TSS concentrations observed at the upstream and downstream water quality sampling locations. Figure 24 shows the cumulative frequency distribution curves of total suspended solids concentrations at the inflow and outflow of the CDS unit under dry weather flow conditions. It is apparent from Figure 24 that the CDS unit does not significantly affect TSS concentrations during dry weather flow conditions although there is a tendency for the unit to slightly increase TSS concentration at the outflow of approximately 22% from a low base level. At this low base level sampling errors can often account for a significant proportion of the differences observed. Both inflow and outflow concentrations indicate a tendency to fluctuate around a TSS concentration of approximately 20 mg/L, with an 80 percentile concentration of approximately 30 mg/L. This is consistent with the intercept level of the fitted line for instantaneous storm event TSS concentrations plotted in Figure 22.

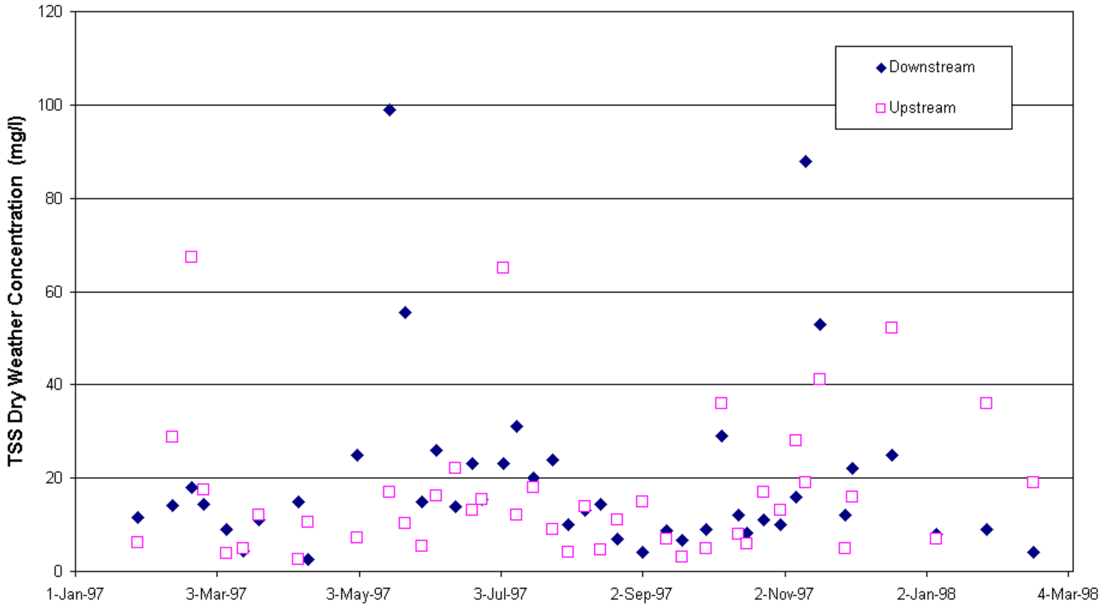

Figure 23: Time Series Dry Weather Flow TSS Concentrations

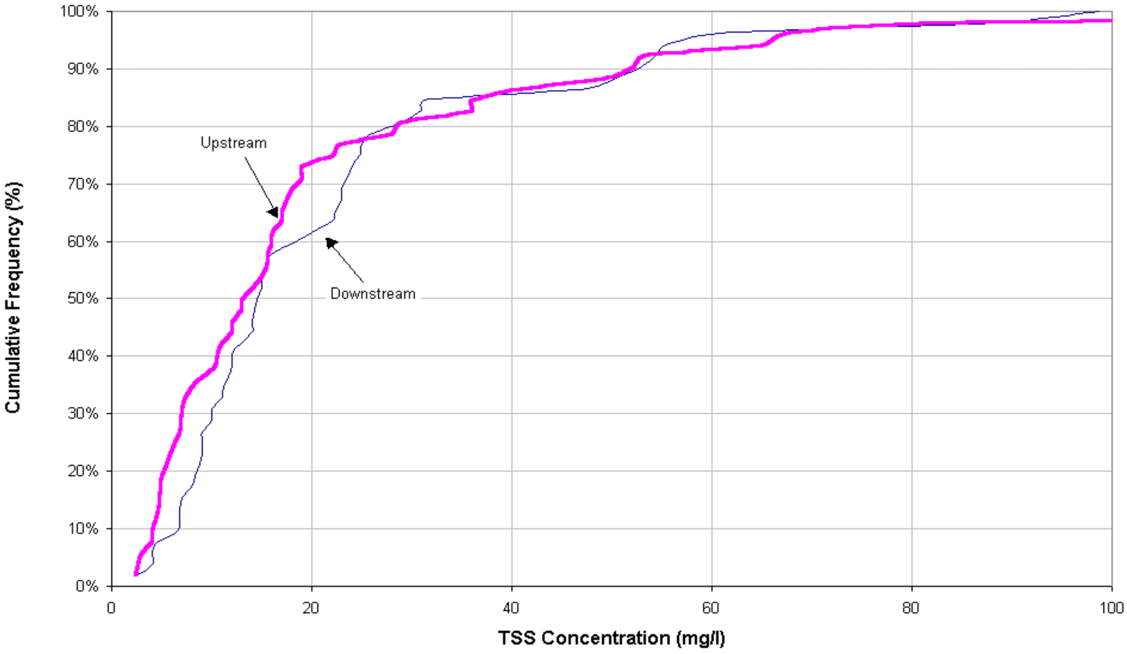

Figure 24: Dry Weather Flow – TSS Concentrations Cumulative Frequency Curves

### *5.5 Total Phosphorous*

Figure 25 shows a scatter plot and a line of best fit for instantaneous TP concentrations entering and leaving the CDS unit during storm events. The plot indicates that there is an apparent removal of TP by the CDS unit for concentrations greater than 0.50 mg/L. There is a higher degree of scatter in the plot compared with the TSS plot of Figure 22, with some occasions where the TP outflow concentrations were higher than the corresponding inflow concentrations. This may be attributed to initial flushing of ambient water quality in the separation chamber of the CDS unit. The phosphorous flushed from the CDS separation chamber is expected to be largely in the soluble reactive form. The relatively high association of TP with suspended solids in the inflow can mask the significance of soluble phosphorous flushing from the sump of the CDS unit during the initial period of a runoff event. The removal of suspended solids (and thus particulate phosphorous) during the initial period of an inflow can often exceed the amount of soluble phosphorous flushed from the CDS sump giving a net removal of TP.

It should be noted that the recorded concentrations of TP (ie. > 0.50mg/L) are high and an order of magnitude greater than the desired concentrations for receiving waters. The estimated removal efficiency of TP above the background concentration of 0.5 mg/L is approximately 30%.

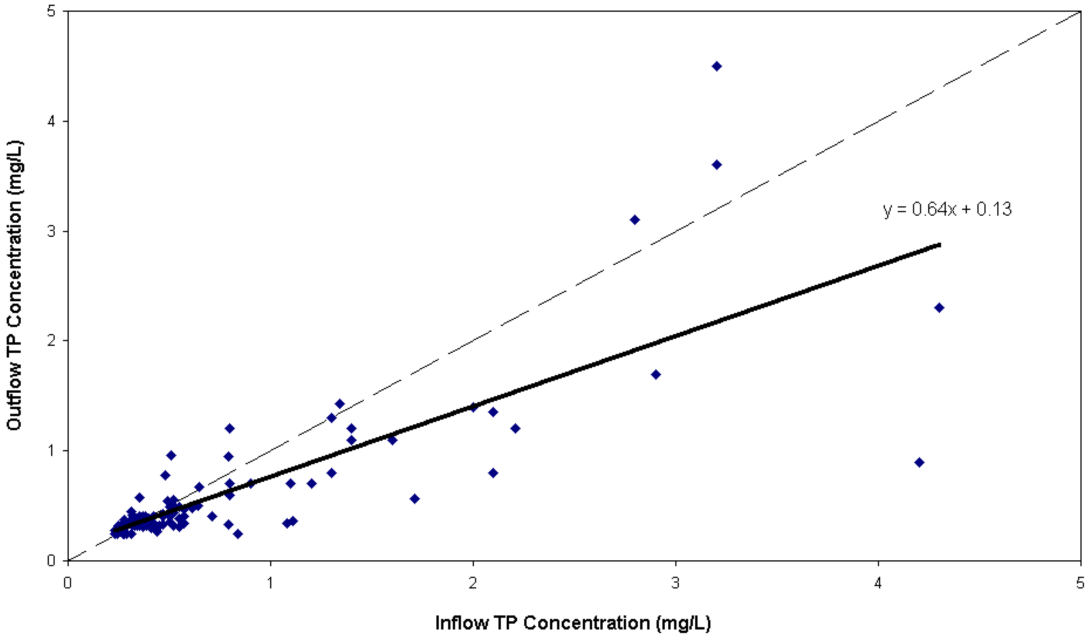

Figure 25: Event – TP Concentrations at the Inflow and Outflow of the CDS Unit

Figure 26 plots the time series dry weather TP concentrations and Figure 27 shows the resulting cumulative frequency distribution curves at the inflow and outflow of the CDS unit. The time series plot and the cumulative frequency curves indicate a slight tendency for the CDS unit to export phosphorous where a trend is evident of increasing TP export with increasing cumulative frequency values. The mean increase in TP is calculated as approximately 23%. The exported TP is most probably in the dissolved form of $PO_4$ during dry weather flow conditions and can be attributed to low redox potential level in the CDS separation chamber leading to phosphorus desorption from the deposited sediment

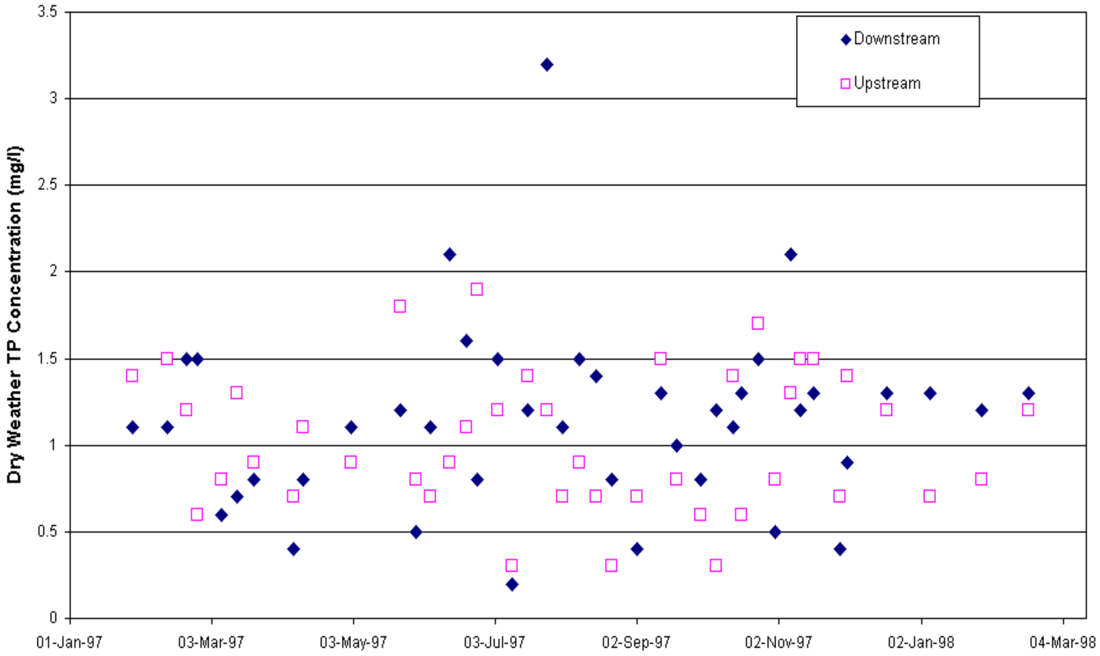

Figure 26: Time Series Dry Weather Flow TP Concentrations

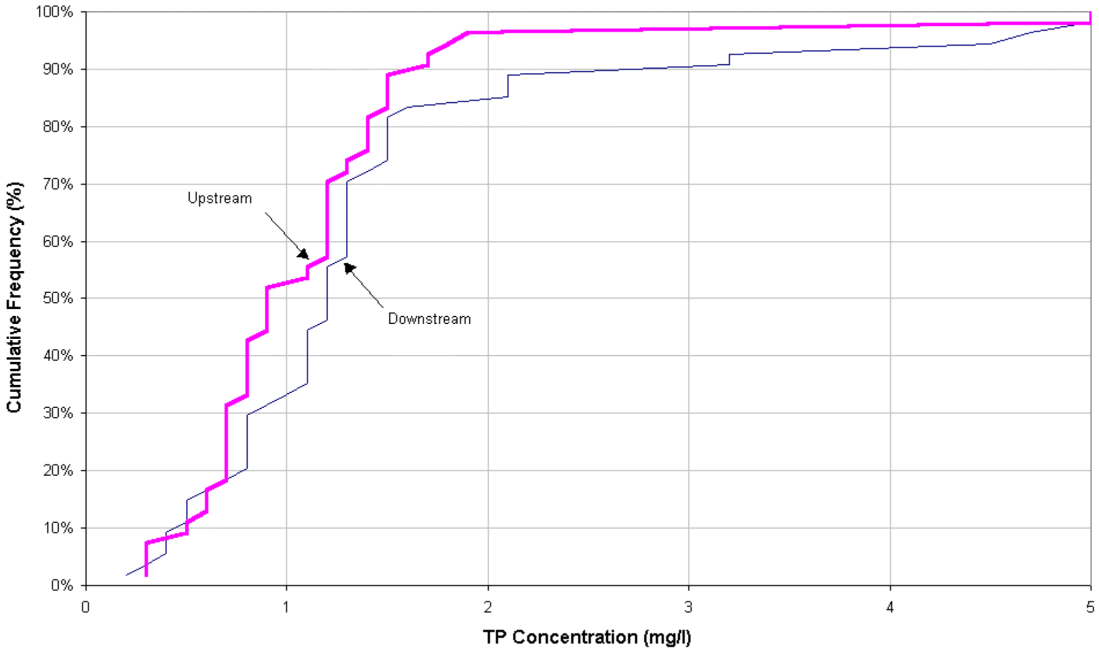

Figure 27: Dry Weather Flow – TP Concentrations Cumulative Frequency Curves

## 5.6 *Total Nitrogen*

Figure 28 shows the scatter plot of TN concentrations observed at the inflow and outflow of the CDS unit. The plot shows that TN removal by the CDS unit is erratic, evident by the broad scatter. This is consistent with the fact that TN is conveyed in urban stormwater in a number of particulate and soluble forms and is least associated with suspended sediment.

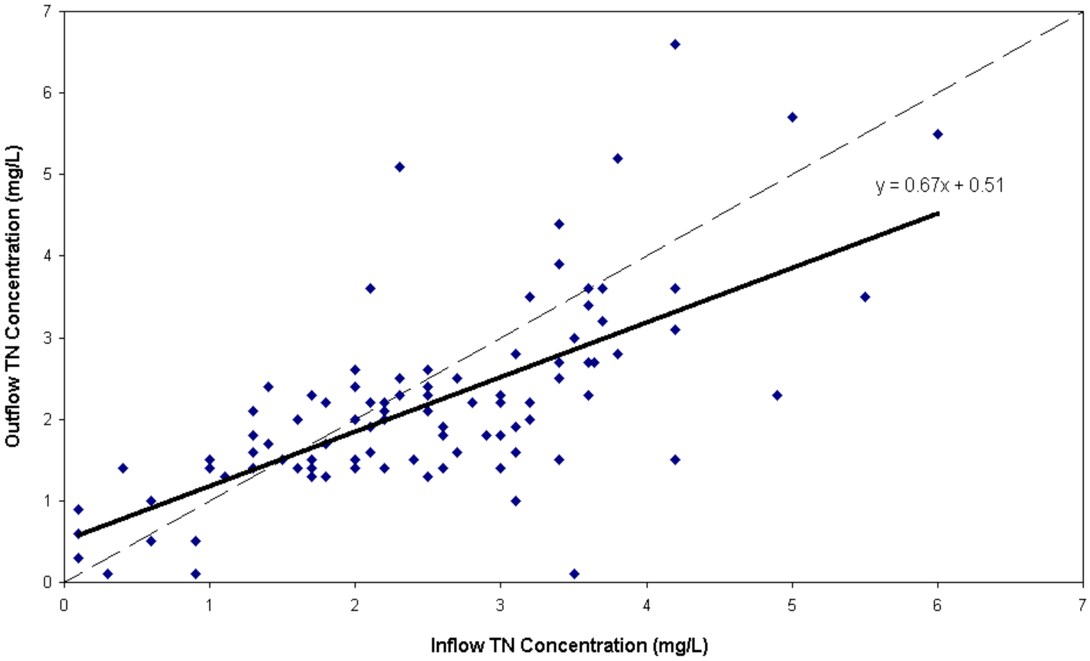

Figure 28: Event – TN Concentrations at the Inflow and Outflow of the CDS Unit

Figure 29 plots the time series dry weather flow TN concentrations and Figure 30 plots the corresponding cumulative frequency distribution curves of TN at the inflow and outflow of the CDS unit. The time series plot and the cumulative frequency curves indicate a consistent removal of TN from the CDS unit during dry weather flow conditions. The mean removal efficiency for TN was calculated to be approximately 13%.

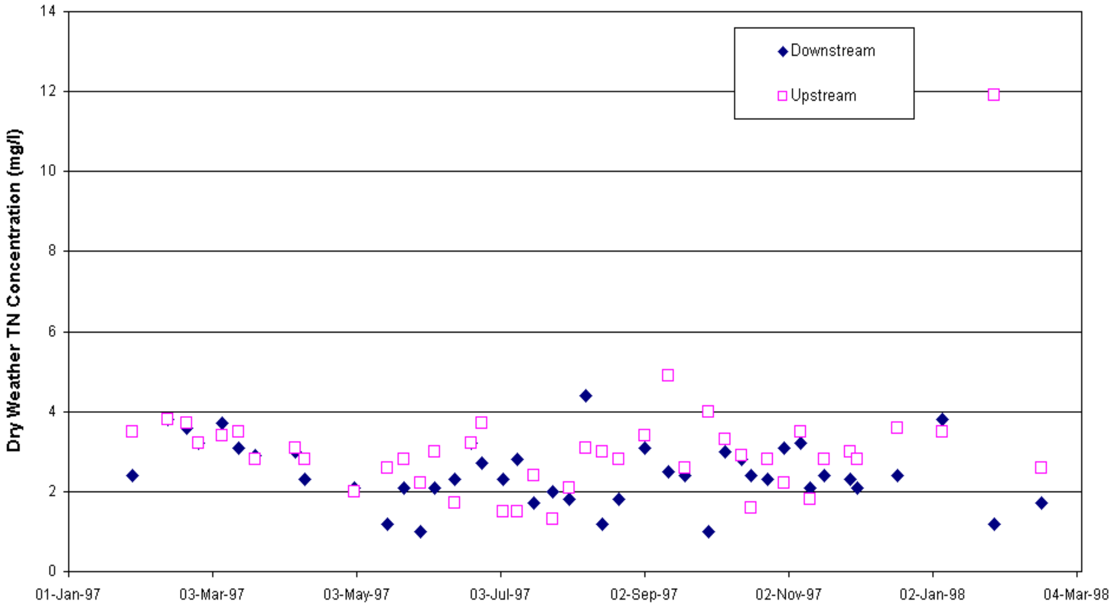

Figure 29: Time Series Dry Weather Flow TN Concentrations

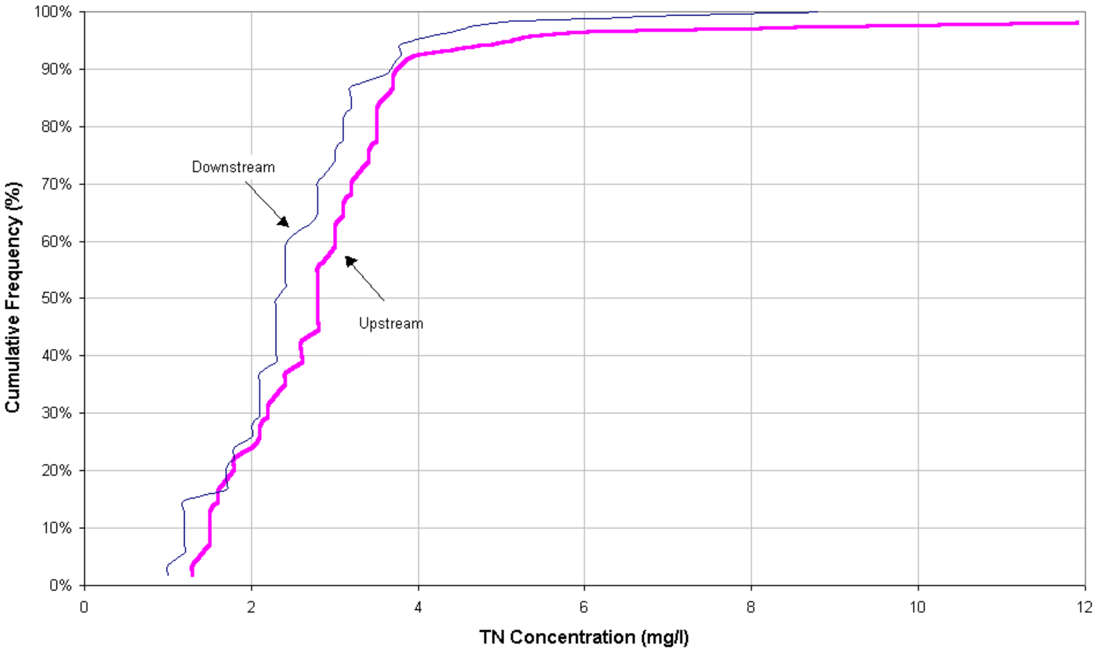

Figure 30: Dry Weather Flow – TN Concentrations Cumulative Frequency Curves

# 6. DISCUSSION

The performance of CDS devices is dependent on the particle size distribution of the solids transported in stormwater systems. These characteristics are influenced by the geology of the catchment and the Coburg catchment generally consists of basaltic soils. Unfortunately, no particle size analysis was undertaken of the suspended solids sampled during the September 1996 to November 1997 monitoring period to allow a clearer insight into the sediment trapping characteristics of the CDS unit. Work is underway to determine the particle size distribution of suspended solids in stormwater runoff from the Coburg catchment. However, limited data of particle size distribution characteristics of road runoff from urban catchments in Eastern Australia suggest the likelihood of finer particle size fractions in urban runoff, compared with street runoff characteristics from overseas (particularly the United States) catchments (see Figure 4). If this is the case, the removal efficiencies of TSS and TP attributed to the CDS unit at Coburg will under-estimate the performance of comparable units installed in overseas catchments with coarser sediment size fractions.

Under storm conditions, inflow TSS, TP and TN concentrations from the Coburg catchment were observed to be as high as 570 mg/L, 4.3 mg/L and 6.0 mg/L respectively. Apart from TP, these concentrations are within the typical range for urban catchments in Australia. The CDS unit effectively reduced TSS concentration levels above 75 mg/L with estimated mean removal efficiencies of approximately 70%. TSS removal was more variable for inflow concentration levels below 75 mg/L. This is thought to be due to flow turbulence within the CDS unit maintaining more particles in suspension. Removal rates for TP were found to be approximately 30% and are potentially attributed to a high proportion of phosphorus being transported in particulate form associated with the solids in the stormwater. However, there were incidences in which comparison of instantaneous TP concentrations entering and leaving the CDS unit showed higher phosphorus concentrations at the outlet. This maybe attributed to an initial flushing of higher TP concentrations contained in the separation chamber of the unit. Analysis of TN data entering and leaving the CDS unit showed a highly erratic TN removal behaviour throughout the full range of TN concentrations. This may be due, in part, to a higher variability in the form of nitrogen in stormwater and sporadic flushing of higher TN concentrations from the separation chamber of the CDS unit.

Monitoring of water quality in the separation chamber during dry weather conditions showed water quality concentrations to be stratified with the highest pollutant concentrations observed near the bottom of the containment sump. This vertical profile was most prominent for TSS, with concentrations in the sump found to have little influence on TSS concentrations at the outflow. This is thought to be because of the limited vertical mixing of the water in the containment sump with relatively quiescent flow conditions. Monitored TSS concentrations were generally observed to be approximately 30 mg/L.

Allison et al. (1998) showed that a large proportion of the gross pollutants transported in urban stormwater is organic matter. The CDS unit retains nearly all gross pollutants, hence the majority of the organic material transported from the 50 hectare catchment was captured and retained within the CDS containment sump. These materials are retained under water and there is the possibility of the desorption of phosphorous due to the reduced dissolved oxygen levels and redox potential in the containment sump. This process could potentially transform the relatively stable forms of particulate phosphorous into more readily available soluble forms, although no analysis was performed. These increased concentrations of dissolved phosphorous could then be flushed from the separation chamber during the initial stages of the following storm event. Monitoring results indicated that this process may be taking place with an average of 23% increase of TP concentrations at the outflow during dry weather flows (see Figure 26 & 27). The overall effect of the phosphorous transformation and subsequent release during dry weather, on the overall TP removal (including storm events) is investigated in section 6.1.

Retaining pollutants underwater is inevitable with the current design of the CDS unit as the containment sump is lower than the outlet of the CDS unit. Therefore there will always be a risk of low redox potential conditions and the transformation of particulate to dissolved forms of phosphorous, and potential transport downstream.

The CDS unit was found to consistently remove dry weather flow TN inflows with a mean removal efficiency of 13% and this is attributed to more varied forms of nitrogen transported through the stormwater system.

The observed data suggest that nutrient concentrations can be higher at the outlet than the inlet of the CDS unit during dry weather flow conditions. This highlights the need to incorporate a treatment sequence in stormwater systems for improved pollutant removal. A treatment measure located downstream could address those pollutants that pass through a CDS unit and would together remove a wider range of pollutants than a CDS unit alone. Dry weather outflow of nutrients can be readily reduced by means of biological uptake processes promoted in constructed wetland systems or stormwater infiltration systems. Biological processes require a much lower hydraulic loading rate compared with gross pollutant traps and are most efficient under dry weather flow conditions. Therefore, combining an efficient gross pollutant trap (such as a CDS unit) followed by a constructed wetland (Wong et al., 1998) or a bioretention zone (Schueler, 1987) would remove a wide spectrum of the pollutants found in stormwater.

The data presented in this report suggest the CDS unit is not only effective at retaining gross pollutants, but also at removing TSS and TP during storm events (TN removal was found to be variable). However, during the periods between storm events the collected pollutants remain underwater with the possibility of material breakdown, as discussed earlier. Thus, the overall effectiveness of the CDS unit is a function of the amount of pollutants it retains during storm events and the amount released during dry weather (or between storm events) and the cleaning cycle frequency. To investigate the overall removal performance of the CDS unit for TSS, TP and TN a range of event mean concentrations are estimated for three flow conditions. The removal rates are estimated using the current monitoring results and both are used to estimate the overall removal performance. The hypothetical calculations are presented and discussed below.

### *6.1. Estimation of Annual Pollutant Removal*

A broad estimate of the annual removal of TSS and TP by the CDS unit was made using rainfall records for Melbourne and assuming event mean concentrations for TSS and TP during storm events and dry weather flows in the Coburg catchment.

*Assumption 1- Storm Events and Flow Volumes*

Analysis of 104 years of rainfall records by Wong (1996) for Melbourne gave the following rainfall characteristics and these are adopted in the current example:

| | |
|---|---|
| Mean Annual Rainfall:- | 635 mm |
| Mean number of storm events:- | 122 |
| Mean annual total of storm duration: | 1144 h |

A large proportion of the mean annual storm events (122) have relatively low rainfall intensities and depths and are not expected to generate any significant flow. The event mean pollutant concentrations for these events is expected to be lower than that typical of measured events. For the purpose of this example, storm events with a rainfall intensity lower than 0.6 mm/h are included in a separate category. An intensity of 0.6 mm/h was selected to coincide with the flow rate at which the automatic water samplers are triggered at the Coburg monitoring sites (100 mm depth). The distribution of storm events were found to be:

| | |
|---|---|
| Storm events with rainfall intensity > 0.6 mm/h: | 54 |
| Mean Annual Rainfall for events with intensity > 0.6 mm/h: | 467 mm |
| Total duration of storm events with intensity > 0.6 mm/h: | 347 h |

The mean annual runoff is computed by adopting a volumetric runoff coefficient of 0.5. The mean annual runoff volumes from the two categories of storm events for the Coburg catchment (50 Ha area) are as follows:

| | |
|---|---|
| Runoff from storm events with intensity > 0.6 mm/h: | 116,750 $m^3$ |
| Runoff from storm events with intensity < 0.6 mm/h: | 42,000 $m^3$ |

*Assumption 2 - Dry Weather Flow*

The mean annual duration of dry-weather flow may be represented by the period when no rainfall was recorded. This is an over-estimate of the dry weather flow period because there will be a period of flow recession following the conclusion of rainfall that cannot be considered as a period of dry weather flow conditions. The period of recession is in the order of the time of concentration of the catchment, which is approximately one hour. For this exercise, the mean annual dry weather flow period is computed as the period of no rainfall recorded less the number of storm events (adopting a one hour recession period), ie.

Mean annual dry weather flow period = (8760 – 1144) – 122 = 7494 h.

A mean flow of one litre per second was adopted as the dry weather flow for the Coburg catchment, ie.

Mean annual volume of dry weather flow = 27000 $m^3$

*Assumption 3 - Mean Pollutant Concentration*

From consideration of the pollutant concentrations in collected water samples from Coburg, the following mean pollutant concentrations were adopted for the present analysis and are shown in Table 2.

Table 2: Estimated Mean Pollutant Concentrations for Coburg

| POLLUTANT | STORM TYPE | EMC |
|---|---|---|
| TSS | Storm events with intensity > 0.6 mm/h | 300 mg/L |
| | Storm events with intensity < 0.6 mm/h | 50 mg/L |
| | Dry weather flow | 20 mg/L |
| TP | Storm events with intensity > 0.6 mm/h | 1.5 mg/L |
| | Storm events with intensity < 0.6 mm/h | 0.4 mg/L |
| | Dry weather flow | 0.9 mg/L |

It is noted from above that the dry weather flow TP concentration is significantly higher than that corresponding to storm events of intensity below 0.6 mm/h. This is thought to be attributed to a combination of higher dissolved fraction of total phosphorus during dry weather flow (eg. detergent) and also dilution during storm runoff events.

*Assumption 4 - Annual Pollutant Removal Efficiency*

The expected annual pollutant removal efficiencies for TSS and TP are estimated using the monitoring results. The values adopted are listed below in Table 3.

Table 3: Expected Annual Pollutant Removal Efficiencies for Coburg

| STORM TYPE | TSS REMOVAL | TP REMOVAL |
|---|---|---|
| Storm events with intensity > 0.6 mm/h | 70% | 30%. |
| Storm events with intensity < 0.6 mm/h | 0% | 0% |
| Dry weather flow | -22% | -23% |

*Results*

Table 4 shows the estimated mean annual pollutant removal efficiency of the CDS unit using the assumptions outlined in this section for the Coburg catchment.

Table 4: Pollutant Loads (kg)

| **Pollutant** | **Storm > 0.6 mm/h** | | **Storm < 0.6 mm/h** | | **Dry weather flow** | | **Total** | | **Removal Efficiency** |
|---|---|---|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out | In | Out | |
| **TSS** | 35030 | 10510 | 2100 | 2100 | 540 | 660 | 37670 | 13260 | **65%** |
| **TP** | 175 | 123 | 16.8 | 16.8 | 24.3 | 29.9 | 216 | 170 | **21%** |

This example has demonstrated that the CDS unit retains a significant proportion of suspended solids that are transported in stormwater. Further, the unit shows an overall reduction in TP despite some incidences where the outflow concentration was higher than the inflows.

# 7. CONCLUSIONS

This study investigates the performance of a CDS unit in the removal of suspended particles, particularly sediment and associated pollutants in stormwater. Storm event and dry weather water samples were collected entering and leaving a CDS unit and were analysed for Total Suspended Solids (TSS), Total Phosphorus (TP) and Total Nitrogen (TN) concentrations. Shown previously to be an effective gross pollutant trap, the CDS unit's performance for suspended material is less well understood.

This study presents monitoring results of TSS, TP and TN concentrations. These results indicate that during storm events the CDS trap:

- removes a considerable amount of TSS above a background concentration during storm events with a mean removal efficiency of approximately 70%;
- consistently retains TP, thought to be because P is in particulate form, with a mean removal efficiency of approximately 30%; and
- has a variable influence on TN concentrations, thought to be because of the variable forms of nitrogen in stormwater.

These results suggest the CDS unit does retain suspended particles and associated pollutants during storm events, however, these pollutants are retained in a permanent pool of water and have the potential of being flushed downstream. Monitoring in dry weather conditions, during flows typically less than one litre per second, investigated the stratification of pollutant concentrations within the separation chamber and their possible export downstream. The results showed:

- concentrations of TSS, TP and TN to be stratified within the separation chamber of the CDS unit due to limited vertical mixing;
- the highest pollutant concentrations (most particularly TSS) were found at the bottom of the containment sump;
- low TSS concentrations in the inflow and no significant trends for TSS removal, with a slight increase in TSS concentrations sometimes observed at the outflow during dry weather flow conditions;
- variable trends for TP removal but overall higher concentrations were observed at the outlet, this was attributed to the phosphorous released from the sediment in the submerged containment sump; and
- a consistent removal of TN during dry weather.

The CDS unit can remove nearly all gross pollutants and a significant proportion of finer pollutants, particularly during storms. An annual removal efficiency of 65% and 21% for TSS and TP respectively were estimated by assuming typical pollutant concentrations during different flow conditions and using removal efficiencies estimated using data collected in this study.

This study suggests a stormwater treatment sequence involving an efficient gross pollutant trap, such as the CDS unit, followed by a constructed wetland or a bioretention zone can be expected to treat a wide spectrum of pollutants found in stormwater. The constructed wetland or bioretention zone in the treatment sequence would be designed to promote biological uptake of soluble pollutants under dry weather flow conditions and removal of fine suspended particulates under storm flow conditions and would compliment the performance of a CDS unit.

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COOPERATIVE RESEARCH CENTRE FOR
CATCHMENT HYDROLOGY

**Centre Office**
Department of Civil Engineering, PO Box 60, Monash University, Victoria 3800 Australia.
Telephone: (03) 9905 2704 Facsimile: (03) 9905 5033 International +61 3 9905 2704
**http://www.catchment.crc.org.au**