Vetiver Grass Hedges for Water Quality Improvement in Acid Sulfate Soils, Queensland, Australia

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Abstract: Acid sulfate soils are weak mechanically and therefore highly erodible, if drain banks are not properly stabilised, they are prone to collapse, dumping into the drains eroded soil and sediments, which are highly acidic and loaded with heavy metals and nutrients. Low flow velocities in the drains allow iron mono-sulphides and metal oxides to accumulate due to the high iron, aluminium and other metal concentrations in drainage waters.

In north Queensland, the establishment of vetiver grass has been shown to control channel bank erosion, lower frequency of drain maintenance, trap sediments in runoff water and reduce acidic loading by exposing less acid sulfate soil in the drain wall to oxidisation and leaching.

A trial was established in south Queensland to demonstrate the effectiveness of vetiver hedges in water quality improvement by stabilising highly acidic drains banks and trapping nutrients, sediment, agrochemicals and cane trash. Intensive monitoring and sampling of the section of drain planted with vetiver, a drain section without and the contributing run-off has demonstrated the economic and environmentally effectiveness of vetiver grass in improving water quality in term of pH, trash input, sediment and dissolved oxygen etc.

Key words: vetiver, water quality acid sulfate, erosion, pH, trash, sediment, dissolved oxygen

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1 INTRODUCTION

The formation of coastal acid sulfate soils has occurred in Australia over the past ten thousand years. During that time the sea level rose and sulfates in the seawater mixed with land sediments containing organic matter and iron oxides. The resulting chemical and biochemical reactions produced large quantities of iron sulfides in waterlogged sediments and formed what is known as acid sulfate soils (ASS) (Cook *et al*., 2000a). When the iron sulphides that are located within these soils are exposed to air, they oxidise and produce sulfuric acid. Urban, agricultural and recreational developments in ASS can result in exposure of sulfides and drainage export to ecosystems of acidic water loaded with heavy metals. This acidic discharge may result in fish kills (Brown *et al*., 1983; Easton, 1989), deterioration of concrete structures and have many other environmental impacts.

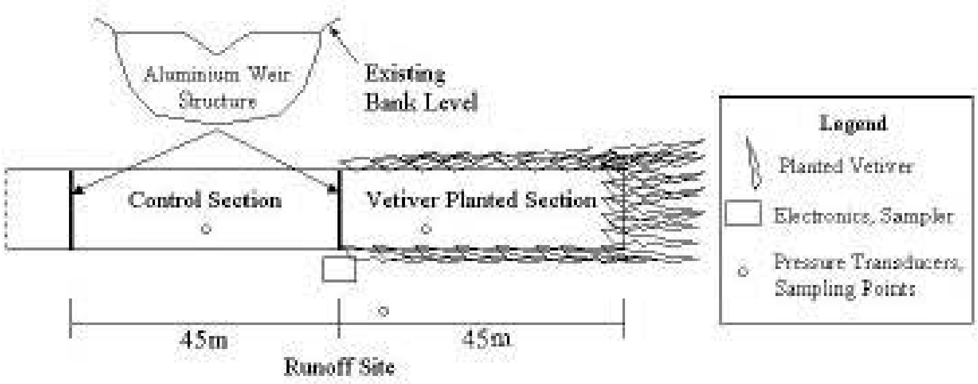
Early agricultural practices in ASS used for sugar cane production established deep drains. It was thought that the deep drains would remove excess ground water from the fields and prevent water logging of the cane. Recent field studies and model development by Cook *et al*. (2000b) suggests that most ASS have low hydraulic conductivities and redesigning drainage systems to minimise drain depth and maximise drain spacing should reduce the amount of acidity exported from ASS. The redesigning of drain systems may require a reasonable capital investment and could take years to implement.

An alternative approach to stabilising the existing drain networks from drained ASS fields is the schemes. Vetiver grass has been used successfully to stabilise banks of drains on ASS in Babinda north Queensland (Truong and Baker, 1996) and more recently it was planted as a hedge in the riparian zones adjacent to drains in the experimental trial that is being established at Pimpama, Queensland. Drain and stream bank erosion is controlled by the Vetiver's vigorous and extensive 3 to 4 m deep, root system that could be fundamental in decreasing freshly exposed ASS. The stiff stems of the thick vetiver hedge slow the movement of runoff waters, trapping silts, sediments and cane trash that may otherwise enter major waterways. Du and Truong (2002) have shown similar results in South Vietnam.

2 EXPERIMENTAL DESIGN

The experiment endeavoured to show the effectiveness of the vetiver grass hedge by comparing the water quality of a vetiver planted section (Fig. 1), an control section with no vetiver grass and the contributing runoff waters.

Fig. 1 Top view of experimental layout of drain showing the vetiver planted on a 45 m section of existing drain



2.1 Vetiver Grass

Vetiver grass (*Vetiveria zizanioides* Nash) is native to South and South-East Asia where its primary use was for soil and water conservation. Due to its special characteristics, vetiver has also been used very effectively for applications such as steep slope stabilisation and environmental protection, (Truong, 1999).

A sterile cultivar has been selected and registered in Queensland as Monto Vetiver, which does not self-seed, is non-invasive and has neither runners nor rhizomes. It can be eliminated easily by uprooting or Glyphosate spray. Vetiver has several characteristics that make it more suitable then other grasses for erosion control and can be grown in a range of soil and climatic conditions:

- It can tolerate extreme acidic and alkaline (pH 3.5-11.5), sodic (Exchange Sodium Percentage 48%), and saline (Electrical Conductivity 17.5 mS cm^{-1}), soils that can even be loaded with very high levels of aluminium (>68 Al/CEC%), iron, manganese (>578 ppm) and other heavy metals often associated with acidic soils such as As, Cd, Cu, Cr and Ni.
- It has a deep dense spongy root system (up to 3 m) that binds soils together and is very tolerant to extreme climatic conditions. Vetiver can withstand frost (-10_), heat (50_) and drought but needs to be established in areas with an annual rainfall greater than 450 mm (Truong, 2001).
- It is resistant to most pests, nematodes and diseases. It can be slashed, trafficked and can withstand burning while green. It does though require full sun and is very sensitive to shade that

2.2 Drain Weir Structures

The two weir structures constructed from 3 mm thick, sheet aluminium were installed to determine the discharge volumes from the vetiver planted and control sections of drain. The structures matched the cross section of the drain and were driven 200 mm into the drain banks and bottom. Pressure transducers were located behind and upstream of the weirs. This gave water height and allowed for an approximate total discharge to be calculated

2.3 Runoff Weir Structure

The runoff weir structure is constructed from 2mm thick stainless steel sheet and is similar in construction to the drain weirs but is quarter of the size. Pressure transducers were also be located behind and upstream of the runoff weir.

3 SITE SURVEY

A site survey of the drain was carried out using a dumpy level. Eight readings of drain cross sections where taken every 5m of drain length. The variation between surveys was to assist in determining the sediment build up in the vetiver planted and control section of drain. Unfortunately due to the drought drain bank erosion was not observed.

4 INSTRUMENTATION

The project budget did not allow for real time water quality monitoring and sampling of the 3 points, being the section of drain planted with vetiver, the drain section without (control section) and the contributing run-off. Each point would have required a combination sensor (pH, electrical conductivity, dissolved oxygen and temperature), turbidity and a pumping sampler. To determine the effectiveness of the vetiver trial all three sampling points needed monitoring, so a system (Multipoint Senor Chamber) has been devised for this purpose.

4.1 Multipoint Sensor Chamber

The multipoint sensor chamber (Fig. 2) enables the sampling of multiple points. A Campbell Scientific data logger (CR10X) is used to control the overall operation of the sensor chamber. A logger program has been written to control pump relays, select pinch values (sampling points) and to take readings from the sensors.

4.2 Combination Sensor

The combination sensor used for this trial is a Greenspan CS4-1200 and it measures Electrical Conductivity (EC), Dissolved Oxygen (DO), Temperature and pH. It was found that the poor response time for the DO sensor made the combination sensor unsuitable for this application.

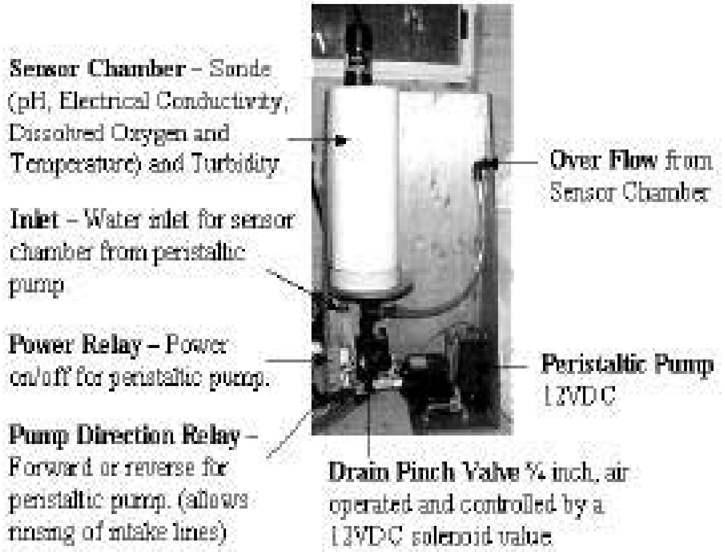
4.3 Turbidity Probe

The turbidity probe that will be used is a Seapoint Turbidity Meter. The Seapoint Turbidity Meter detects light scattered by particles suspended in water, generating an output voltage proportional to turbidity or suspended solids. The turbidity probe worked well and is recommended for this application.

4.4 Pressure Transducers

Three Greenspan PS700 will be used for monitoring the water heights of the three sampling points, transducers in the drain assisted in determining the discharge volumes though the weirs and accuracy of measurements due to flooding.

Fig. 2 Multipoint Sensor Chamber – enables water quality monitoring from multiple sources using one set of sensors



4.5 Pumping Sampler

An ISCO 3700 pumping sampler was used to take samples from the three sampling points, vetiver planted, control section and runoff site. The data logger monitored the runoff and drain pressure transducers at 60-second intervals to determine when to sample from each sampling point. The data logger then triggers the pumping sampler to take a 1-litre sample. The sample was then used to determine heavy metal (particularly Aluminium and Iron) and nutrient concentrations (Photo 1).

Photo 1 Multipoint Sensor Chamber mounted in electronics cabinet, pluviometer, pressure transducers, runoff and vetiver planted section weirs

5 RESULTS AND DISCUSSION

5.1 Vetiver Growth

- Despite the drought vetiver growth was very vigorous, reaching 50 cm tall after 4 weeks and

- Although small gaps existed between plants within the hedge, both sediment and trash started accumulating along the hedge.
- On the older planting part of the site, vigorous growth was also attained and vetiver plant reached over 1.5 m tall (Photo 2).
- Growth was so rapid that the hedge became fully functional 5 months after planting, despite the record 1 in 100 year drought.
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Photo 2 Good establishment despite the dry weather (Left) and excellent growth despite the record 100-year drought (Right)

5.2 Performance

5.2.1 Controlling bank erosion

Despite the record drought, the driest in more than 150 years in southeast Queensland, vetiver maintained a lush and vigorous growth, reaching over 2m high at the end of January 2003. To sustain this enormous amount of growth during this extremely dry period, with a root system more than 3m deep, the vetiver plant would have obtained adequate supply of moisture and nutrients from the drain and/or subsoil, resulting in localised lowering of the water table and preventing deep drainage of plant nutrients and agrochemicals, particularly nitrate.

The uptake of groundwater by vetiver may also limit the flow of groundwater to the drains. Acidic discharge events in coastal areas occur after periods of heavy rainfall following when drainage of acidic runoff and groundwater occurs. The acidic event peak occurs as surface runoff ceases and ground waters enter the drain. Vetiver may prove useful not only as a bio-filter but also in reducing the groundwater flow to drains, decreasing the levels of acidity, nutrients and agrochemicals in the drain water that are eventually flushed out to the sea.

Photo 3 Vetiver was planted on this eroded section in November 2001 (left) and it was completely stabilised 6 months later (right)

Photo 4 Exposed and highly erodible banks of the control section (left) as contrast to the well stabilised section of the trial (right)

Vetiver was very effective in controlling channel bank erosion. Photo 3 shows the excellent outcome of vetiver planting on an eroding section of the channel. And the contrast between protected and control section of the trial can be seen in the amount of rilling in the control section (Photo 4).

In addition to the direct effect of vetiver in stabilising the edged of the channel, vetiver planting also promoted the establishment of other plants on the steep batters. This establishment stopped the erosion of the exposed and steep slope, preventing the collapse of the highly acidic soil into the channel stream (Photo 5).

Photo 5 Establishment of other plants provided further protection to the steep and highly erodible slopes

5.2.2 Trapping sediment and pollutants in runoff water

Eroded soil washed down from the channel banks and roads into the drain increases the levels of acidity, nutrients and agrochemicals in the drain water. The drain water is discharged into local waterways and ultimately out to the sea. In addition the trapped sediment also contains other pollutants and carboniferous materials, which further pollute the water by increasing BOD and COD of the drain water (Bohl *et al*., 2001; Cook *et al*., 2003).

The vetiver hedge formed a thick bio-filter strip trapping eroded materials (soil and trash) from both cane fields and access roads (Photo 6). The small event during November gave some encouraging visual results (Photo 7) and it was estimated that the amount of sediment concentrations in the Vetiver planted section of drain had been reduced by more than 80%.

After harvesting we were able to measure the amount of trash that entered the drain (Photo 8). The trash is blown into the drains, due mainly to the fans on the harvester, when the harvesters turn at the end of the rows. A small amount of trash was blown into the drain after harvesting but its impact was insignificant when compared to the effects of the harvester.

The trash was collected from the vetiver and control sections of drain and weighed (Table 1). A small amount was taken from the surrounding paddock and a sub sample from the drain sample was then used to calculate the percentage moisture. The trash from the field contained 3.5% moisture while the sample from the drain contained 80% moisture.

Photo 6 Vetiver, an effective bio-filter trapping trash and sediments after the runoff event in November 2002

Photo 7 Vetiver, an effective bio-filter trapping trash and sediments after the small runoff event in November 2002

Photo 8 Impact of cane trash on control section of drain after harvesting

From these measurements taken we where able to show that the vetiver section of drain prevented 98% of cane trash made airborne during harvesting from entering the drain. The amount is in part related to the prior climatic conditions that existed during and for 5 days after harvesting. However, this is likely to occur in many harvest seasons, as the harvester is the cause not wind blown trash.

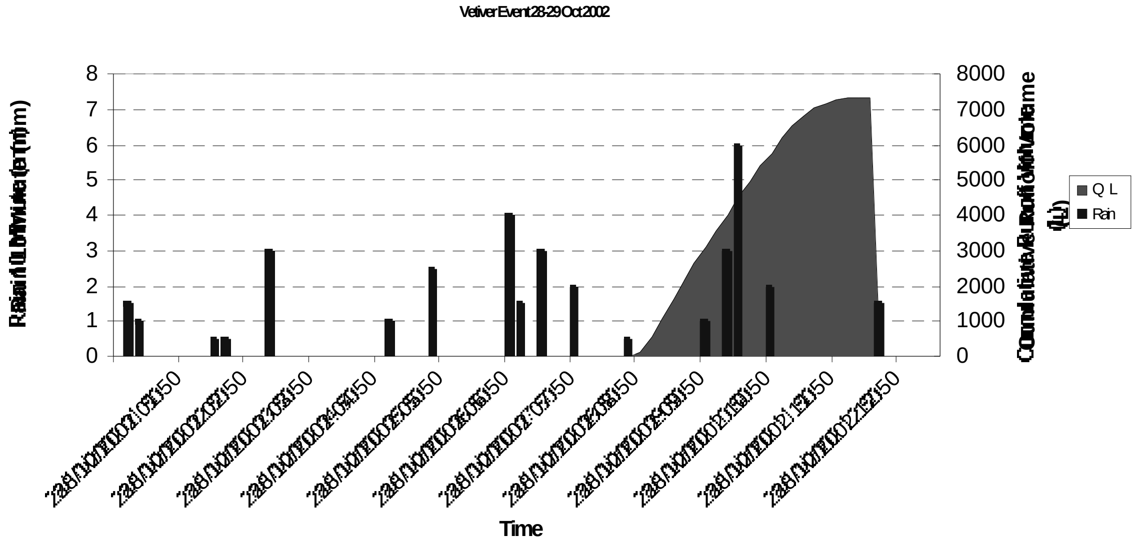
Table 1 Dry and wet weights of trash collected from the Vetiver and Control sections of drain 5 days after harvesting

Sugar cane trash	Vetiver planted drain	Control drain
Total wet weight	2.5 kg	126 kg
Total dry weight	0.5 kg	25.2 kg

5.2.3 Climate conditions and runoff events

As stated previously the Gold Coast has suffered its longest period of drought on record. Hence only three small runoff events occurred during the trial period (Fig. 3 & 4) from the fields adjacent to the study drain. These have not been enough to illustrate the true benefits of using vetiver for this application, but data shows that vetiver hedge was 90% effective in filtering cane thrash in runoff water

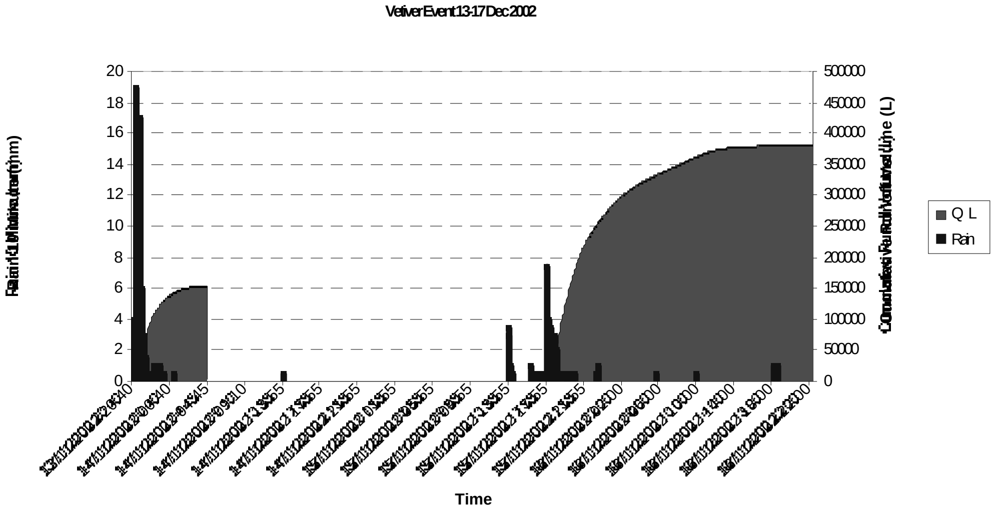
Fig. 3 Cumulative runoff (QL) and 10 minute rainfall event, 28-29th October 2002



The only event that produced enough runoff to sample was during the 15-16th of December (Fig. 4). This event occurred after only 40 mm of rainfall but followed an 80 mm rainfall event 2 days earlier. During the event it is estimated that 17.3 mm of runoff occurred which represents 43% of the rainwater.

The catchment area from which the runoff occurs is approximately 22,000 m^2 and represents 40% of the total catchment area entering the drain.

Fig. 4 Cumulative runoff (QL) and 10 minute rainfall event, 13-17th December 2002



5.2.4 Lowering of the watertable in the drain due to transpiration and uptake of nutrients

Despite the record drought, driest January in more than 100 years in southeast Queensland, vetiver maintained a lush and vigorous growth throughout this drought, reaching over 2 m high at the end of January 2003. To sustain this enormous amount of growth during this extremely dry period, with a root system more than 3 m deep, vetiver plant must have obtained adequate supply of moisture and nutrients from the drain or subsoil, resulting in lowering the watertable and preventing deep drainage of plant nutrients and agrochemicals, particularly nitrate. The effect of vetiver is indicated by the lower water table height recorded at the vetiver site compared to the control site (Fig. 5). Given this we would expect less groundwater flow into the drain for the vetiver section compared with the control during the

5.2.5 Reducing acidity and Fe in drain discharge

Data collected during a runoff event gave an indication as to how effective the vetiver would in raising pH levels. The data does show that pH for the vetiver site declines initial similar to the control and then rises to a pH similar or greater than that of the runoff water (Fig. 6). This is could be due to a lower contribution of ground water into the water in the drain in the vetiver section compared with that in the control, as suggested by the water table height data. However, as is explained below this is probably not the reason. The organic material may have also had an absorption effect on acid generating chemicals present in the runoff water.

Fig. 5 Pressure transducers in the vetiver (V-PT) and control (NP-PT) show the effect of minor runoff

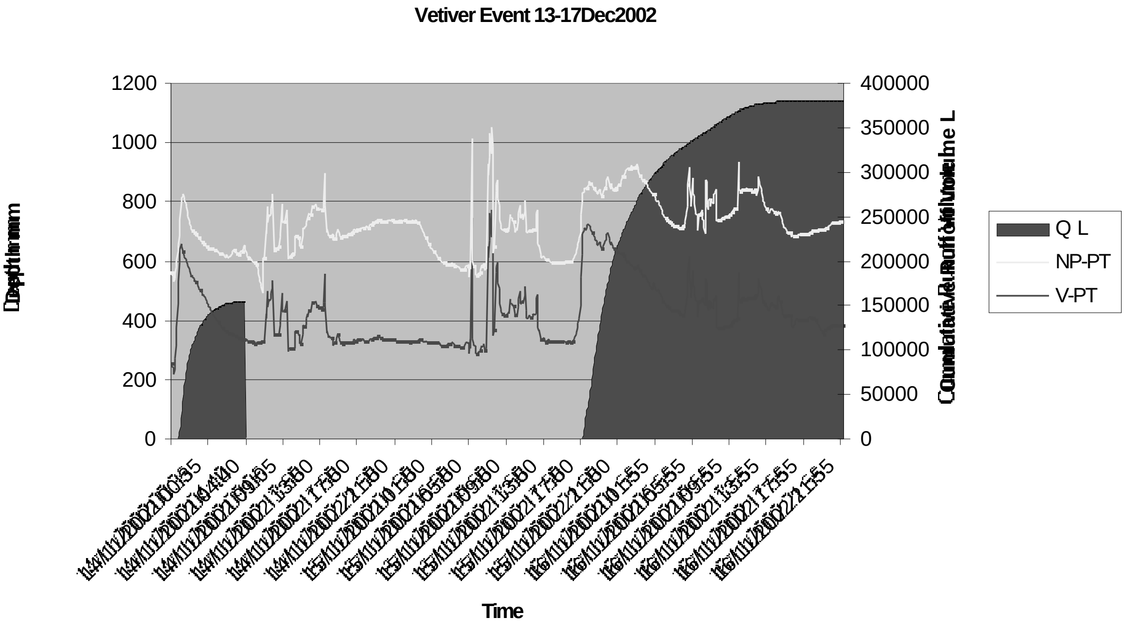


Fig. 6 pH of; runoff water (R), drain water in vetiver planted section (V), and drain water in control (NP) section

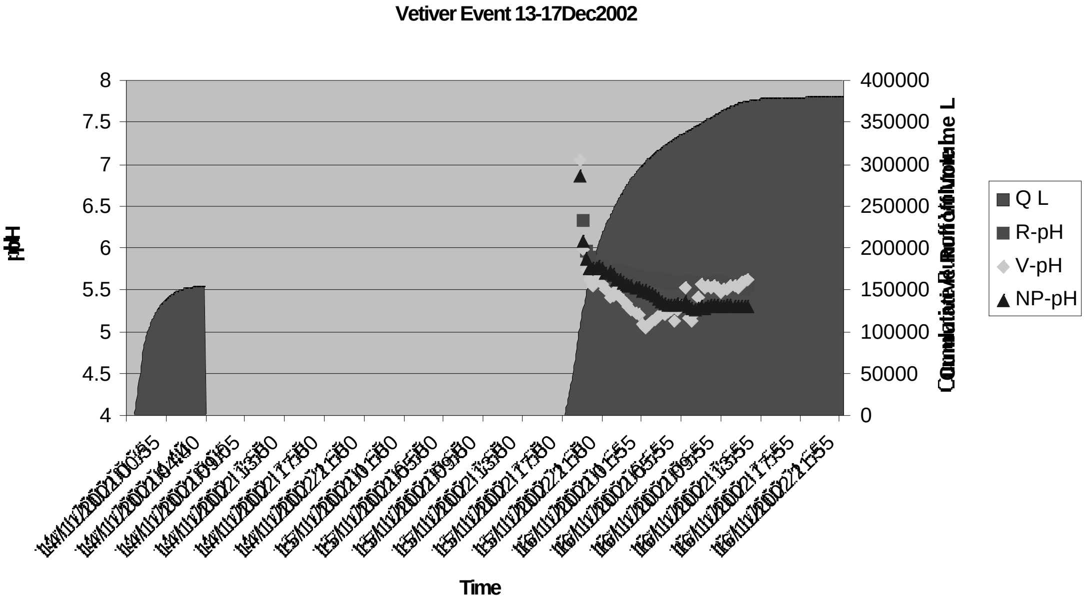
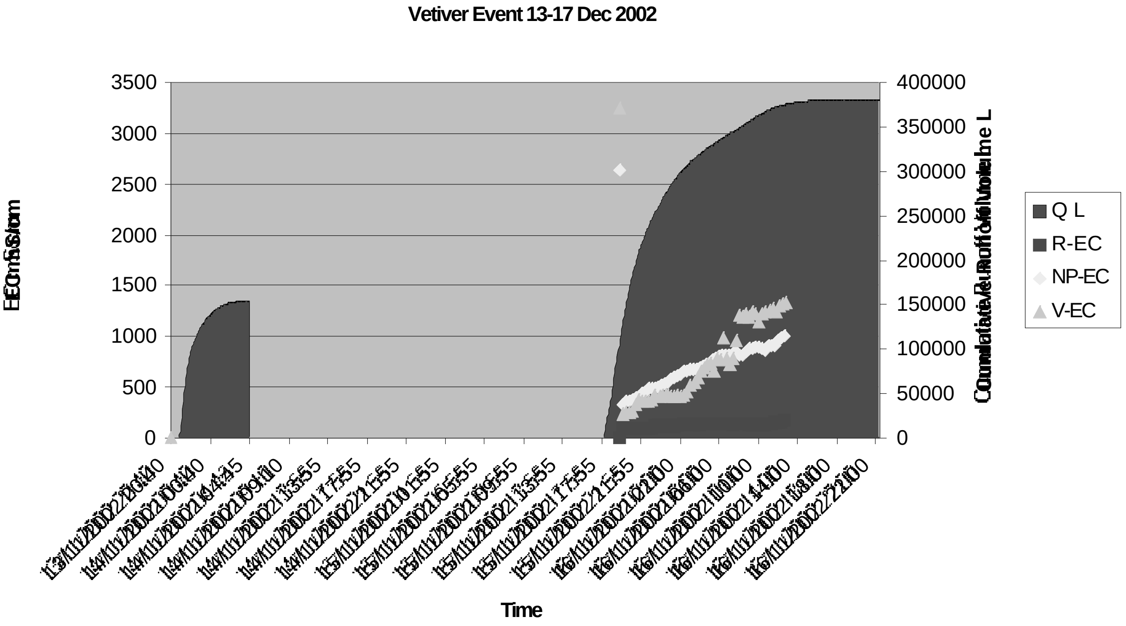


Fig. 7 Electrical Conductivity (EC) of runoff (R) vetiver planted drain section (V) and control (NP) section of drain



However, the EC data show similar values for the vetiver and control sites, which are elevated in comparison to the runoff water. These data suggest an initial reduction in the EC to similar levels to the runoff water and then an increase in EC as ground water starts to contribute more to the flow (Fig. 7). The EC is lower in the vetiver section until runoff has almost ceased and then rises above the control section. As water flows from the vetiver to the control section this suggest some dilution has occurred in the control section. The pH showed opposite effect with the rise in EC coincident with the rise in pH. The reduction in iron (Fe) concentration was also noted this may be attributed to the filtering by the vetiver of the precipitated Fe out of the water column or higher absorption by vetiver roots (Fig. 8). This reduction although minor has occurred as the concentration of Fe in runoff has increased and occurs when runoff is probably still the major component of water in the drain as indicated by the pH and EC data. This extrapolation is supported by the results recorded in Vietnam, where concentrations of some toxic elements such as Al, Fe, and SO_4 in vetiver grass were very high, much higher than those species considered tolerant to ASS. Moreover these concentrations tend to increase as the plant matures. These high contents indicate the level of these elements could be reduced in both surface runoff and deep drain water, thus reducing the contamination of canal water (Du and Truong, 2003). The reduction in iron may also explain the rise in pH, as the oxidation of Fe in the drain by dissolved oxygen will generate pH (Cook *et al*., 2000)

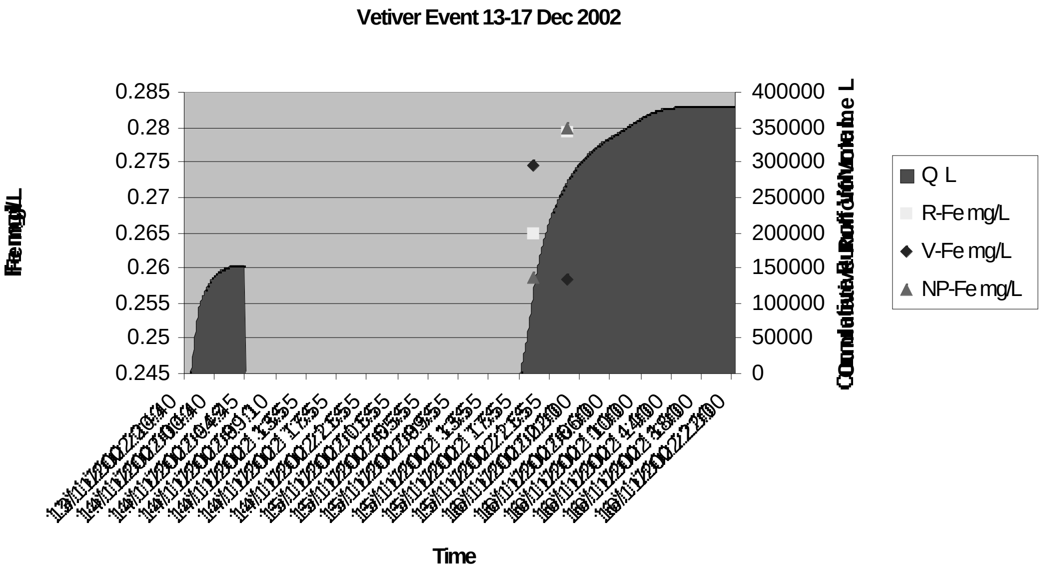
5 CONCLUSIONS

The main objective of the project was to stabilise the existing drain from drained ASS fields by the use of vetiver grass planted in riparian zones adjacent to drains. The stabilisation achieved though the planting of the vetiver grass was fundamental in decreasing freshly exposed ASS due to drain and stream bank erosion. The filtering effect of the vetiver grass also limited the transport of sediments and cane trash into major waterways that would normally require regular clearing.

The data collected suggests that pH improves in a site planted with vetiver and this could be vetiver plants. The organic material may have an absorption affect on acid generating chemicals present in the runoff water, particularly Fe. Also the reduction in iron (Fe) concentration may be attributed to the filtering by the vetiver of the precipitated Fe out of the water column. Of course this is speculation but these results suggest that future research on the use of vetiver hedges in acid sulfate soils is required to confirm these tentative conclusions.

The project will also serve as a demonstration project to promote environmentally sensitive agricultural practices, targeted at the local canegrower community in particular and to land users on drained coastal ASS in general.

Fig. 8 Iron in runoff water (R), drain water in vetiver planted section (V), and drain water in control (NP) section



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A Brief Introduction to the First Author

Dr Paul Truong, a Director and East Asia and South Pacific Representative of The Vetiver Network, and recently Principal Consultant of Veticon Consulting, he has conducted extensive Research, Development and Applications of the Vetiver System in the last 15 years. In the last five years he has concentrated on the development of a low cost, efficient and natural method of wastewater treatment both at the domestic and industrial levels.