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Acknowledgements

Sid-Grains Limited derived its name in recognition of the valuable contribution of Professor George Sidrak in researching and presenting to the National Commission on Science and Technology (NCST) the potential for using treated domestic wastewater for the production of agricultural crops. The project is deeply indebted to Prof. Sidrak, for laying the foundation for further commercial studies.

To the initial Waste water Taskforce chaired by Hon. Minister Phillip Paulwell and comprising individuals from both public and private sectors, who designed and guided the project through its initial phase goes sincere appreciation. Similarly, kudos go to the Project Managers Messers Rampair, Gordon and Johnson each contributed expertise in the implementation of the various phases and worked assiduously in meeting the challenges presented.

The Scientific Research Council, Jamaica Broilers, Trafalgar Development Bank, National Investment Bank of Jamaica, Agricultural Development Bank made investments by way of funds, time and technical expertise, without which the project would not have been able to proceed and succeed. Additionally, the SRC is specially recognized for their role in managing and co-ordinating (in collaboration with the NCST Secretariat) all aspects of the demonstration project, and in particular, their efforts in facilitating the technical analyses. The Technology Investment Fund (TIF) of the National Foundation for Development of Science and Technology (NFDST) provided financial assistance to the project during the critical phase, when it was necessary to prove definitively whether or not the technology was worthwhile for transfer to the wider society. For this we are extremely appreciative.

The Chairman and members of the Board of Directors of Sid-Grains Limited, the company formed to manage the demonstration project, overcame the many hurdles and insightfully steered activities to results-oriented outputs. Members of the second

Wastewater Task Force together with the Board of Directors are to be complemented for their role in guiding activities through the latter phases of the project.

The participation of the West Indies Home Contractors Ltd. (WIHCON) in the project from the onset in providing expertise, elements of the necessary infrastructure and of course the treated wastewater was invaluable and the project therefore grateful.

To Pioneer Seeds, Jamaica Agricultural Development Foundation (JADF), Conrad Douglas and Associates, International Centre for Nuclear Sciences (ICENS) and all the organizations which lent their support directly and indirectly, goes our heartfelt thanks.

The implementation of the project would not be possible without the tireless efforts of the workers and farmhands who both assimilated and put into practice the information delivered during the transfer of technology.

NCST Secretariat

Executive Summary

Water resource planners worldwide have acknowledged merit in the use of alternative water supplies for increased food production. Utilizing waste water in this way offers immediate advantages of conservation of potable water, recycling nutrients and the prevention of polluting ground and surface water. Reuse of treated effluent for the irrigation of crops and urban "greenspaces" such as golf courses has expanded significantly in Australia, Latin America, North Africa, Mediterranean countries, USA, over the years (WHO, 1989).

In Jamaica, with some 171,000 hectares of cultivable land, only 14,250 hectares are being served by irrigation (Sidrak, 1995). In addition, the application of saline ground water over the years has resulted in vast acreages of arable lands gradually becoming too saline to be economically productive. In the Kingston metropolitan region, approximately seventeen (17) million gallons of domestic waste water are generated daily, the effluent of which end up in the already polluted Kingston Harbour. Obvious benefits to be derived from utilizing domestic waste water in agriculture would include :

- Reduction in the amount of effluent discharged in the Kingston Harbour
- Release of additional water for domestic use
- Savings in the application of inorganic fertilizers
- Recharge of the aquifers
- Savings in foreign exchange used to import fertilizers.

Professor Sidrak *et. al*., in 1991 demonstrated that wastewater could be used to support the growth of grains such as sorghum and rice, without the use of inorganic fertilizers on one (1) acre parcels of land. This study set the stage for further investigations to be carried out on a larger scale to assess the commercial prospects of the technology

The Scientific Research Council and the National Commission on Science and technology solicited the technical expertise of various stakeholders and with the co-operation of the West Indies Home Contractors Ltd. Embarked on a programme to utilize the maturation and stabilization ponds in Greater Portmore for evaluating the benefits of this technology on a semi-commercial scale.

Sid-Grains Limited was established to manage and evaluate the demonstration project, utilizing some 100 acres (40 ha) land in close proximity to the ponds. With subscription of over $7m, and a budget of over $9m, the project was undercapitalized from the onset by some $2m. The irrigation system, pump house, container office were the main capital expenses, while land preparation, planting, harvesting and plant protection procedures incurred recurring expenses. Preliminary trials proved inconclusive due to undercapitalization, challenging weather conditions, and technical inadequacies.

A second demonstration trial was undertaken, ensuring that the necessary monitoring and management systems were in place, in addition to the requisite infrastructure. The Waste water Task Force played a pivotal role in monitoring and guiding the operations, when 5 ha of sorghum and 1 ha of cash crops including tomatoes, okras, sweet peppers were cultivated.

Yields obtained were favourable and exceeded those recorded for sorghum by Prof. Sidrak. Furthermore, the yields and quality of the vegetable crops were consistent with industry standards.

Constraints and problems experienced during the implementation of this study included the following :

- Equipment - high labour costs were incurred due to the lack of appropriate planting and harvesting equipment.
- Analyses - Results for samples contracted for analysis outstanding.
- Marketing - Marketing arrangements were not honoured.
- Funds - Disbursement of TIF funds occurred mid-way through the crop.

Notwithstanding the above shortfalls, the project is deemed to have significant potential for impacting positively on the country's utilization of water resources, the environment and agricultural crop production. Divestment options should be investigated.

1. Background and Introduction

Some ten (10) years ago Professor George Sidrak, formerly of the then Botany Department of the University of the West Indies demonstrated the value of reclaimed waste water for the production of crops such as sorghum, corn and rice. Obtaining favourable yields without the use of fertilizers, Prof. Sidrak was convinced that the technology had vast potential for Jamaica, where potable water was a scarce resource. A presentation was made to the National Commission on Science and Technology at which time it was accepted that a scale-up to pilot testing was necessary to demonstrate the economic feasibility of utilizing waste water for agricultural crops.

The Greater Portmore Housing Scheme provided an ideal testing site due to the availability of treated waste water from the West Indies Home Contractors Ltd. (WIHCON) maturation and stabilization ponds, availability of arable land and its proximity to the metropolis.

The project was first directed by a Task Force, chaired by Minister Phillip Paulwell. During this initial phase members of the Task Force approached various organizations (private & public) for financial assistance. This was provided by way of investments as equity, loans transferable to equity, and grants. Funds to the tune of $7m were thus obtained. Sid-Grains Limited was formed as the management company for guiding the demonstration studies with Directors being drawn from the shareholders. The Task force provided vital inputs in the design and installation of the irrigation system, in addition to acting in an advisory capacity.

Although the company was undercapitalized, preliminary pilot scale experiments were carried out on sea-island cotton and sorghum. Limited success was achieved due to a variety of reasons chief among which were inadequate funds for acquisition of certain equipment, analytical constraints, environmental and plant protection problems.

An in-depth study was carried out on the results obtained from the preliminary trials and apart from the injection of additional funds, several areas relating to agronomy and scientific data collection were identified for attention.

With the acquisition of additional funds from the Trafalgar Development Bank and the Technology Investment Fund, the demonstration project was revisited, with more rigorous control being exercised over the irrigation regime and the scientific & technical data collection and analyses.

Sorghum was the primary crop cultivated on 5 ha, while secondary crops which included tomato, sweet pepper, yellow corn and okra were cultivated on 1 ha. The demonstration trial lasted four months from land preparation through to harvesting and marketing.

2. Project Goal and Objectives

2.1 Goal of Project

To determine the economic feasibility of and sustainability in using treated domestic wastewater for the production of sorghum (and other minor crops) in an environmentally safe and reproducible manner.

2.2 Objectives, Activities and Outputs

PROJECT OBJECTIVES	ACTIVITIES	OUTPUTS EXPECTED
1. To develop a reproducible technology package utilizing wastewater for irrigation of agricultural crops. .	• Procure land for demonstration farm • Design and install irrigation system • Prepare land for planting • Establish crops • Scientific data collection • Harvest and post harvest operations • Marketing and Selling products.	• A practical "technology package" suited for replication in other population centres in Jamaica . • 30-40 tonnes of sorghum • Earnings from the sale of products. • Contract agreements.
2. To improve aquifer recharge and soil quality.	• Testing of soil and water at predetermined intervals.	• Improved salinity in the soil. • Reduced volume of effluent into waterways.
3. To reduce the volume of potable water used for irrigation purposes.	• Monitor volume of treated wastewater used for irrigation purposes.	• For every litre of wastewater used for irrigation, one litre made available for domestic use.
4. To sensitize the public to the value of wastewater for agricultural crop production.	• Prepare Fact Sheets & Flyers for agricultural shows. • Participate in JIS & radio shows. • Talks at Community meetings & schools.	• Consumer acceptance. • Sale of products produced utilizing wastewater.

3. Methodology

The project objectives was achieved through the establishment and monitoring of a demonstration farm in Greater Portmore utilizing the WIHCON maturation and stabilization ponds as the source of treated wastewater.

Co-ordinated by a Project Manager, the four month demonstration project included the following activities :

a. Procurement and lease of farm equipment
b. Detailed soil survey and analysis
c. Land preparation
d. Upgrading irrigation procedure and application
e. Crop establishment and management
f. Technical Data collection and analyses
g. Harvesting and post-harvest activities
h. Public Education
i. Evaluation and reporting.

Sorghum was cultivated on approximately 5 ha while secondary crops including hot, sweet pepper, okras and tomatoes was cultivated on 1 ha.

3.1 Scientific and Technical Information

Tests were conducted on the waste water, soil and plants throughout the demonstration trial.

3.1.1 Waste water

Water from the Greater Portmore Sewage Treatment Plant was used to irrigate Sid-Grains Ltd. experimental crops. Effluent from maturation pond 2 as well as water from the rrigation sump were analyzed.

Both the influent and effluent were sampled every two weeks and analyzed for the following :

pH	Potassium
Dissolved Oxygen	Phosphate
Temperature	Nitrate
Conductivity	Lead
Biochemical Oxygen Demand	Copper
Chemical Oxygen Demand	Manganese
Total Soluble Solids	Cadmium
Total Coliform	Zinc
Faecal Coliform	Sulphate
	Chromium
	Iron

3.1.2 Soil

A range of chemical elements in the soil is essential for the growth of plants, the main ones being, nitrogen, phosphorus, potassium, magnesium, calcium and sulphur. In addition, it is known that trace elements play a role in plant vigour. Soil samples were taken before planting and after harvest to determine the effect of the treated effluent on the soil.

The area designated and prepared for sorghum and six secondary crops was sampled according to the sampling plan (Fig. 1). Soil samples were taken before crop establishment, five weeks after germination and after crop harvest to ascertain the effect of irrigating with the treated effluent .

Analyses were as follows :

Nitrogen	Cation Exchange Capacity
Potassium	Electrical Conductivity
Phosphorus	Estimated Nitrogen Release
Calcium	Organic Matter
Magnesium	Moisture Content
Iron	pH
Manganese	Sodium
Zinc	Suphur
Copper	Cobalt
Molybdenum	

The following format was used for taking samples (Fig. 1).

Figure 1. Sampling Plot for Demonstration Farm Site

3.1.3 Plant

The following crops were cultivated using treated effluent from the Greater Portmore Ponds as the source of irrigation water.

i. Sorghum
ii. Tomato (*Lycopersicon esculentum L*) var. Heat Master
iii. Yellow Corn (*Mais L*)
iv. Sweet Pepper (*Capsicum annum L*) var. King Henry
v. Cantaloupe (*Cucurbita maxima L*) var. Magnum 45
vi. Okra

Leaves, stems and roots of plants were assessed during the crop growth. Sampling took place when the plant was approximately 22.5 cm above ground, half way through the crop and at the end of the crop.

At harvest (end of crop) the straw, grain and roots of the sorghum were analyzed to determine the nutritional quality of the crops, the rate of drying and the possibility of contamination with heavy metals and/or pathogenic bacteria.

The following tests were carried out :

Nitrogen	Manganese
Phosphorus	Sodium
Potassium	Sulphur
Calcium	Lead
Magnesium	Cadmium
Copper	Mercury
Boron	

Vegetables were all checked for Faecal Coliforms to determine safety for human consumption.

3.2 Environmental Conditions

Temperature, Relative Humidity and Rainfall were all checked and recorded daily. Where necessary, data was obtained from adjoining Bernard Lodge Sugar Estate.

3.3 Plant Protection Regime

Pre-emergence herbicide was used on the field prior to planting. Neem oil was used as the main chemical for controlling insects and fungi. In addition, Diazinon was used to control caterpillars and stinkbugs on tomatoes, sweet peppers and sorghum.

3.4. Irrigation Regime

The wastewater was pumped from the second maturation pond and piped to a distribution chamber at the test plot. Water was allowed to flow via gravity through an perimeter canal into the various plots via furrows.

The rate of application of the effluent was monitored and recorded. The frequency of irrigation, the pump rate & efficiency and the length of time the crops were irrigated were all noted.

The nutrient load deposited was calculated as well as a water balance established. These were intended to evaluate the following:

- The economic benefit of using nutrients from wastewater in irrigation
- Possible positive impacts on the local groundwater resources by recharge through infiltration.

The following parameters were used to calculate the deposition :

Nitrogen Concentration c(N)	sum of NO_3- N (1.167 mg/l) and NH_4- N (8.145 mg/l)/see table 1
Phosphorus Concentration c(P)	PO_4 -P (5.28 mg/l) /see table 1
Potassium Concentration c(K)	10 mg/l / see table 1
Field size (A)	13.3 acres/5.38 ha or 53,842 m^2

Pumping rate (Q)	500 igpm or 2273 l/min
Irrigation Efficiency (Ep)	distribution efficiency (0.65) * furrow irrigation (0.65) ≅ 0.4
Pumping period (t)	Oct. 7 hrs Nov. 50 hrs Dec. 35 hrs and Jan. 9 hrs
Deposition (Z) (to be calculated)	= in kg/ha

Assumptions:

1. *Even distribution of wastewater on the entire plot.*
2. *Irrigation Efficiency = distribution efficiency (0.65) * furrow irrigation (0.65) [source: FAO Paper 24]*
3. *Water Quality Data were sparse, it was therefore assumed that the average data covered the period October to January.*

3.5 Water Balance

The possible positive impacts on the local groundwater resources by recharge through infiltration was assessed by the determination of the Water Balance.

Water balance defined as :

Recharge = Rainfall + Irrigation – Evapotranspiration

$$R = P + I - ET$$

was calculated.

Input Parameters

Evapotranspiration	-	averaged data from the Bernard Lodge Station covering the period 1950 – 1985 (source: Ministry of Agriculture RPPD)
Kc value	-	since Sorghum was planted on 85 % of the test field, this value was used for the entire plot.

Precipitation - Data were obtained for October and November 2000 from Bernard Lodge Station, while data for December and January were obtained from a weather station at the test field.

Volume of Irrigation - See calculations above.

Irrigation Efficiency (Ep) 40 %

The following formula was applied for each of the growth stages :

Deficit/Surplus [mm] = P_{period} + (I/A * 1000 * 0.4) - (ET_{period} * $kc_{sorghum}$)

3.6 Public Education

Efforts were made to inform the public on the option of utilizing waste water for agricultural purposes through the preparation and distribution of a Fact Sheet, Radio and Television interviews, Television Feature Story (JIS).

4. RESULTS AND DISCUSSION

4.1 Scientific and Technical Data

4.1.1 Water Quality

The irrigation water obtained from the maturation pond 2 appeared to be sufficient in nitrate, phosphate and potassium (Table 1). Nitrogen is considered one of the most important plant foods, and is responsible for the growth of shoots had leaves. Deficiency of this nutrient is not unusual as leaching in open soils often causes loss of nitrogen. Phosphorus is considered the next most important element after nitrogen. It is needed in approximately one tenth the amount (of nitrogen) and present usually as phosphate, is responsible for good root growth. Potassium is required in similar quantities as nitrogen. It affects the size and quantity of flowers and fruit, and is essential for the synthesis of protein and carbohydrates. Other elemental nutrients such as magnesium, calcium and sulphur are thought to be important to the plant growth and health. Micronutrients including zinc, manganese, boron, sodium and molybdenum were also assessed. (See Appendix for full report.)

Table 1. Wastewater Quality at Second Maturation Pond

Date of Sampling	Nitrate (NO_3^-) [mg/l]	Phosphate (PO_4^{3-})[mg/l]	Ammonia (NH_4^+) [mg/l]	Potassium (K^+) [mg/l]
Nov-9-2000	-	15.5	8.39	10
Nov-22-2000	4.96	16.25	12.58	-
Nov-29-2000	5.72	17.5	-	-
Dec-5-2000	4.84	15.5	-	-
Average	5.17(NO_3^-) /1.167 (NO_3- N)	16.18 (PO_4^{3-}) /5.28 (PO_4 -P)	10.19 (NH_4^+) /8.145 (NH_4- N)	10 (K^+)

Source: SRC Report/January 2001

The following formula was applied for each of the nutrients :

$$Z\ [kg/ha] = Q * t * 60 * c * 10^{-6} * 1/5.38 * Ep$$

Table 2. Deposition of Nutrients for the Test Crops

Month	N [kg/ha]	P[kg/ha]	K[kg/ha]
October	0.66	0.37	0.70
November	4.72	2.67	5.06
December	3.30	1.87	3.54
January	0.84	0.48	0.91

Based on the table 2 a total of

- 51.3 kg nitrogen
- 29.1 kg phosphorus and
- 55.1 kg potassium

were deposited during the months October 2000 through to January 2001.

The economic assessment of fertilizer application was calculated based on the NPK provided by the waste water.

A total of 135.5 kg of nutrients with a N:P:K ratio of 16.27 : 9.23 : 17.48 were applied between October 2000 and January 2001 through the use of treated wastewater.

Approximate savings generated through the use of the treated waste water was a modest $1,774.00, however, other benefits accruing to the plants as evidenced by the vigorous growth and excellent yields are thought to include the ready availability of the nutrients to the plants.

The water balance indicated that during the various growth stages evapotranspiration consistently exceeded rainfall and irrigation. available for recharging.

The bacterial profile obtained was also within the limits for irrigation of edible and non-edible croprs, according to the World Health Organization (WHO) guidelines. Heavy metals were absent, presumably due to the lack of industrial influences in the sewage. (See Appendix).

4.1.2 Soil Quality

Incomplete sample analysis of soil prevents a thorough assessment of the soil before and after growth of crops irrigated with treated waste water. Such data would also aid in the assessment of how much nutrients were retained in the soil for leaching to the water table during the rainy season.

4.1.3 Crop Assessment

During the period of irrigation substantial amounts of fertilizer were deposited on the field. This is considered a positive impact in economic terms. The water balance shows that water may become available for recharge purposes during the crop development phase - and additional studies in this regard are warranted.

The yield obtained for the sorghum was in excess of projections, being 10 MT/ha for grain, as compared with the 6 MT/ha obtained from previous work (Sidrak, 1995). Some 44 MT of sorghum grain were harvested, however, not all produce was sold due to circumstances beyond the control of Sid-Grains Ltd. The Goat Breeders Association and Bodles Agricultural Research Station purchased most of the grain, with Content Farms (Jamaica Broilers Group) purchasing a small quantity. Efforts were made to optimize profits by chaffing the green chop and mixing with the grain, however the chaffing machine procured was inefficient for this purpose. Furthermore, the sale anticipated to Jamaica Broilers did not materialize, and grain and green chop lost significant amount of moisture (weight) in the interim.

Secondary crops of tomatoes, okras and sweet pepper were harvested and sold. Some spoilage (early and late blight) was evident in tomatoes, while pilferage also took place.

APPENDIX 1: Technical Report on Nutrient Deposition and Establishment of a Water Balance

1.0 Introduction

The National Commission on Science and Technology along with other agencies have implemented a project where reclaimed wastewater is being used to irrigate a plot of 13.3 acres in the Greater Portmore area on Bernard Lodge Estate lands. The wastewater generated in households of the Greater Portmore Housing Scheme is treated by a series of ponds; facultative and maturation ponds.

Sorghum, tomato, corn and sweet pepper have been planted and irrigated with the reclaimed wastewater. In this report the nutrient load deposited is calculated as well as a water balance established. These would evaluate the following.

- The economic benefit of using nutrients from wastewater in irrigation
- Possible positive impacts on the local groundwater resources by recharge through infiltration.

2.0 Nitrogen, Phosphorus and Potassium Deposition

One aspect of this report is to assess the amount of Nitrogen (N), Phosphorus (P) and Potassium (K) being deposited on the fields through the use of reclaimed wastewater.

2.1 Wastewater Characteristics

The wastewater has undergone some level of treatment by facultative ponds and a series of maturation ponds. The wastewater from the second maturation pond is sufficiently treated to minimize the risk of pathogens, while retaining sufficient nutrients which become available as a fertilizer.

The wastewater is being pumped from the second maturation pond and piped to a distribution chamber at the test plot. From where the water flows via gravity through an exterior dug canal and from there into the various plots via furrows.

The following table shows the water quality at the second maturation pond.

Table 1: Wastewater Quality at Second Maturation Pond

Date of Sampling	Nitrate (NO_3^-) [mg/l]	Phosphate (PO_4^{3-})[mg/l]	Ammonia (NH_4^+) [mg/l]	Potassium (K^+) [mg/l]
Nov-9-2000	-	15.5	8.39	10
Nov-22-2000	4.96	16.25	12.58	-
Nov-29-2000	5.72	17.5	-	-
Dec-5-2000	4.84	15.5	-	-
Average	5.17(NO_3^-) /1.167 (NO_3- N)	16.18 (PO_4^{3-}) /5.28 (PO_4 -P)	10.19 (NH_4^+) /8.145 (NH_4- N)	10 (K^+)

Source: SRC Report/January 2001

2.2 Calculation Procedure

The following parameters were used to calculate the deposition

Nitrogen Concentration c(N)	sum of NO_3- N (1.167 mg/l) and NH_4- N (8.145 mg/l)/see table 1
Phosphorus Concentration c(P)	PO_4 -P (5.28 mg/l) /see table 1
Potassium Concentration c(K)	10 mg/l / see table 1
Field size (A)	13.3 acres/5.38 ha or 53,842 m^2
Pumping rate (Q)	500 igpm or 2273 l/min
Irrigation Efficiency (Ep)	distribution efficiency (0.65) * furrow irrigation (0.65) $\cong$ 0.4
Pumping period (t)	Oct. 7 hrs Nov. 50 hrs Dec. 35 hrs and Jan. 9 hrs
Deposition (Z) (to be calculated)	= in kg/ha

Assumptions:
Even distribution of wastewater on the entire plot
Irrigation Efficiency = distribution efficiency (0.65) * furrow irrigation (0.65) [source: FAO Paper 24]
Water Quality Data are sparse it was therefore assumed that the average data cover the period October to January

The following formula has been applied for each of the nutrients

$$Z\ [kg/ha] = \quad Q * t * 60 * c * 10^{-6} * 1/5.38 * Ep$$

Table 2: Deposition per month

Month	N [kg/ha]	P[kg/ha]	K[kg/ha]
October	0.66	0.37	0.70
November	4.72	2.67	5.06
December	3.30	1.87	3.54
January	0.84	0.48	0.91

Based on the table 2 a total of 51.3 kg nitrogen, 29.1 kg phosphorus and 55.1 kg potassium were deposited during the months October 2000 through to January 2001.

2.3 Economic Assessment of Fertilizer Application

A total of 135.5 kg of nutrients with a N:P:K ratio of 16.27 : 9.23 : 17.48 have been applied between October 2000 and January 2001 though the use of treated wastewater. A ton of NPK fertilizer is available for 13,143 $ (incl. GCT). The ratio is 16 : 9 : 18.

Nutrient deposition by using treated wastewater generated savings to the amount of $ 1,774.00.

3.0 Water Balance

The objective of the water balance is to ascertain:

- Possible positive impacts on the local groundwater resources by recharge through infiltration.

A water balance is defined as

Recharge = Rainfall + Irrigation – Evapotranspiration

R = P + I - ET

3.1 Input Parameters

Evapotranspiration	-	averaged data from the Bernard Lodge Station covering the period 1950 – 1985 (source: Ministry of Agriculture RPPD)
Kc value	-	since Sorghum has been planted on 85 % of the test field this value has been used for the entire plot
Precipitation	-	October and November 2000 from Bernard Lodge Station, December and January from a weather station at the test field
Volume of Irrigation	-	see information under the section 2.2 "Calculation Procedure"
Irrigation Efficiency (Ep)		40 % see information under the section 2.2 "Calculation Procedure"

The following formula has been applied for each of the growth stages (see table 3 for the input values)

$$\text{Deficit/Surplus [mm]} = P_{period} + (I/A * 1000 * 0.4) - (ET_{period} * kc_{sorghum})$$

3.2 Result

The water balance shows that during the various growth stages evapotranspiration consistently exceeded rainfall and irrigation hence no water was available for recharging.

3.3 Recommendation

At present there are no actual soil chemistry data available. This data would help to assess how much nutrients have been retained in the soil for leaching to the water table during the rainy season.

Table 3: Water Balance Calculation (changed field size)

Growth Stage	initial	crop development	mid-season
Duration of Growth Stage [days]	20	35	45
period	2000-10-15 to 2000-11-5	2000-11-6 - 2000-12-11	2000-12-12 - 2001-01-26
weighted evaporation [mm]/Et_{period}	79.30	122.85	152.41
weighted evaporation [mm/day]	3.97	3.51	3.39
$kc_{sorghum}$	0.48	0.70	1.00
$ET_{sorghum}$/day [mm]	1.90	2.46	3.39
$ET_{sorghum}$/period [mm]	38.06	86.00	152.41
effective prec.[mm]/P_{period}	4.00	31.00	30.60
Irrigation [m^3]/I	2182.08	7228.14	4364.16
Irrigation efficiency/I_{eff}	0.40	0.40	0.40
Field Size/A	53842.00	53842.00	53842.00
Conversion factor/f	1000.00	1000.00	1000.00
Irrigation [mm]	16.21	53.70	32.42
Water Supply Deficit/Surplus (-/+) [mm]	-17.85	-1.30	-89.39

4.0 Conclusion

During the period of irrigation substantial amounts of fertilizer were deposited on the field. This is considered a positive impact in economic terms. The water balance shows that no water was available for recharge purposes and assumed a total uptake of nutrients by the plant there would be no impact on the quality of water resources.

Water Resources Authority
March 29, 2001

Appendix 2: Science and Technology Parameters

Appendix 3: Initial Wastewater Task Force

APPENDIX 4: Sidgrains Board of Directors

Appendix 5: Current Wastewater Task Force