PROJECT DAW45: CHANGING IRRIGATION SYSTEMS AND MANAGEMENT IN THE HARVEY WATER IRRIGATION AREA

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PROJECT TEAM

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The National Program for Sustainable Irrigation focuses research on the development and adoption of sustainable irrigation practices in Australian agriculture. The aim is to address critical emerging environmental management issues, while generating long-term economic and social benefits that ensure irrigation has a viable future. The Program has fourteen funding partners who are: Land & Water Australia (Managing Partner); Department of Agriculture, Fisheries and Forestry; Department of Natural Resources and Mines, Queensland; Department of Primary Industries & Resources, South Australia; Department of Environment Water & Catchment, Western Australia; Department of Agriculture, Western Australia; Cotton Research & Development Corporation; Horticulture Australia; Goulburn-Murray Water, Victoria; Harvey Water, Western Australia; Lower Murray Water Authority, Victoria; Sunwater, Queensland; Grampians Wimmera Mallee Water, Victoria and the Ord Irrigation Cooperative, Western Australia.

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EXECUTIVE SUMMARY

The Harvey Water Irrigation Area (HWIA) is Western Australia's prime irrigated dairying area supplying Perth and the south west with more than 40 per cent of its milk. Irrigated agriculture commenced in Harvey with the establishment of a weir in 1916. Since that time, pastures have been watered through surface irrigation of paddocks which over time have been leveled and divided into irrigation bays.

When this project was envisaged in 2001, there were no centre pivots being used for the irrigation of pasture in the Irrigation Area. Discussions between south west agricultural water management company, Rob Kuzich & Co., and Harvey dairy farmer, Dale Hanks, on the need to substantially increase pasture yields and milk production per hectare highlighted the case for more efficient and effective irrigation methods. The urgency of exploring ways to improve productivity and farm profits was heightened by the deregulation of the dairy industry and a resulting cost-price 'squeeze'.

However, purchase of a centre pivot irrigator was seen as a large investment for a relatively small dairy farm and required more information, understanding of how to manage the pivot and assessment of its performance. At that time, there was no local information available on the performance of centre pivot irrigation for pasture production.

The concept of a trial was gradually developed and, in 2003, the National Program for Sustainable Irrigation approved a funding application from a consortium of partners to undertake the project over two irrigation seasons (2003-04 and 2004-05). Detailed planning for the project took place during the period 2001 – 2003, and Project DAW45 commenced in September 2003.

The essence of Project DAW45 evolved from the initial idea of an on-farm trial comparing centre pivot and surface irrigation; to a demonstration case study of the comparative performance of pivot and surface irrigation; to recognition that the greatest benefits will accrue to farmers and the HWIA by improving the performance of both centre pivot and existing surface irrigation.

Even though the essence of the project was about on-farm water use efficiency and productivity, it also demonstrated that system-wide water, energy and environmental issues need to be brought together to fully understand and achieve, or maximize wider, benefits.

Centre pivot irrigation of dairy pasture

Following this two-year case study and some four years in thinking about the issues, we present the results of this Project not as a scientifically controlled comparison of the respective irrigation systems or sites, but to demonstrate from on-farm research, that centre pivot irrigation can be successfully built into irrigated pasture systems for dairying. In addition, there are management tools available to farmers and water supply companies to assist in measuring and improving the performance of surface irrigation.

Furthermore we have demonstrated that both production gains and water savings are likely with appropriate management practices. Farmers or others reading this report should note, however, that these results could vary between farms due to differences in the physical aspects of farms such as soils, in the skills of farmers and in their management practices.

While centre pivot technology is a major factor in having more control over irrigation, a critical factor is the management of the technology and associated fertiliser and grazing management. However, the Project observed a direct relationship between improved centre pivot management and production outcomes.

A further conclusion of the Project is that learning to manage a centre pivot to achieve optimum performance is a significant exercise which takes time, practice, and measurement and analysis of results. We see a need for our future centre pivot irrigators to be encouraged to adopt this approach and for training programs to be designed that facilitate the approach. Such training could involve identifying a series of single critical learning steps that will give measurable results and, therefore, increase the confidence of the irrigator. This could be a more results' oriented approach to training in comparison with some of the more detailed irrigation scheduling and water management training packages that are available.

These observations and views apply equally to surface irrigation practices and improving performance.

Achieving productivity gains from irrigation is a strong motivator for addressing economic issues relating to overall farm performance, management of the environmental impacts of irrigation, and the broader system-wide and regional issues.

Surface irrigation management

A survey of irrigators undertaken prior to the commencement of the case study found that the respondents either did not know how much water they were applying to their pasture or what they thought they were applying was obviously incorrect. We observed that the surface irrigation practices and management applied on the Hanks' property were similar to those applied generally in the area. We did not have the resources to actually measure average or best practice in the Harvey Water Irrigation Area as a basis for comparison with the case study site.

However, the performance of surface irrigation on the case study site was able to be improved over the duration of the Project. There was a reduction of 15 per cent in the water applied to the surface bay in the 2004-05 season and this was associated with an improvement in pasture growth rates, amount grown and the quality of the pasture in comparison with 2003-04. This result was assisted through the close monitoring and management by Department of Agriculture staff who attended most the surface irrigation events in 2004-05.

While we were unable to analyse surface irrigations practice in detail during the Project, we are confident that improvements could be achieved by Harvey irrigators through further analysis of present practices. At a more sophisticated level, there would be value in using models such as SIRMODII and Infiltv5 and then making associated adjustments to surface irrigation management. It is noted that the Cooperative Research Centre for Irrigation Futures (National Centre for Engineering in Agriculture) provides technical support and training for the models, on a fee for service basis.

Farmer investment in centre pivot irrigation

A key element of this Project was to integrate the establishment of centre pivot irrigation into whole farm planning and operations. The planning process followed the steps below:

1. Articulation and review of farm family profitability, development and lifestyle goals;
2. Review of the farm's biophysical attributes and infrastructure – soils, water availability, topography, farm layout and milking infrastructure;
3. Review of land availability and suitability for centre pivot irrigation;
4. Assessment of the returns from a centre pivot and investment required. This not only includes the capital cost of the pivot, but also additional investment required such as increased land required (either leased or purchased), increased herd size, increased milking shed size and increased labour; and
5. Making the investment decision.

The successful performance of centre pivot irrigation of dairy pasture has been clearly demonstrated in this case study. However, the financial returns likely to be achieved are farm specific and there appears to be little value in generalisations across farms. This is due to the different strategies that may be applied and likely differences in the efficiency of existing surface irrigation practices. For example, Dale Hanks is considering a 40-hectare centre pivot on available dryland and to shut down the surface irrigation until late February to fit in with his calving program. Other farmers may adopt different strategies for using pivot irrigation in association with their present surface irrigation.

The investment costs of a pivot are not only the price of the equipment (plus power supply, pipeline costs and connections), but the other things needed to make the venture pay (ie, in Dale's case, an extra vat and the extra operating costs for labour, feed and water for the larger herd size). He has already leased additional land and is increasing his herd size naturally.

In relation to returns, the critical variable is the operating surplus (ie, the amount of money left to pay finance and personal living costs after all of the production costs - herd, shed, feed, labour and overheads) and this is farm specific. The operating surplus needs to be sufficient to pay finance costs and principal payments associated with buying a centre pivot. Dale is utilizing a Dairy Australia 'Taking Stock' exercise with his farm consultant to examine his strategies and the costs and benefits of a centre pivot.

Environmental impacts of irrigation

No water run-off was observed from the centre pivot system during the Project. While run-off from the surface irrigation site was substantial in 2003-04, this was greatly reduced in 2004-05 (ie, from 65% to 20%) due to measuring and monitoring and then revising management of the system.

Nutrient concentrations in irrigation water within the surface irrigation bays were extremely high indicating that, at times, large nutrient losses can occur. We noted, however, that phosphorus concentrations are scale related; ie, concentrations coming off individual bays are higher than combined bays for the same events. Phosphorus concentrations at 'end of farm' monitoring points approached background levels, but were still above recommended maxima for ecosystem protection. Around 90% of phosphorus in run-off was the soluble and more ecologically active form.

Nitrogen concentrations in drain water are also scale related, but opposite to phosphorus. That is, nitrogen concentrations increase with increasing scale of measurement. This is expected and is likely to be due to in-drain, microbial nitrification processes.

Further consideration of installing re-use dams to manage and reclaim these nutrients is needed for surface irrigation systems, particularly with Western Australia's new environmental laws. However drains carrying the run-off are now recognized as creeks by the community and provide both social and environmental values.

Neither the surface or centre pivot irrigation systems resulted in any net groundwater accessions throughout the length of the trial.

The single most important point in terms of the sustainability of irrigated farming in the south west of Western Australia is likely to be the real (or more importantly, perceived) issue of nutrient export to regional waterways. State regulators have the power to prosecute landowners for 'environmental harm' if those landowners cannot show that they are farming sustainably.

It has been suggested that 'sustainability' may be measured in this context by the collection of water samples and their analysis for nutrient concentrations. The data collected in this Project and the associated DairyCatch project shows a very clear relationship between catchment size and nutrient concentration in runoff water. This is a clearly established relationship internationally, but is lacking in domestic data. This information is likely to convince regulators that point measurement of water quality is not a good indicator of sustainability.

Development of the Harvey Water Irrigation System

The Harvey Water Irrigation Area (HWIA) has progressed a long way from the days of government ownership and control of the irrigation scheme. Privatisation of scheme assets and supply management in the hands of local irrigators provided the stimulus for change and diversity through greater participation of a wide range of stakeholders from the private and public sectors. The key players are now Harvey Water, irrigator members of the two cooperatives, and various government agencies that continue to have a direct role in irrigation regulation and water storage (Department of Environment as the licensor for irrigation water use and the Water Corporation as the owner of water storages and release points).

The HWIA has a gravity fed system with no energy input required for pumping in the delivery system. It is a totally energy efficient distribution system and as such provides strong competitive advantages for the development of irrigated agriculture.

In terms of future system development, Harvey Water has now modelled and planned for a distribution system that will deliver water to meet the requirements of a multiple and growing number of outlets for varying pivot sizes, other pressure irrigation systems, including multiple sites per farm and scheduled supply to meet demand.

The possibility of water trading within the Irrigation Area over the past 9 years has lead to the creation of an internal market of buyers and sellers and provides opportunities for additional investment in further developing irrigated agriculture. An associated benefit of water trading is that it leads to closer connections between irrigators and service providers such as agribusinesses, farm advisors and financial service providers.

The proposal to totally pipe the Harvey Irrigation Area which is to be funded by a water trade of the resulting savings to the Western Australian Integrated Water Supply Scheme will create new opportunities for irrigators to invest in an expansion of irrigated agriculture and to change to more efficient spray, sprinkler and dripper systems.

Private-public partnerships in R&D

Formation of a partnership that brought together the key commercial players to be directly involved in the Project supported by public sector experience in research and knowledge generation was a successful feature of the Project.

The Department of Agriculture accepted the role of the host research organisation for the purposes of the contract with Land & Water Australia due to difficulties for the private sector participants in establishing professional indemnity insurance at the levels requested. The project was led by an independent Principal Investigator and private sector participants undertook key roles in the agronomy and irrigation aspects of the Project in close association with the farmer, Dale Hanks.

An important principle for the Project was that there is likely to be greater acceptance of change to the irrigation system used and associated management practices by farmers if they can directly observe the results from the changes that they make. This provides a driver for change and strongly reinforces the need for active farmer participation in R&D activities, extension strategies and training programs.

The approach and principles established by this Project and outlined in the following report need to be considered in future irrigation research and are transferable to other irrigation communities.

Communication and learning

The Project's communication and learning activities generated strong interest amongst Harvey Water irrigators and others outside the irrigation area. A number of producers purchased centre pivot systems after the Project commenced and others were considering changes to their surface and centre pivot irrigation systems at the completion of the Project.

A key achievement of this stakeholder initiated project was its drive to seek further connections and links both within the HWIA and outside. This included its communication, education and learning activities involving other irrigators and an interested audience Australia-wide that has been promoted through articles, presentations (eg, to the 2003-2005 NPSI Investors' Forums) interviews and workshops (eg, Fundamentals of Irrigation presented by the CRC for Irrigation Futures). These networks have brought new knowledge and perspectives on opportunities and change.

A highly influential relationship was with the National Program for Sustainable Irrigation (NPSI) which not only provided essential funding for the Project, but provided national links and knowledge from its own partners and networks.

Another crucial relationship was with the CRC for Irrigation Futures (National Centre for Engineering in Agriculture) which provided a level of expertise that opened new horizons for improving irrigation performance and farm profitability. Encouraged by the contact with the CRC for Irrigation Futures, the Project adopted a philosophy of learning from the best in relation to issues and problems which have arisen.

The Project sponsored visits to Harvey by irrigation researchers to advise on aspects of the Project and give presentations to Harvey Water Irrigation Area farmers on centre pivot and surface irrigation practices.

It also funded the participation of a group of six young south west dairy farmers in the Australian Dairy Conference in 2005 and visits to innovative irrigated dairy farms in the Shepparton area. In addition, it funded a trip of six south west beef producers to the central west of New South Wales to observe, and discuss with peers, centre pivot irrigation of pasture and forage crops.

The Project was selected as one of 12 case studies from across Australia featured in the Australian Government Innovation in Irrigation Showcase in Goolwa, South Australia, in October 2004.

It also received a Special Commendation in the 2004 Western Australian Environmental Awards and was a finalist in the Premier's Water Foundation Water Conservation and Management Award. In 2005, it was the winner of the Water Conservation and Management Award.

2004 Innovation in Irrigation Showcase

2005 WA Environmental Awards

1. PROJECT OBJECTIVES AND APPROACH

1.1 Project objectives

The following set of broader objectives for the Project were developed in consultation with the National Program for Sustainable Irrigation:

1. *Bring innovation to irrigation systems and agronomy on-farm in the Harvey Water Irrigation Area that will increase water use efficiency and farm productivity, and reduce ecological impacts through factors such as water and nutrient seepage to the water table, downstream nutrient run-off and soil structural problems.*

2. *Demonstrate a model of partnership research that engages the key decision makers in research design, conduct and evaluation, and leaves a legacy of understanding and learning that allows on-going research in the same or other areas.*
3. *Demonstrate and leave in place, a communication and learning strategy that ensures research results are effectively communicated to end users in a way which allows their application, and creates openness to learning from other areas.*

4. *Demonstrate the energy efficiencies and overall energy balance of a pressurized gravity-fed piped system of irrigation water delivery.*

5. *Understand the issues surrounding the operation/ordering procedures for the water authority (managing a pressurized irrigation supply system) and irrigator if there was wide spread adoption of centre pivot sprinkler technology.*

1.2 Project activities

Project DAW45 was conducted over the Harvey irrigation seasons 2003-04 and 2004-05. Seasons in Harvey are relatively consistent extending usually from October to May with hot dry conditions prevailing. The weather conditions for the two seasons of the case study were similar in terms of evapotranspiration, mean temperatures and rainfall. More rain was recorded in year 2, but this occurred during the winter months.

An important principle of the Project was that any advances in irrigation needed to be in balance with other farming improvements and the lifestyle needs of the Hanks.

The Project was conducted in two stages to ensure adequate consideration of the issues and planning for the case study, along with integration with other related research work, prior to the commencement of the case study.

As a result, **Stage 1** involved:

- working with the project partners, including NPSI to develop the project plan;
- locating the centre pivot on a case study site on the Hanks' property and bringing it up to farm operational standards;
- selecting a surface irrigation site on the Hanks' property for the case study (in 2004-05, the actual monitor bay on the site was changed after independent assessment);
- establishing working relationships between the partners;
- establishing links with the Australia Dairy project *'DairyCatch'* (this was a nutrient measuring and management project);
- examining research and experiences elsewhere in Australia on changing irrigation systems and the relative merits of surface versus centre pivot irrigation;
- surveying irrigators as to their level of knowledge and interest in changing and/or improving irrigation systems; and
- considering the aspects of farm planning and decision support necessary for farmers to make informed decisions.

The output was the Stage 1 Report of February 2004.

Stage 2 of the Project involved the actual case study conducted over the two irrigation seasons, with the first season's results and plans for the second season being presented as a Progress Report in December 2004.

1.3 Project outputs

This **final report** is a report prepared for a wider audience of irrigators, advisors, researchers and policy makers on the key aspects of the Project and its results. It includes technical reports which set out in detail the methodology used and findings as Appendices.

Associated with this final report is a **summary report** in the format required for Land & Water Australia research reports. Other outputs of the Project include a **fact sheet** highlighting its key findings of relevance to end users and a **photographic record**.

1.4 Project approach

In 2001, Rob Kuzich of Rob Kuzich & Co. foresaw both a productivity and water use efficiency issue with surface irrigation of dairy pasture. He also saw the need of farmers and their service providers for locally tested results that enables sound investment decisions to be made when considering changes to irrigation systems and management practices.

Rob Kuzich approached a local farmer, Dale Hanks, to incorporate centre pivot irrigation in his dairy system and to observe management practices of both sites and the results. He supplied a centre pivot at his cost and during the 2002-03 irrigation season, the centre pivot was trialed and brought up to an operational standard to meet pasture irrigation requirements.

There was also support from David Chester, the Development Officer of Harvey Water, who recognised that special efforts were required to respond to the economic imperatives for vastly improved water use efficiency and pasture production in the irrigated dairy industry.

Rob and Dale then enlisted other necessary skills including:

- a research and project manager, Ken Moore of Boorara Management to manage the project and to prepare a case for funding from the National Program for Sustainable Irrigation;
- agronomy expertise through Dario Nandapi, originally from agronomy company, Horizon Farming, WA;
- water monitoring and sampling expertise through Mark Rivers of the Waroona Office of the Department of Agriculture.

In 2003, Dale's property was selected as the DairyCatch monitor farm for the Harvey Water Irrigation Area. This project is managed by Mark Rivers and is monitoring effluent management; and water and nutrient infiltration and run-off. Dale's selection as a Dairy Catch monitor farm provided the opportunity to integrate the two projects as an on-farm case study in water management.

Funding of $231,600 was granted from the National Program for Sustainable Irrigation (NPSI) in 2003 to add to partner contributions valued at $410,600. These contributions established total resources of $642,200 for a two-year project. With the inclusion of NPSI funding, the Department of Agriculture assumed the responsibility of being the Research Organisation for the purposes of Land & Water Australia's Research Agreement.

Establishment of a research partnership between private and government players became an important aspect of the Project. Formation of the partnership took place over an 18-month period from 2001. It involved preparing and endorsing a Partnership Agreement that set out the roles, responsibilities and required outputs of individual partners.

A Steering Committee of stakeholders oversaw the project and provided industry and community input to the Project's progress. This comprised skilled individuals from key government agencies, research institutions, water cooperatives and irrigation farms. Details on the methodologies and protocols used in this Project are set out in the Appendices.

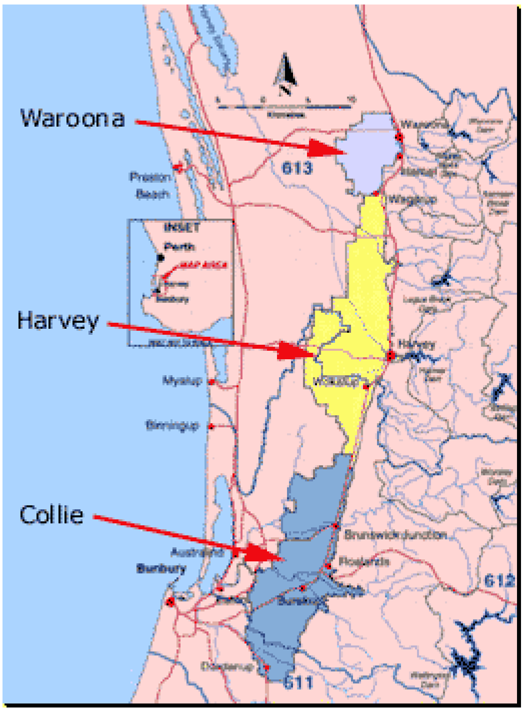
Inspecting pasture under the pivot

Dale checking soil moisture monitoring equipment (Arthur Mostead)

2. BACKGROUND ON THE IRRIGATION AREA

2.1 Introduction

Irrigated agriculture is the economic and community lifeblood of the Harvey Water Irrigation Area (HWIA). The HWIA covers three irrigation districts: Waroona, Harvey and Collie.



The northern edge of the HWIA is approximately 100 kilometres south of Perth and the area is about 75 kilometres long and 15 kilometres wide on the Swan Coastal Plain lying to the west of the Darling Scarp.

Over 90 per cent of the land has been cleared for agriculture, mainly for dairy farming and beef cattle grazing, with expanding horticultural and viticultural activities. The gross value of agricultural production in the Harvey Irrigation Area is estimated at over $120m per annum (ABS, 2000) and 45 per cent of this comes from dairy production. More than 40 per cent of Perth's milk supply comes from this area and it is also a centre for agribusiness and downstream processing – abattoirs and fruit juice production are important in the local economy.

The HWIA is a region of considerable potential for the further development of irrigated agriculture. The total area is over 112,000 hectares with 34,370 hectares having access to the irrigation system, but only 10,000 hectares of farm land is irrigated.

Historically, more than 65 per cent of irrigation water has been used on dairy pasture, with 30 per cent on beef pasture and the balance on citrus, fruit and vegetables.

Originally it was assumed that there was only enough water to surface irrigate about one third of each irrigable property at 9.2 megalitres per hectare and this was the basis for water entitlements.

Over two thirds of the lots in the Irrigation Area are 20 hectares or less and could cater for hobby farms or rural lifestyle lots or intensive high value horticulture. Other farms are broadacre dairy and beef cattle which over the years have been consolidating into larger properties.

Surface irrigation is the traditional system, although drip systems have been established for horticulture and viticulture. Most irrigated pasture remains under the surface system, although there is increasing momentum for a change to sprinkler systems such as centre pivots and for improved management practices to enable far greater precision in surface irrigation.

2.2 The landscape, water and soil resources

The area sources water from seven dams located on the edge of the Darling Scarp within jarrah forests. The steep grades from the dams to the irrigation zones means that water can be supplied under gravity pressure to farms without the energy costs of pumping.

The climate is Mediterranean with mainly winter rainfall of about 800 mm in an average year, although rainfall has been declining in line with other areas of south-west Western Australia. Summers are hot and dry. Irrigation of pasture normally commences in October and extends through to April or May.

The landform is gently undulating to flat with alluvial soils laid down by streams descending from the Darling Scarp. Soils vary across the Swan Coastal Plain from sandy gravels in the foothills of the Scarp to brown loamy duplex soils on the Plain proper and then to sand dunes and swampy flats nearer to the coast. Most of the irrigated area is on the Pinjarra Plain. This gently slopes from an eastern elevation of 40 metres above sea level to a western elevation of 15 metres.

The plain is poorly drained and naturally moderately saline. In general, any build up of salts in the soil due to irrigation is flushed out by winter rainfall. However, salinity is an issue in the Collie irrigation zone where soil salinity has built up due to saline water from the Wellington Dam.

During winter, much of the area is waterlogged or inundated by groundwater perched on the region’s loamy duplex soils. This is a major factor limiting production, although subsurface drainage has been shown to improve soil conditions and plant growth.

2.3 Irrigation history

The area was settled in the 1890s and irrigation began when the Harvey Agricultural Area was selected for government sponsored irrigation. The Harvey Weir was completed in 1916 to supply water to irrigable land which included citrus orchards that were producing fruit for export to the United Kingdom.

In these early years, flooding and waterlogging were a problem leading to the construction of a main drain that took water to the lower Harvey River. Unemployed relief workers in the depression years of the 1930s provided the labour for irrigation works in the area. JM Powell in Watering the Western Third: Water, Land and Community in Western Australia, 1826-1998. Water and Rivers Commisssion, Perth, 1998 noted that "...dams were given substance; channels were progressively lined in concrete; paddocks were systematically graded; and struggling orchards continued to give way to irrigated dairy properties."

Work started on a piped scheme in the late 1970s and has progressed slowly over subsequent decades. The delivery systems now consists of around 150 kilometres of lined channel, 280 kilometres of unlined channel, and 170 kilometres of pipeline.

The greatest change in irrigation infrastructure is about to commence with a five-stage plan for completely piping the HWIA. This is discussed in the report below.

2.4 Changing institutional arrangements

From 1914 to 1996, the Harvey irrigation scheme was built, owned and managed by the Western Australian Government through its agencies: the Public Works Department, later the Water Authority of WA and now the Water Corporation. The Water Corporation continues to own the water storages and release points, but not the distribution system to farms.

As a result of reviews of the operation of the scheme and the 1994 Council of Australian Governments' national water reforms, the irrigation distribution system was privatised and ownership of assets and management of water delivery passed to irrigators.

This was a milestone event in the move from government to private ownership that enabled local irrigators to take responsibility for their own destiny. It also created greater diversity in institutional arrangements requiring more effort to engage a range of stakeholders and achieve greater connection amongst groups that had interests in the broader social and economic development of the area.

Irrigators established a dual cooperative business structure with the irrigation assets owned by the South West Irrigation Asset Cooperative and water supply management owned by the South West Irrigation Management Cooperative (South West Irrigation SWI). In July 2002, the trading name of SWI was changed to Harvey Water to provide better recognition for the irrigation area and to link in with the branding of other agricultural businesses in the district.

The Department of Environment controls the allocation of water from the seven dams that supply the Harvey Irrigation Area. Harvey Water is licensed to draw an annual amount of 153,460 megalitres from the dams.

Irrigator membership of Harvey Water is via shares. Each member owns shares in each cooperative based on the megalitres of water allocation owned prior to the 1996 privatisation. A member also holds a Certificate of Water Entitlement which provides a property right in water which is able to be traded separately to the land through temporary transfers (within one season) or permanently provided both types of transfers take place within the Irrigation Area.

The ability to trade water has further diversified institutional arrangements in creating sellers and buyers of irrigation water who engage in trading through the rules of the Cooperative.

2.5 A new era of change

With the establishment of Harvey Water and the deregulation of the dairy industry, it was realized that for area to grow and prosper information needed to be gathered and shared amongst stakeholders, the region promoted and water used efficiently. This led to the establishment of the INTERACT partnership of key agencies for land use planning and the *Invest for Success* strategies. The INTERACT Project is seen as the strategic plan for agricultural development in the future and outlines the economic, biophysical and social conditions necessary for future change and development.

In looking for ways to help its irrigator members, Harvey Water searched previously compiled resource information and found that very little was readily accessible, easily used or up-to-date. It also found that very few people had an appreciation of development opportunities in the Harvey Irrigation Area given competitive advantages in the availability of water, suitable soils and location close to the main metropolitan market. The necessity of promoting the area was recognized, but also the need to seek out actual opportunities in the market place.

There was also an attitude amongst key participants to look outwards. Chair of Harvey Water, Danny Norton, noted in June 2002 (Foreword to Invest for Success: Investing in agriculture in the HWIA, Department of Agriculture) that in searching for alternative uses of land and water that:

> *"…the previous regulation of the dairy industry is quite likely one of the reasons why there has been so little diversification of production in the HWIA….Often, those who live in the area saw no need to actively promote it or seek alternatives."*

Mr Norton foreshadowed a focus on improving water use efficiency in noting that if Harvey Water is to:

> *"…retain its licensed allocation and protect the livelihoods of those who use it, it must demonstrate to the licensors that its use of water is defensible in the face of competition for water."*

He noted that:

> *"…surface irrigation, for example, is the least efficient use of water – and unlikely to be sustainable in the longer term."*

In this respect, he believed that Harvey Irrigation Area had a window of opportunity of about 10 years or maybe less in which to demonstrate optimal use of water. Implementation of water conservation plans, including water use efficiency strategies and best management practices are a requirement for licensing which for Harvey Water will take place again in 2006.

2.6 Stakeholders initiating R&D

At around the same time as the commencement of INTERACT, the idea for Project DAW45 arose as described above and with the provision of funding from the National Program for Sustainable Irrigation, sufficient resources were established to undertake the Project.

Formation of a research partnership took place over an 18-month period. The team members regard this Project as a learning experience in all aspects of on-farm and system-wide research. While all are highly experienced and successful in their individual fields, being involved in the project planning issues, establishing a working team and implementing the actual case study provided major learning outcomes. In particularly, it created opportunities for bringing in outside perspectives, varied experiences and new networks.

Pressurised water delivered to the farm (Arthur Mostead)

3. WATER USE, PASTURE AND MILK PRODUCTION

Dairy farmers are well aware of the need to get more value ($'s) in the form of milk from their inputs. In the Harvey area, irrigation is a key input and this Project involved demonstrating the incorporation of centre pivot irrigation into a farmer's dairy system and observing the results in terms of pasture and milk production per megalitre of water applied per hectare. We also monitored the results of a similar sized bay under traditional surface irrigation management. The surface system was improved in the second year to reflect management advances in surface irrigation.

The potential to improve surface irrigation was shown to be possible through improving application efficiency, distribution uniformity and/or requirement efficiency. This required a monitoring, measuring and managing regime that can vary from simple observation to sophisticated modelling techniques (eg, SIRMODII and Infiltv5).

3.1 Water use efficiency

The main reference for this activity was the NPSI report, *Water use efficiency; an information package, Irrigation Insights Number 5.* Water use efficiency (WUE) is described as an umbrella concept covering a number of crop and irrigation water use indices, but in this Project we calculated and used the Irrigation Water Use Index (WUI) as the main measure of water use efficiency. This is defined as:

Irrigation WUI = Yield /Irrigation water applied = kilograms of dry matter/megalitre of water applied

A standard flow meter measured the volume of water applied to the centre pivot site and for the surface site, Dethridge Wheel measurements were used. The accepted accuracy of a Dethridge Wheel is x plus or minus 6% when the wheel and housing is new, deteriorating to x plus or minus 25% when the wheel and housing age. The compares poorly with the accuracy of the mechanical ABB meter used for the centre pivot of around x plus or minus 2-5%.

Results

The results for the respective sites for the 2003-04 and 2004-05 irrigation seasons are shown below:

Table 1: Water use measures, irrigation seasons 2003-04 and 2004-05

Water measures	2003-04 Centre pivot	2004-05 Centre pivot	2003-04 Surface site	2004-05 Surface site
Water applied, ML/ha	10.0	8.2	14.0	11.9

Pasture grown, kg dm/ha	14,272	27,357	9,322	13,668
Irrigation WUI, kg dm/ML	1,427	3,336	666	1,149

The results show the superior performance of the centre pivot in delivering the amount of water required for pasture production. With the centre pivot, 29% less water was applied in year 1 compared with the surface bay and 31% less in year 2. For the pivot itself, 18% less water was applied in year 2 compared with year 1. For the surface bay, 15% less water was applied in year 2.

As discussed below, the centre pivot results can be largely attributed to improved scheduling and management that resulted from the increased experience and confidence of Dale Hanks. In the case of the surface site, Department of Agriculture research staff attended the site for most of each irrigation event in the 2004-05 season to open and close gates at optimum times which allowed quicker movement of water across the bay. This resulted in less water being applied in 2004-05 compared with 2003-04 as the optimal flow rate based on visual observation was achieved.

It's all about pasture and milk (Arthur Mostead)

3.2 Pasture production

Both sites were perennial rye grass and clover mix pastures. A NPK fertiliser blend, with other elements such as sulphur, was applied to both sites in both seasons (see Appendices 2 and 3 for details on amounts applied and frequency).

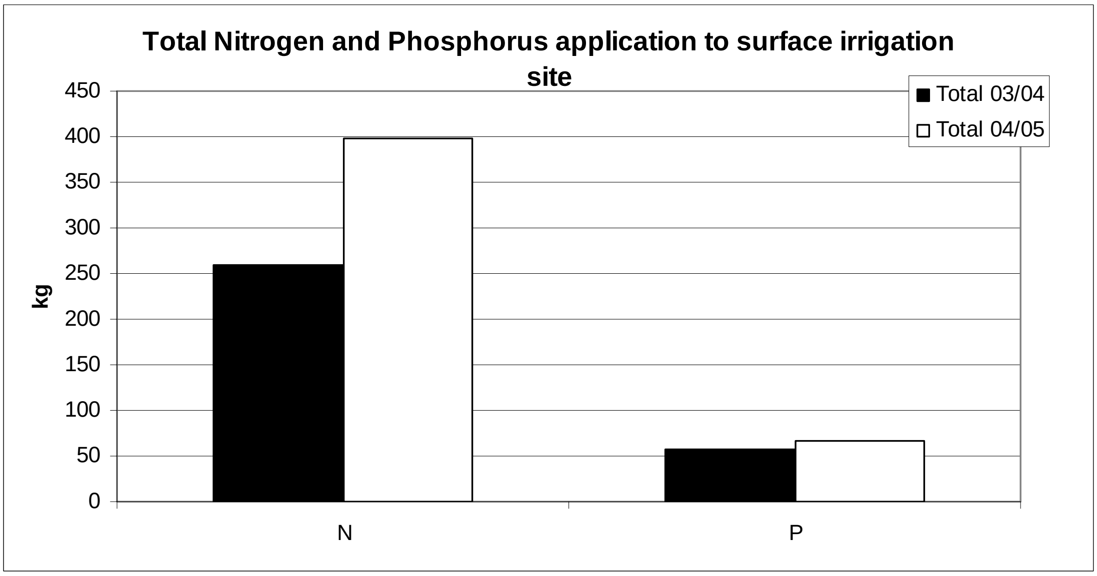
In terms of nitrogen and phosphorous, the following table and figures show the respective applications on both sites.

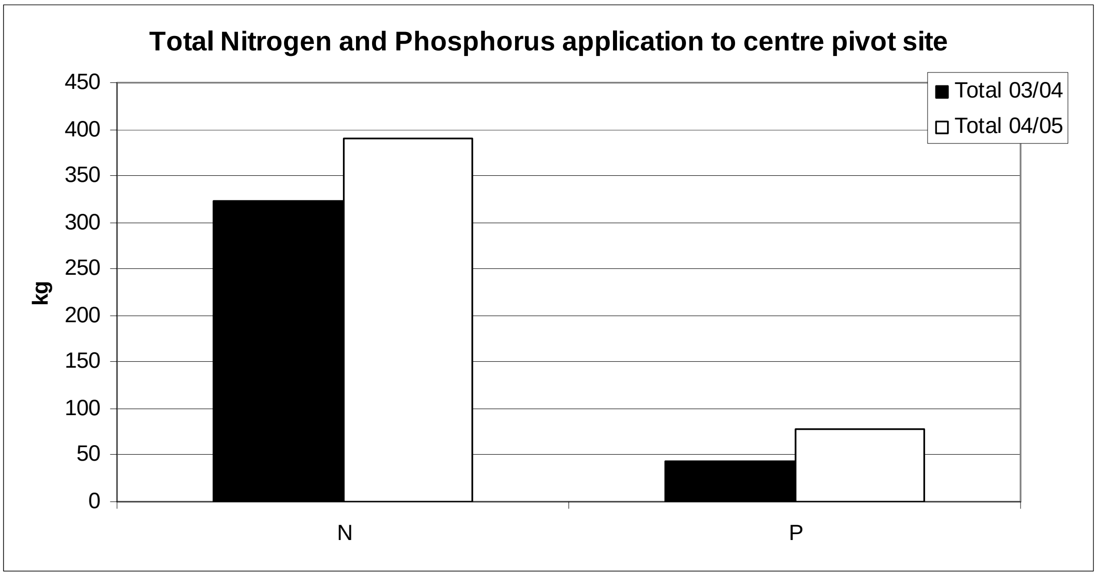
Table 2 : N and P applications to surface and centre pivot sites

	Surface		Centre Pivot	
	Nitrogen (kg)	Phosphorus (kg)	Nitrogen (kg)	Phosphorus (kg)
Total 2003-04	259.0	58.0	323.0	44.3
Total 2004-05	398.0	67.5	389.5	78.6
Av.individual application 2003-04	32.4	7.3	40.4	6.3
Av. individual application 2004-05	39.8	6.8	39.0	7.9

These amounts are also shown graphically in figure 1. Both nitrogen and phosphorus applications increased on both sites with applications in 2004-05 being more comparable between the sites.

Figure 1 – Fertiliser applications





Grazing and feed management

Apart from the amount of pasture produced and its quality, another significant factor in milk production was grazing management. The centre pivot was able to be grazed more frequently during the season due to the greater amount of pasture produced, but in 2004-05, the number of grazings was reduced to allow the growth stage of the rye grass to reach 2 to 2.5 leaves per plant before re-grazing.

While there is always some pugging on heavy loamy soils, the extent of pugging on the centre pivot site was not a factor in determining the number of grazings which were based on pasture growth rates.

Table 3 – Grazing management

Measures	2003-04 Centre pivot	2004-05 Centre pivot	2003-04 Surface site	2004-05 Surface site
No. of grazings	23	15	15	14
Area/grazing	1.0 ha	1.17 ha	2.0 ha	1.29 ha

Obviously, the total ration required by the cows was not completely fulfilled by the case study pivot and surface sites. The cows had to eat other supplements or more daytime pasture to make up for this, so the difference between the pivot site and surface bay could not actually be seen in the vat, especially as the pasture intake from the pivot site or surface bay averaged 4.4 kg DM/cow/day in 2003-04 which was only 25% of the total ration.

In 2004-05, there was slightly higher milk production per cow in the vat (27.1 litres for the pivot compared to 26.6 litres for the surface site) and better milk protein (3.07% m/m for the pivot compared with 3.04% m/m for the surface). This could be attributed to the better pasture quality and quantity, but other variables such as the day paddock, hay and silage offered and eaten could also affect milk quantity.

Grain feeding on average was the same for both paddocks (5.7 kg as fed /cow/day), but on average 3.1 bales of silage and 0.6 bales of hay were fed to cows while grazing the pivot site compared with the surface bay where 2.9 bales of silage and 0.8 bales of hay were fed. As silage was better quality than hay this could also have caused the difference in milk solids produced as shown in Table 7.
.

Growth rates

Pasture growth rates per day on the centre pivot site were considerably above the surface bay for both years in terms of average, minimum and maximum growth rates. It is noticeable that the growth rates in 2004-05 for both sites were substantially above the rates in 2003-04. There was some incursion of kikuyu on the centre pivot site which contributed to the very high maximum pasture growth rate in February 2004.

Table 4 – Pasture growth rates

	Av. growth rate (kg dm/ha/day)		**Max. growth rate** (kg dm/ha/day)		**Min. growth rate** (kg dm/ha/day)	
Site	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05
Pivot	71.7 (a)	121.6 (c)	123.3	245.0	28.8	38.0
Surface	44.9 (b)	60.7 (d)	86.8	110.0	14.5	25.0

(a) 14 measurements of pre-grazing pasture mass and post-grazing pasture residuals
(b) 13 measurements
(c) 15 measurements over the period September to May.
(d) 14 measurements over the period September to May.

Pasture yield

In 2003-04, the centre pivot site grew 54% more pasture per hectare than the surface bay and in 2004-05, pasture production on the centre pivot was double that of the surface bay. In 2003-04, some of the difference could be explained by higher nitrogen application, but in 2004-05 slightly less nitrogen was applied compared with surface bay.

Table 5 – Pasture grown

	Yield tonnes of dry matter/hectare	
Site	2003-04	2004-05
Pivot	14.3 (a)	27.4 (c)
Surface	9.3 (b)	13.7 (c)

(a) Measured over 216 days
(b) Measured over 227 days
(c) Measured over 225 days

Pasture quality

The pivot site, on average was higher in crude protein and energy and lower in both fibre measurements, which indicate better quality pasture.

Table 6 – Pasture quality

	Megajoules metabolisable energy		Crude protein		Neutral detergent fibre	
Site	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05
Pivot	10.8	11.2	23.75%	23.4%	43.2%	48.9%
Surface	10.1	10.5	19.40%	22.3%	50.2%	51.0%

The reason for the difference in feed quality is a combination of the following factors:

1. The surface site had far more weed as a percentage of the sward. As weeds are poorer quality than ryegrass/clover the resulting feed tests will be poorer.
2. As the surface site puts more stress on ryegrass/clover due to its cycle of waterlogging and then drying out compared to the pivot, plants tend to lignify which increases the fibre level of the plant and reduces its digestibility and hence its energy content.
3. Also due to the waterlogging drying cycle, the surface site plants did not take up as much nutrient (including nitrate) which resulted in lower crude protein level in the plants and also added to the stress on the plants as mentioned above.

Results of tissue testing from both sites in both years indicated the following. Nitrate and crude protein levels were higher for the pivot site due to better mineralisation occurring in the pivot site compared to the surface bay. This is mainly due to the surface site going through a waterlogging and drying cycle, which restricts soil microbial action and hence mineralisation compared with the pivot site. On the pivot site, readily available water was maintained in the soil through regular and controlled irrigation allowing constant soil microbial action and mineralisation. Leaching may also be an issue with more nutrient leaching occurring on the surface site.

Plant tissue levels of the other major nutrients (P, K & S) are all lower on average for the surface site compared with the pivot site, even though both sites received about the same amount of these nutrients. This again can be attributed to less mineralisation and leaching on the surface site.

3.3 Milk production

The following are derived values for milk production based on the assumption of cows utilizing 70% of pasture grown and each litre of milk requiring five megajoules of metabolisable energy (MJ of ME).

Table 7 – Milk production

Yield measures	2003-04 Centre pivot	2004-05 Centre pivot	2003-04 Surface site	2004-05 Surface site
Total metabolisable energy/Ha	154,784 MJ of ME/Ha	302,667 MJ of ME/Ha	93,883 MJ of ME/Ha	141,384 MJ of ME/Ha
Milk production (derived value)	21,670 L/Ha	42,373 L/Ha	13,144 L/Ha	19,794 L/Ha
Milk solids	1.76 kg	1.93 kg	1.77 kg	1.89 kg

Value of milk production
In gross terms, the value of the additional production from the centre pivot site is shown in the table below. These are estimated values based on average milk prices over the respective irrigation seasons. In terms of farm budgeting the values are not appropriate measures, but they do show gross values of production per megalitre of water used for the respective irrigation systems. Industries tend to quote such measures when illustrating the value of production from irrigation.

Table 8 - Value of milk production

Milk production and value	2003-04 season Centre pivot	2004-05 season Centre pivot	2003-04 season Surface irrigation site	2004-05 season Surface irrigation site
Milk production (derived value) L/Ha	21,670	42,373	13,144	19,794
Av milk price cents/litre	30	29	30	29
Est. gross value milk produced/Ha	$6,500	$12,288	$3,940	$5,740
Gross value of milk/ML	$928	$1,499	$394	$482

3.4 Conclusion

Following this two-year case study and some four years in thinking about the issues, we present the results of this Project not as a scientifically controlled comparison of the respective irrigation systems or sites, but to demonstrate from on-farm research, that centre pivot irrigation can be successfully built into irrigated pasture systems for dairying. Furthermore we have demonstrated that both production gains and water savings are likely with appropriate management practices. Farmers or others reading this report should note, however, that these results could vary between farms due to differences in the physical aspects of farms such as soils, in the skills of farmers and in their management practices.

4. MANAGEMENT OF CENTRE PIVOT IRRIGATION

4.1 The centre pivot set-up

The centre pivot was a manual 8-hectare “Steriline” centre pivot installed on a 8-hectare site with loam on clay soils. It was a pre-used machine supplied by Rob Kuzich & Co. and was brought up to farm operating standard during the 2002-03 irrigation season.

The pivot was fitted with Nelson yellow plate spinner sprinklers and 10 psi pressure regulators. It was operated with a nominal flowrate of 18.5 litres per second with a centre pressure of 13 metres fed from a pressurized pipeline without the need of a booster pump.

In 2003-04, the pivot was run with a 20mm precipitation package for up to 10 -12 hours per day applying 9 -10 mm per pass. A 20mm package was selected as the pivot was, initially, only to be operated during daylight hours due to the age of the pivot and because it did not have telemetry equipment. This allowed Dale to operate the pivot within daylight hours to fit in with his normal farming program.

Spare parts were on-hand to prevent major outages that could effect scheduling. During operations, the pivot generally worked smoothly and breakdowns were quickly corrected. With increasing confidence in its reliability, Dale extended the operating hours during 2004-05 which also allowed him to extend the frequency of irrigation to approximately every two days.

The pivot design flow rate [and/or the system capacity (mm/day), ie, nozzle flow rate over the irrigated area], was based on the following information:

- peak daily water use calculations for consecutive high evaporation days. The calculation ensured the system could handle this period including a 25% reserve;
- the crop factor for the peak evaporation period;
- the soil holding capacity (RAW);
- the rooting profile and, with the RAW value, the maximum theoretical irrigation interval established from the plant available water (PAW)
- inclusion of a 5% allowance as a leaching fraction, but we accept that this may not be necessary based on the soil chemistry and winter rainfall;
- allowance was made for irrigation sprinkler efficiency of 95%. The Nelson yellow plate spinners fitted with 10 psi regulators provided what we believe is the highest efficiency combination. We acknowledged Joe Foley’s advice that recent US research shows 98% efficiency, but we continued to use 95% efficiency for the 2004-05 season based on local weather conditions including the incidence of severe winds during summer.

In summary, for both the surface bay and pivot sites the following information was recorded.

- Irrigation events and application
- Total water applied monthly
- Rainfall events
- Soil profile (RAW) and nutrient analysis
- Water analysis
- Monitoring of surface water flows and water quality was undertaken by the Department of Agriculture through DairyCatch.

Checking pivot sprinklers (Arthur Mostead)

4.2 Centre pivot scheduling

The issues of irrigation scheduling and the appropriate system capacity measured as mm of water applied per day required close analysis of rootzone RAW values for the soil type, soil moisture data and weather conditions.

The centre pivot scheduling was based on the following information:

- evaporation and rainfall data from the Bureau of Meteorology;
- continuous logging of soil moisture from the Sentek Enviroscan sensors;
- plant available water holding capacity of soil;
- growth stage of the crop; and
- effective rainfall events.

A Department of Agriculture sampler and flume measured rainfall events. Typically, the Harvey Irrigation Area, with a Mediterranean climate, has few effective rainfall events during summer. For the Harvey area, effective rainfall events are defined as those above 5mm - effective rainfall being that which infiltrates into the crop root zone after discounting for run-off, evaporation and deep drainage.

Early in the Project, a member of the Steering Committee, Joe Foley, of the CRC for Irrigation Futures, suggested that as the centre pivot was only operated during daylight hours, observing farmers may conclude that this is the recommended practice whereas modern automated machines are designed to run continuously.

We acknowledged this and stressed in our communication activities that this machine is an older manual pivot that was available for the demonstration and that the system set-up was designed to meet the operating hours requested by Dale during 2003-04.

In 2004-05, the centre pivot scheduling was fine-tuned based on Sentek soil moisture data. This allowed controlled drying and re-wetting of the soil profile. It enabled longer irrigation events and larger intervals between events to better match the water holding capacity of the soil. The total water applied was reduced compared with the previous year and, as a result, the production figures significantly increased. This increase can be attributed to a combination of improved irrigation scheduling, crop driven fertilizer applications and improved grazing management.

One of the significant observations of the Project was the continuous development of Dale Hanks' irrigation management skills with the centre pivot. His involvement in collecting and analysing data from soil monitoring equipment, weather observations and pasture sampling gave him confidence in the data with which he was working. This objective and learning approach to irrigation, which resulted in improved irrigation scheduling, is seen as one of the reasons for the increased pasture production figures and the reduced amount of water applied.

Our conclusion is that a 'learn and grow' approach is more successful than imposing 'hard and fast' guidelines for best practice scheduling. This former approach combines the irrigators developed experience, overall intuition and growing confidence in the use of data.

A KEY MESSAGE:
As a result of the Project, we see a need for our future centre pivot irrigators to be encouraged to adopt this approach and for training programs to be designed that facilitate the approach. Such training could involve identifying a series of single critical learning steps that will give measurable results and therefore increase the confidence of the irrigator. This could be a more results' oriented approach to training in comparison with some of the more detailed, and possibly overwhelming, irrigation scheduling and water management training packages that are available.

The potential for productivity gains and labour savings, or more effective use of management time, are important factors for Western Australian farmers in making decisions about irrigation systems. Dale spent approximately 10 minutes per day for 4 to 5 days per week in operating the centre pivot. This compared with around

10 minutes spent on starting the surface irrigation followed by five checks of 10-15 minutes during each irrigation event. While the total time spent operating and monitoring the respective systems may have not been greatly different in total time per month, the main constraint of surface irrigation was that Dale had to remain on the farm all day.

A KEY MESSAGE
A step up to a large system, such as a fifty-hectare pivot, does not require more labour time than the eight-hectare demonstration system (and maybe less with a fully automated system). However, for surface irrigation there is a direct relationship between area irrigated and the time required to operate and monitor the system (ie, as area increases, the time required increases).

4.3 Centre pivot size

As the demonstration pivot was a 8-hectare machine, in 2003-04, we undertook simulations of larger machines to observe water infiltration on Harvey's clay-based soils (30% - 70% clay). An issue that we were interested in was the high instantaneous application rate at the end of the span of large pivots which increases with size.

Within the pivot site, we set up a strip of approximately 100 metres by 10 metres which included an additional Sentek Enviroscan probe. Our method was to simulate larger pivots by calculating the nozzle sizes and pivot rotation speed representing the outside of a large pivot. We modified the test span to represent the last span of a simulated pivot. The intervals between the tests were three to four days during April 2004.

The simulations were undertaken with a sprinkler package of 11 mm per 24 hour period for pivot sizes of 16, 21, 30, 40, 52, 66, 81 and 98 hectares. This package is sufficient to meet the growing requirements of perennial pastures on heavy brown loam soils in the Harvey area using a large pivot.

For pivot sizes up to and including the 52 hectare simulation, there was little evidence of water lying on the surface and the limited amounts disappeared within 15 minutes. For pivot sizes of 66 to 98 hectares, more surface water was evident, but it was also generally absorbed by the soil within 30 minutes.

Due to these encouraging results, we undertook simulations with a 15mm per 24 hour package for pivot sizes of 40, 52 and 66 hectares. More surface water was evident, but this was again absorbed by the soil within 30 minutes.

The results strongly support the potential for using larger pivots with a larger application rate. From these initial observations, we concluded that a 55 hectare pivot being considered by Dale Hanks with a application rate of 11mm per 24 hours appears suitable for the heavy brown loamy earths of the Harvey area.

4.4 Impact of irrigation on the soil

A soil and water consultant engaged by the Project in 2003-04 noted that in Western Australia there seems have been very few attempts to improve the physical condition of the soil on a farm (see Hignett, Appendix 7).

Hignett considered that while most farmers accept that soil chemical condition can be improved through fertilisers, few have considered the physical condition as something that can be substantially improved through management, particularly irrigation management. Soil physical improvements allow for the intervals between irrigations to be increased so that the pasture gets more time to grow in non-saturated conditions and produces more growth for less water use.

Benefits of better soil physical properties include higher productivity. For crops, maximum productivity will result from supplying the plants with the amount of water equal to evaporation potential. The plants need to obtain sufficient water via their root system to prevent the leaves from wilting. This will happen most effectively when the root system is deep and spread evenly through the soil.

A KEY MESSAGE

"It is the improvement in the rooting depth allowed by better irrigation practice which will ultimately produce productivity gains with the pivot" (Hignett, 2003).

The centre pivot allows more flexible management and a changed schedule of watering, draining and grazing. This will allow the plants more time to benefit from the watering between grazing periods and they will not go into stress as easily resulting in higher productivity. At the same time, total water use would be unchanged.

With surface irrigation, it is more difficult to manage the schedule of water, draining and grazing, although with appropriate monitoring and measurement improvements can be made.

4.5 Conclusion

- While centre pivot technology is a major factor in having more control over irrigation, a critical factor is the management of the technology and associated fertilisationer and grazing management. The Project observed a direct relationship between improved centre pivot management and production outcomes.

- A key conclusion of this Project is that learning to manage a centre pivot to achieve optimum performance is a significant exercise which takes time, practice, and measurement and analysis of results. It cannot be achieved by formal training from a best practice manual, and requires practical experience in addition to the underlying theory.

- There is likely to be greater acceptance of change to the irrigation system used and associated management practices by farmers if they can directly observe the results from the changes that they make. This provides a driver for change and strongly reinforces the need for active farmer participation in R&D activities, extension strategies and training programs.

- Achieving significant productivity gains from irrigation is a strong motivator for addressing economic issues relating to overall farm performance, management of the environmental impacts of irrigation, and considering broader system-wide and regional issues.

Soil water monitoring - a future view (Arthur Mostead)

5. MANAGEMENT OF SURFACE IRRIGATION

5.1 Surface irrigation bay

The surface irrigation site used in the 2003-04 demonstration was an existing 6-hectare paddock adjacent to the centre pivot site. The site is laser leveled with soil type described as heavy brown loamy earth (see Appendix 6 for detailed description). Irrigation of the site is fed from an open channel and it is necessary to order the water three to six days in advance from Harvey Water.

Following an independent review of the surface site by Associate Professor, Steven Raine, for the 2004-05 season, the bay closest to the water supply intake point was preferred to the third bay used in 2003-04 for measuring irrigation events. Selection of the first bay was to enable greater accuracy in the measurement of water inflow to resolve problems in the measurement of both water applied and water advance on the third bay.

Dr Raine also recommended installing a lay-flat flume for applying water to the bay, but after investigating this, we were unable to achieve adequate discharge (litres/second) to irrigate the bay. An alternative was also considered involving lining the clay delivery channel with an 800 mm poly pipe, cut length-ways, to form an even channel from the Dethridge Wheel to the entrance of an automated gate 26 metres away. The volume of water that was directed on to the monitor bay was to be measured by an ultra sonic area velocity flow meter.

This concept was to make sure all the water from the Dethridge Wheel was directed either on to the monitor bay or allowed to flow to other irrigation bays. However, the cost of the 800 mm poly pipe made this option uneconomic with the result that water applied to the surface bay was again measured by the Dethridge Wheel.

The compromise action taken was to install concrete housing around wheel and to upgrade the head ditch in an attempt to improve the accuracy of the Dethridge wheel measurements. The accepted accuracy of a Dethridge Wheel is x plus or minus 6% when the wheel and housing is new, deteriorating to x plus or minus 25% when the wheel and housing age. The compares poorly with the accuracy of the mechanical ABB meter used for the centre pivot of around x plus or minus 2-5%.

5.2 Surface irrigation practice

A survey of irrigators undertaken prior to the commencement of the case study found that the respondents either did not know how much water they were applying to their pasture or what they thought they were applying was obviously incorrect. We observed that the surface irrigation practices and management applied on the Hanks' property were similar to those applied generally in the area. We did not have the resources to actually measure average or best practice in the Harvey Water Irrigation Area as a basis for comparison with the case study site.

The scheduling of irrigation for the surface site was based on similar information to the centre pivot scheduling, namely:

- evaporation and rainfall data from the Bureau of Meteorology;
- continuous logging of soil moisture from the Sentek Enviroscan sensors;
- plant available water holding capacity of soil;
- growth stage of the crop; and
- effective rainfall events.

The surface irrigation system is manual requiring the opening and closing of gates by hand. Dale scheduled irrigations events for approximately every 14 days at the beginning of the season and increasing to 8-9 days during January/February. Water is ordered 3 days in advance.

5.3 Monitoring water movement

Following the review of the monitoring program by Dr Raine, it was recommended that additional measurements be made of the rate of progress of water over the bay surface in the surface irrigation system during the 2004-05 season. Gates were closed when water had progressed 66% of the way down the bay.

The movement of water across the bay is shown below in figure 2.

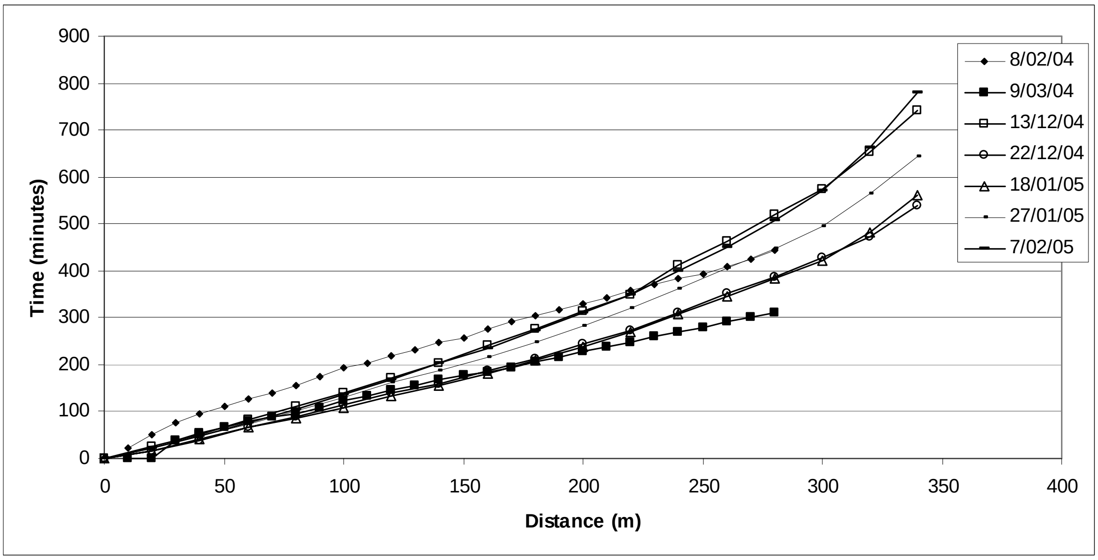


Figure 2: Rate of water progress down surface irrigation bay

The rate of progress is relatively uniform over all irrigation events with water from each event taking between 10 and 13 hours to traverse the entire 340m bay. This would be expected when following a consistent irrigation scheduling program. Water samples were also taken at each 10m or 20m point down the bay and these are discussed later.

5.4 Impact of irrigation on the soil

In relation to soil, water and plant relationships on the surface bay, Hignett (2003) commented that the complete saturation of the soil for an extended period was characterised by:

- more water than is needed to fill the root zone is applied and this is wasted and drains to the water table;
- the extended saturation means that number of beneficial soil biota are severely depleted. Higher order biota (eg, worms) drown and lower order biota (aerobic bacteria) is replaced by anaerobic bacteria;
- loss of soil animals means that larger soil pores destroyed by cattle trampling are not rebuilt meaning that infiltration is progressively reduced;
- sodic clay which is characteristic of the trial site disperses in water (clay goes into suspension in the water and turns it milky) which may block the soil pores;
- as a consequence of poor infiltration, compacted soil and anaerobic conditions, the water evaporates quickly, roots do not penetrate deeply, the available soil water store is small and irrigations are required at ever smaller intervals; and
- trampling by stock in wet conditions contribute to the development of a hard pan.

5.5 Conclusion

The results of the surface irrigation monitoring have been outlined in Section 2. As discussed, there was a reduction of 15% in the water applied to the surface bay in the 2004-05 season associated with an improvement in pasture growth rates, amount grown and the quality in comparison with 2003-04. This was largely due to the close monitoring and management by the Department of Agriculture staff who attended most the surface irrigation events.

While we were unable to analyse the surface irrigation practice in detail during the Project, we are confident that further improvements could be achieved by Harvey irrigators through further analysis of present practices and adoption of improved irrigation management practices. Close management of the surface irrigation events, as was undertaken by research staff during the second monitoring season, was very labour intensive. It is likely that this would be impractical for irrigators on a routine basis and simple automation equipment would probably be a more effective practice to extend into the irrigation community.

At a more sophisticated level, there would be value in using models such as SIRMODII and Infiltv5 and then making associated adjustments to surface irrigation management. It is noted that the National Centre for Engineering in Agriculture provides technical support and training for the models, on a fee for service basis.

6. WHOLE FARM PLANNING

6.1 Introduction

Another key aspect of the Project was farmer learning in whole farm planning that improves decision making for investment in changes to irrigation systems to improve water management.

The following table provides a summary of the Hanks' farm statistics prior to and after commencement of the Project. The statistics relate to financial years which encompass the associated irrigation season. 2001-02 was prior to the set up of the centre pivot. In 2002-03, the pivot had been set up and was trialled, and 2003-04 represents the first year of the case study with a fully functioning centre pivot. Farm results for the second year of the case study, 2004-05, will be available in March 2006 from the Department of Agriculture.

Table 9 – Farm statistics

Farm statistics	2001-02	2002-03	2003-04
Total dairy area, ha	158	143	143
% irrigated	29	38	45
No. calvers	184	254	237
Milk production, mill. litres	1.562 m	1.718	1.993
Milk production, litres per ha	9,887	12,014	13,936
Total water purchased, ML	450	394	410
Milk prod'n/ML	3,472	4,360	4,861

Dale has been increasing the percentage of his total dairy area that is irrigated which indicates the importance of irrigation in improving farm performance. The core issue he has been facing is whether to invest in a large centre pivot to further increase the irrigated area.

A key element of this Project was for Dale to integrate the establishment of centre pivot irrigation into his whole farm operations and planning. Following the completion of the second year of the case study, he is presently considering whether to invest in a 50-hectare centre pivot as a result of the favourable outcomes of the Project.

Dale has been working through the following steps:

1. articulation and review of his profitability, development and lifestyle goals;
2. review of the farm's biophysical attributes and infrastructure – soils, water availability, topography, farm layout and milking infrastructure;
3. review of land availability and suitability for centre pivot irrigation;

4. assessment of the returns from a centre pivot and investment required. This not only includes the capital cost of the pivot, but also additional investment required such as increased land required (either leased or purchased), increased herd size, increased milking shed size and increased labour; and
5. making the investment decision.

6.2 Goals

Dale and Leanne Hanks are operating as a recently formed business entity developed from involvement in a family dairy farm. Key initial goals for the Hanks were to establish profitability and time-saving targets in operations where possible for personal and family reasons.

Continuing cost pressures which have not been offset by price increases, have meant that Dale’s focus has been to substantially increase productivity. Variable costs (herd, shed and feed costs) have increased largely due to an increase in feed costs. Controlling feed costs and increasing milk components are presently key issues for the business and as a result grain feeding practices and pasture management and productivity have been reviewed and reassessed.

Farm operating surplus is impacted by several factors including a fall in the average price received for milk (formerly 80% quota), increasing feed costs as mentioned and historically high fixed costs.

To improve business profitability in the medium to long term, Dale has been working on increasing milk production, reducing costs of production and increasing the area of irrigated land.

While the concentration of the case study was on the irrigation season (approximately October to May) and the irrigated trial site, Dale is seeking to optimise performance across the whole farm for the whole year. In relation to water management, this includes the importance of irrigation scheduling and water application for establishing a pasture base for spring and winter growth.

Opportunities which he has identified for the farm business include:

- increasing productivity from existing resources and infrastructure;
- investing in new infrastructure, particularly for irrigation (eg centre pivot); and
- leasing additional land.

6.3 Assessment of local conditions

The bio-physical characteristics of the Hanks’ property are typical of clay-based soils in the Harvey Irrigation Area. Dale has addressed the complete set of biophysical, economic and institutional factors including soils and their distribution, water availability, available land for expansion, water table and sub-surface drainage, farm paddock layout and fencing, native vegetation remnants, land use and management regulations and environmental management requirements.

Soils and distribution

Soils on the property are generally heavy brown loamy earths. Detailed soil/nutrient surveys have been undertaken at the property by the Department of Agriculture's Natural Resource Assessment Group (see Appendix 6). This is allowing the development of nutrient budgets based on soil characteristics and plant requirements. Additionally, RAW values were calculated for all soil horizons at all soil sample sites under the centre pivot and surface irrigation sites. These were used in scheduling irrigation at both sites.

Water delivery

Harvey Water supplies piped water under gravity driven pressure past the Hanks' property and Dale is the first farmer on this particular line. Pressures are adequate to operate a large centre pivot without a booster pump. With continuing increases in water use efficiency, supplemented by purchases of temporary allocations, Dale would be able to expand the irrigated area with a centre pivot.

The gravity pressure pipe system is capable of delivering 12 ML per day to the Hanks' property with an estimated energy saving to Dale of between $6,000 and $13,000 in comparison with having to pump from a dam or bore over say 1 kilometre.

Watertable and subsurface drainage

As part of DairyCatch, an effluent management plan was prepared by a private consultant and developed into a full nutrient management plan with some coverage of drainage issues. The watertable on the sites, as with most of this low lying and flat land, is above the surface in winter and falls to 1-1.5 metres below in summer. Water logging is a considerable problem in winter and careful irrigation management is required to ensure waterlogging does not occur in the irrigation season. The economic viability of drainage is an issue that requires more analysis and will be addressed in DairyCatch including use of recycled groundwater and tail water.

Native vegetation remnants

Present land is fully cleared with some remnant and planted trees down fence lines and stock and vehicle pathways. There are no impediments for expansion of the area of centre pivot irrigation apart from the removal of a limited number of trees on existing laneways and fence lines. There are no regulatory restrictions on the removal of these trees.

Land use and environmental regulations

Land is zoned for agricultural use and there are no land use or environmental regulations which prevent changes to irrigation systems or an expansion of the irrigated area.

6.4 System design, economics and feasibility

The decision faced by the Hanks' partnership is whether to invest in a centre pivot system and of what size.

Dale has the opportunity from this case study involving his property to generate information that will help him to make a decision to invest in a centre pivot.

Similarly, the results of the Project are assisting other farmers in assessing their irrigation systems and their future investment in improved systems and management.

In relation to investing in a centre pivot system, the partners have considered:

- business and personal goals including those relating to family and personal time;

- the operational requirements of a centre pivot, including labour, time and maintenance requirements to keep the pivot operating to meet the irrigation scheduling plan. The assessment of Dale Hanks and Rob Kuzich is that it takes at least a year of operation for farmers to become competent in managing a centre pivot and up to two years to become fully proficient;

- the issues and knowledge required for management of irrigation scheduling, nutrition management and grazing rotations for both the centre pivot and surface bay systems based on a review of results in order to optimise the performance of both systems. This is a key characteristic of the case study approach on a commercial farm as distinct from a scientific experiment on a research station. In the former, the farmer cannot afford to hold non-irrigation variables constant in both sites, but must move to optimise performance in both sites and then make a comparison on relative performance. In a scientific experiment, non-irrigation variables would be kept constant and results used to design an optimum system to adopt on-farm;

- the costs of centre pivot operation and their impact on business performance (includes labour, time, energy and maintenance costs);and

- the production potential converted to dollar values of the centre pivot versus the existing surface irrigation system.

6.5 Making the investment decision

The superior economic performance of centre pivot irrigation of dairy pasture has been clearly demonstrated in this case study. Dale has no doubts about returns available from investing in a centre pivot and will be installing a 40-hectare machine in February 2007.

The approximate capital costs involved for a 40 hectare pivot installed on Dale’s property are as follows:

- Pivot cost and installation - $110,000 including GST
- Power supply costs - $10,000
- Pipeline costs - $30,000
- Connections - $5,000
- Total capital cost - $155,000

The centre pivot would operate over 40 ha of existing dryland paddocks. This would be associated with a strategy of phasing the surface irrigation with around 20 ha watered from the start of the season and increasing this by another 30-40 hectares later in the season to obtain an early start of the pasture for spring calving.

Dale has already leased additional land and, therefore, is looking to use available land more effectively. While investing in a centre pivot will require increasing his herd size by about 100 cows, he is increasing his herd size naturally, although there is an opportunity cost associated with this strategy as a result of a reduction is heifer sales.

Another major investment associated with purchasing the centre pivot and increasing herd size is expanding the milking shed to another vat, which could be of the order of $100,000.

In addition, there will be extra operating costs for labour, feed and water purchases.

Dale has undertaken a Dairy Australia ‘Taking Stock’ activity in association with his farm financial consultant to examine his business and consider future investment decisions. A critical factor in farm performance is the operating surplus. This is the amount of money left to pay finance and personal costs after all the production costs (herd, shed, feed, overhead and labour costs) are paid from total farm income (milk and other farm income). Operating costs is a critical variable because it supports finance costs and principal payments associated with investing in the centre pivot.

Project team meeting

7. MANAGEMENT OF ENVIRONMENTAL ISSUES

7.1 Deep drainage

Shallow observation bores were installed in both the surface irrigation and centre pivot sites. The bore under the centre pivot was not completed in time to record comparative data for 2003-04, but data was obtained for both sites for the 2004-05 season and the results are shown below.

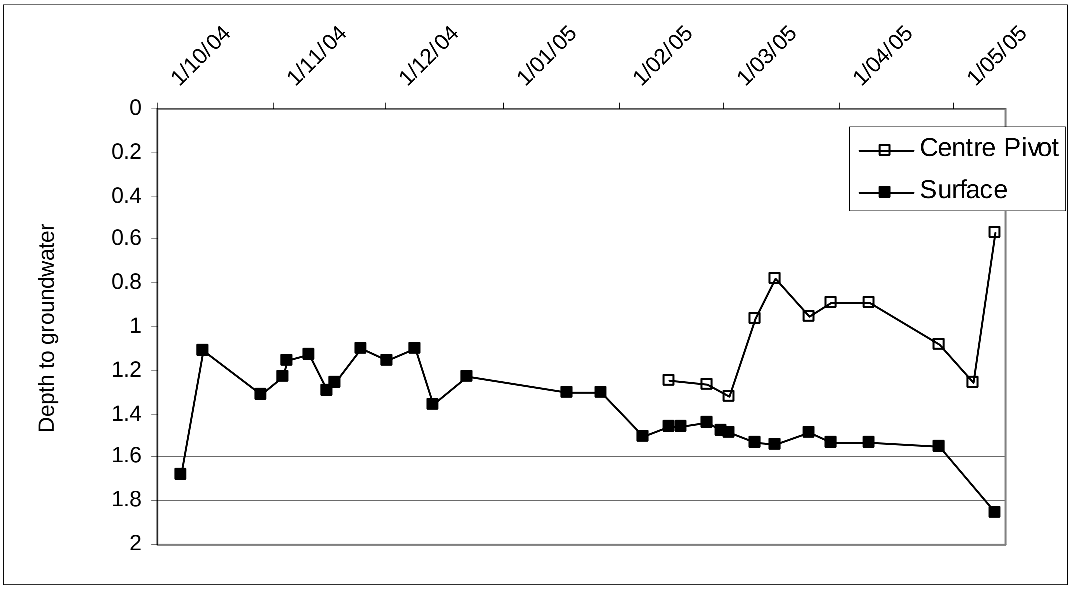


Figure 3: Groundwater levels under surface and centre pivot irrigation systems

The centre pivot site is slightly lower in elevation than the surface irrigation site and this may explain some of the difference in groundwater depths between the sites. However, the data is limited, and no firm conclusions should be made from the data other than that no marked rise or fall in groundwater levels under either system was apparent during the monitoring period. Additional data gathered following the conclusion of the monitoring period indicates that the groundwater level of the centre pivot is stable at approximately 1.0 m and the level of the surface irrigation site is stable at 1.4 m.

Groundwater tables in this region are generally shallow and/or perched and are in close contact with the regional surface drainage network. Also, winter rainfall is intense and most of these areas are subject to inundation and waterlogging for many of the winter months. Any groundwater accessions due to irrigation activities are likely to be negligible when compared with winter rainfall and would be relatively rapidly negated through the nearby drainage networks.

7.2 Groundwater quality

Water samples were also taken from the shallow observation bores as well as from a series of lysimeters installed under the two systems. In all cases, groundwater quality in terms of both nitrogen and phosphorus was not of concern and were within the recommended maximum levels of 0.75 mg/L and 0.1 mg/L respectively. Average figures are shown below in table 10.

Table 10: Average nutrient concentrations in ground water samples from both irrigation systems

	Soluble Phosphorus (mg/L)	Soluble Nitrogen (mg/L)
Surface	0.06	0.09
Centre Pivot	0.07	0.06

Depths at which the samples were taken varied from 1.05 – 1.9 m on the surface irrigation site and from 0.6 – 1.3 m.

7.3 Water losses to runoff

Losses to runoff from the surface irrigation site for the 2003/04 irrigation season were very high (approximately 65%). These figures were reported for the ’Front’ monitoring site which captures runoff from the six hectare-three bay surface irrigation trial site. Some flume submergence issues were apparent during this monitoring season and the runoff figures were calculated and reported using a number of correction factors for flume submergence.

Following a review of the monitoring design and protocols, an additional flow control structure and automatic water sampler was installed at the tail drain of the first, individual irrigation bay. This site is referred to as ‘Bay 1’. The runoff figures for the 2004/05 irrigation season, expressed as a percentage of applied water are shown in Table 11 below.

Table 11: Runoff losses from individual and combined surface irrigation bays

	Average (%)	Range (%)
Bay 1	12	7 – 19
Front	20	7 - 35

These figures are significantly better than the 65% measured during the 2003/04 irrigation season for the ‘Front’ point. However, this would be expected given the reduction in water use and the ability to better manage the surface irrigation at the site during this season as discussed earlier. (Gates were closed when water had progressed 66% of the way down the bay).

It is also interesting to note the reduction in ‘efficiency’ between the individual bay scale and the 3-bay scale measured at the ‘Front’ point. This illustrates the cumulative effect of runoff from a series of irrigation bays irrigated together, and is also likely to be due to the less timely closing of gates in bays 2 and 3 because of less intensive monitoring and management of these bays. An option to improve performance would be to install automatic irrigation gates, but this was not considered by the farmer during the project.

7.4 Nutrient concentrations in runoff water

Nutrient concentrations measured in water samples taken during the irrigation seasons followed relatively predictable patterns at various scales. Highest concentrations of nutrients were measured in water flowing overland during irrigation events and, within events, concentrations were highest at the bottom of the irrigation bays. This would be the point when the water has had the maximum exposure to available nutrients on the soil surface and in the shallow subsurface. Levels of up to 44 mg/L and 66 mg/L for phosphorus and nitrogen respectively were measured in irrigation water flowing over the soil surface.

However, maximum concentrations of nutrients measured at the tail drain of Bay 1 had reduced to 6.4 mg/L and 23.4 mg/L for phosphorus and nitrogen respectively. Nutrient concentrations at this scale again followed predictable patterns with the maximum values occurring at the commencement of runoff flow through the drain.

Maximum nutrient concentrations in water samples from the automatic sampler collecting water from the three combined irrigation bays, however, had increased concentrations. This may again show the importance of good irrigation management discussed above in terms of water losses.

Overall, average nutrient concentrations at various scales within the trial followed a very predictable pattern and are an important dataset in terms of characterising processes within irrigated and dryland agricultural systems when discussing nutrient concentrations and using these values to apply sustainability tests to land management practices.

Figure 4 illustrates the average nutrient concentrations of surface water collected at four points within the surface irrigation trial: irrigation water running over the surface of bay 1; runoff from bay 1; runoff at point “Front” (which collects runoff from bays 1 to 3), and; the final collection point as water leaves the property and enters the regional drainage system (referred to as “back”).

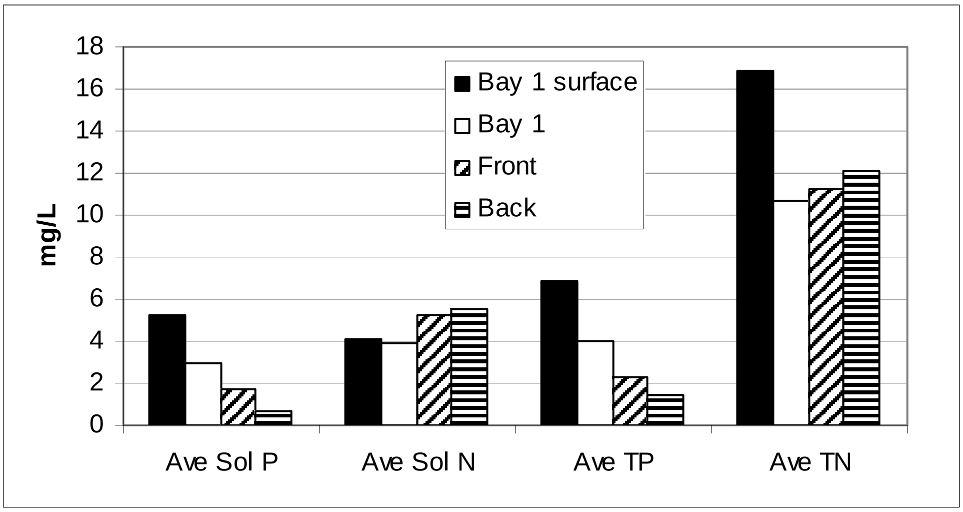


Figure 4: Average P and N concentrations in runoff water

A distinct reduction in both total and soluble phosphorus concentrations is observed as well as a general increase in nitrogen concentrations.

Figure 5 further develops the relationship between phosphorus concentration in water samples and catchment scale. This data shows the strong relationships between both total phosphorus and soluble phosphorus and catchment size (R^2 of 0.98 and 0.96 respectively).

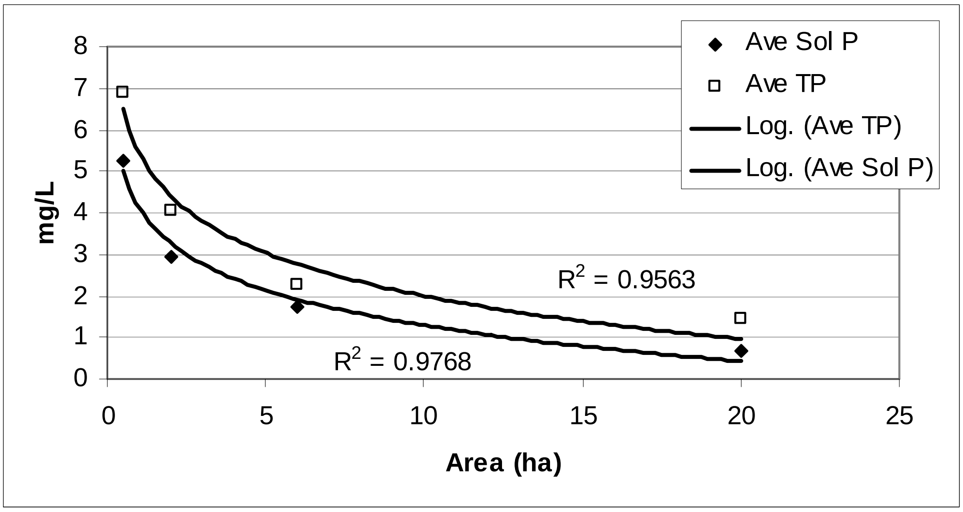


Figure 5: Nutrient concentrations at increasing catchment areas

This is a very important point as the same land management practices are in place throughout the catchment from the irrigation bay scale to that of a large portion of the farm. It illustrates the fact that monitoring of land management practices at any scale larger than that at which the practices are implemented (in this case the irrigation bay) is unlikely to yield meaningful information because of the diluting influences of those parts of the catchment (farm) which do not contribute nutrients.

A KEY MESSAGE
Monitoring of nutrient concentrations at the Hanks property, supported by results from work elsewhere in the catchment, illustrates the fact that phosphorus export reduction practices need to be targeted at the appropriate small scale at the nutrient source.

Nitrogen trends across scales are less clear, although it appears as though in-paddock and in-drain nitrification processes increase nitrogen concentrations in water as it moves across the landscape.

7.5 Nutrient loads in runoff water

Through combining the runoff loss information and nutrient concentration data discussed previously it is possible to determine the nutrient loss rates from the various parts of the trial and at the various scales (Table 12).

Table 12: Nutrient losses from surface irrigation site over an irrigation season

Area (ha)	Phosphorus loss (kg)	Nitrogen loss (kg)	Phosphorus loss / ha	Nitrogen loss / ha
2	11.15	30.89	5.58	15.44
6	44.84	107.21	7.47	17.87
20	7.51	93.83	0.38	4.69

This again illustrates the importance of the issue of scale in terms of determining nutrient export rates from farming systems. At the irrigation bay scale, phosphorus and nitrogen losses of approximately 6 kg/ha and 16 kg/ha are observed. However, at the farm-scale monitoring point, these figures have reduced to approximately 0.4 kg/ha and 5 kg/ha.

The fact that the 20ha farm-scale monitoring point has lower total nutrient loss values than the smaller-scale points also highlights the important issue of on-farm and in-drain nutrient assimilation and storage.

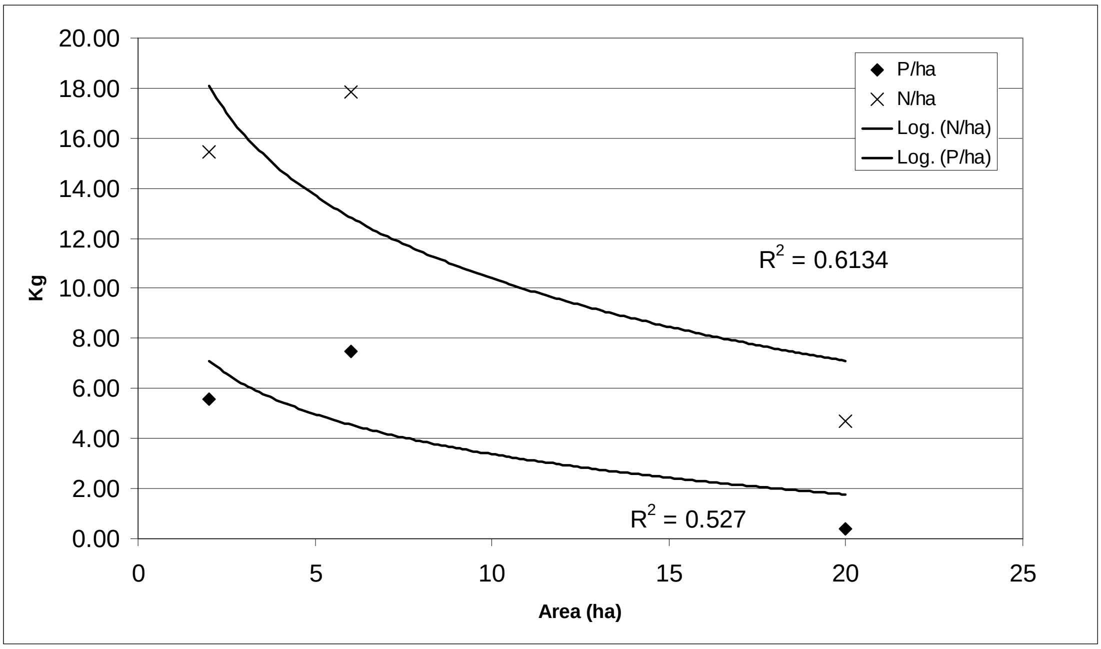


Figure 6: Nutrient loss rates at increasing catchment areas

7.6 Conclusion

In summary, the following conclusions can be drawn from the water monitoring that was carried out in both irrigation seasons:

- Neither the surface or centre pivot irrigation systems resulted in any net groundwater accessions throughout the length of the trial.
- A large reduction in the run-off loss from the surface irrigation site occurred in the second season (ie, from 65% to 20%) due to closer management of

the system. This has significant implications for automation of irrigation bay gates and suggests that this may be one of the more effective best management practices (BMPs) to pursue in this area.

- No runoff was observed at all from the centre pivot system.

- Nutrient concentrations in irrigation water within bays can be extremely high indicating that, at times, large nutrient losses can occur. Further work is required to analyse the distribution of nutrients across irrigation bays following irrigation events. This was not undertaken during the project.

- There was no relationship between nutrient concentrations in run-off water and the time between fertilising and irrigating. This indicates that factors other than timing are affecting nutrient export rates. It is likely that the inherently high solubility of present phosphatic fertilisers is the dominant causative factor for phosphorus loss rather than any fertiliser management methods per se.

- Phosphorus concentrations are scale related; ie, concentrations coming off individual bays are higher than combined bays for the same events. Associated monitoring at the catchment scale indicates that drains are large sinks for nutrients, but we don't know if or when they will re-release those nutrients.

- Phosphorus concentrations in tail drains and larger farm drains are similar to phosphorus concentrations in drains on non-irrigated properties.

- Phosphorus concentrations at 'end of farm' monitoring points approached background levels, but still above recommended maxima for ecosystem protection. Around 90% of phosphorus in run-off is the soluble and more ecologically active form.

- Nitrogen concentrations in drain water are also scale related, but opposite to phosphorus. That is, nitrogen concentrations increase with increasing scale of measurement. This is expected and is likely to be due to in-drain, microbial nitrification processes.

- Scale issues are important if water quality monitoring is to be used to determine how "sustainable" farming systems are.

The single most important point in terms of the sustainability of irrigated farming in the south west of Western Australia is likely to be the real (or more importantly, perceived) issue of nutrient export to regional waterways. State regulators already have the ability to prosecute landowners for 'environmental harm' if those landowners cannot show that they are farming sustainably. It has been suggested that 'sustainability' may be measured in this context by the collection of water samples and their analysis for nutrient concentrations. The data presented here shows a very clear relationship between catchment size and nutrient concentration in runoff water – already a clearly established relationship internationally, but lacking in domestic data. This information is likely to convince regulators that point measurement of water quality is not a good indicator of sustainability.

Dale Hanks checking water sampling equipment (Arthur Mostead)

Mark Rivers discussing water sampling

8. IRRIGATION AREA SYSTEM DEVELOPMENT

8.1 Introduction

The National Program for Sustainable Irrigation asked the project team to investigate issues relating to the future development of the Harvey Water irrigation system based on multiple or widespread adoption of centre pivot technology. The objectives specified were:

Objective 4: Demonstrate the energy efficiencies and overall energy balance of a pressurized gravity-fed piped system of irrigation water delivery.

Objective 5: Understand the issues surrounding the operation/ordering procedures for the water authority (managing a pressurized irrigation supply system) and irrigator if there was widespread adoption of centre pivot sprinkler technology.

8.2 Background on improving distribution efficiency

Harvey Water is a cooperative of 556 irrigators farming 30,000 irrigable hectares. It manages a licensed resource of 153,000 megalitres of water under a system of transferable water entitlements. The irrigation water is supplied from seven dams located in the Darling Scarp, which adjoins the eastern side of the Irrigation Area. Due to the location of these dams and their height above sea level, the system is gravity driven with sufficient pressure to not require an energy input for pumping water.

The distribution system that Harvey Water manages covers some 600 kilometres of water supply of which 25% is lined channel, 47% unlined channel and 28% piped. The pipe system includes the Harvey Central system in the Harvey District and the Waroona System from Drakesbrook Dam (see Table 13).

Improving distribution efficiency has been an important requirement for the Harvey Irrigation System for many years. Replacing the open channel system with a piped system has long been advocated to reduce seepage and evaporation losses. In the case of the Harvey Irrigation Area, evaporation is not a significant issue because the channels are narrow and the gravity fed water moves very quickly.

Water distribution loss is the difference between the volume of water delivered to the system and the volume supplied to irrigation customers.

By definition, distribution loss is calculated as:

Distribution loss (%) = 100% - distribution efficiency

where distribution efficiency (%) = volume delivered (ML)/ volume diverted (ML)

With channel systems, factors which determine the extent of losses include:

- Earth versus concrete channels.
- Soil types – lighter textured soils allow for higher seepage losses when compared to areas of heavy clays.
- Delivery infrastructure age where old open channel systems have high losses due to seepage and (to a lesser extent) evaporation.
- Distance of delivery system – some systems have to deliver water over long distances which increases the likelihood of losses.
- Service standards – trying to optimize customer service in reducing delays between ordering and actual delivery and the associated losses in channel-fill requirement that is not used (outfall).
- Operating practices – a situation is when water is ordered and delivery starts through system as a rainfall event occurs and the irrigator diverts water which then flows out of the system as it is not required. The irrigator is only charged for water that has passed through their measuring system and not for what has been ordered and lost.
- Meters – generally the older systems within parts of the irrigation system are reliant on less accurate Dethridge wheel readings while other areas (piped) have more precise modern measuring systems.
- Other impacts – requirements to meet recreational, amenity and environmental demands. Another factor that affects several of the above is climatic conditions, which will impact on irrigator scheduling and channel evaporation rates.

8.3 Development of the Harvey Water system

Future development of the Harvey Water system involves three integrated and complementary projects centred around replacing irrigation channels with pipe. The proposal seeks total system harmonisation including water and energy efficiencies from storage to paddock, trade of water savings to the WA Integrated Water Supply System (IWSS) to contribute to project costs, improvement of water quality, and reduced environmental impacts from irrigation.

The project comprises:

1. Piping the whole system and accessing distribution losses due to seepage and other causes.
2. Reducing salinity in the system's largest water supply (Wellington Dam) and saving water used for scouring.
3. Providing a gravity pressure driven water supply system to farmers that will cater for on-farm innovation in irrigation, thereby delivering further water savings, energy savings and reduced environmental impacts from irrigation.

The project builds on considerable preliminary work and an integration of results of a range of activities and studies that have been conducted since 2000. This includes:

- Demonstration of the benefits of investment in over 170 kilometres of pipes that have been installed since 2000, thereby accessing 10GL of distribution losses.

- Design and planning for a five-stage project to completely pipe the HWIA with agreement having been reached with the Western Australian Government on Stage 1.
- Completion of this NPSI funded project that has demonstrated changes to irrigation systems and management on-farm arising from water delivered to the farm by pipe under gravity driven pressure.
- Regional and catchment scale natural resource management and irrigation projects involving a range of stakeholders including the Department of Agriculture, Harvey Water, South West Catchments Council, Western Dairy, and Alcoa World Alumina.
- Activities of key agencies for land use planning and for developing existing industries and attracting new industries. These set out a strategic plan for agricultural development and outline the economic, biophysical and social conditions necessary for future development.

Piping the HWIA (Arthur Mostead)

8.4 Issues being addressed and project benefits

The project involves a whole of system approach to water resource management that addresses several objectives:

- innovation in water supply and delivery;
- improving water quality and the general health of water systems; and
- efficiency of water use.

The project capitalises on the water and energy efficiency of a gravity pressure pipe system. It offers the opportunity of a complete re-think of the water/energy nexus in irrigation water supply and opportunities to investigate technical innovations. Many of these are not presently envisaged, but may include oxygen enriched water for irrigation and small scale hydro-electricity generation.

The drivers of the project are the enhancement of the productive capacity and sustainability of the HWIA as the prime area for WA irrigated agriculture; to provide more diverse opportunities for irrigators; to improve the State water supply; and achieve harmonious environmental management.

Innovation in water supply and delivery

The project addresses achieving water savings through improvements in irrigation infrastructure. The innovations are:

- replacing channels with pipes;
- gravity pressure pipe supply that introduces a new water/energy paradigm in irrigation water; and
- funding through trading the water savings to pay for the capital cost of piping.

Water savings can be achieved through offsetting delivery losses of up to 30% between the dams located in the Darling Scarp and farms on the Swan Coastal Plain that are caused by seepage, channel fill, leaks and end of system losses.

Piping the Waroona Irrigation District has resulted in distribution losses falling from 27% to 2% of the water released from the dams. This investment has enabled Harvey Water to trade 6 GL of water to the Water Corporation for the State Integrated Water Supply Scheme. In addition, piping increased the irrigated area used for horticulture from 48ha to more than 150ha in the 2004 irrigation season. Success from the Waroona scheme has demonstrated benefits for fully piping the Harvey Water Irrigation Area.

Table 13 – Distribution losses, Harvey Irrigation Area dams

Scheme	Supply method	System length	Irrigation deliveries 2004 (ML)	Distribution losses 2004 %
Collie	Channel	211 km	27 262	35.5
Harvey Central	Pipe	118 km	7 962	5.0
Harvey	Channel	154 km	19 827	19.0
Logues	Channel	40 km	5 860	20.0
Samson	Pipe/channel	30 km	3 595	5.1
Drakesbrook (Waroona)	Pipe	40 km	3 179	2.0

Planning, design and preliminary funding has taken place for a project to fully pipe the Harvey Water Irrigation Area. The proposal is to stage the development in 5 steps over about 10 years which is estimated to cost about $220 million. It involves a new pipe network that will replace the open irrigation channels and deliver water to the farm gate in both the Harvey and Collie Irrigation Districts.

The WA Government has allocated $29 million in 2005 as a trade for the saved water with the funds being used to contribute to piping the Harvey Irrigation District. The full initiative will result in a piped irrigation water supply for all of the District's 250 irrigation farmers at a cost of $70 million and will provide 17.1 gigalitres per year for the State Integrated Water Supply System annually. Harvey Water and the Water Corporation have entered a trade agreement for this water.

Piping the Collie Irrigation District would be dependent on an improvement in water quality in Wellington dam (see below). If this is successful, the Collie District could be piped over 5 to 8 years at a cost of around $120 million to deliver 22 GL of water.

Table 14 - Summary of project costs and water savings

Piping Harvey Irrigation District	$70 M	17.1 GL
Salinity reduction Welling Dam	$30 M	12.0 GL
Piping Collie Irrigation Dist	$120 M	22.0 GL
Total	$220 M	51.1 GL

<u>Improving water quality and the general health of water systems</u>

This project involves reducing the salinity of irrigation water and at the same time achieving further water savings.

The Wellington Dam has a yield of about 105 GL. Over half of this water is licensed for use by irrigators, but it is very poor quality (over 1100 ppm TDS or 200 mS/m in recent years). It is not suitable for potable purposes and barely acceptable for irrigation.

An integral part of the overall project is that it will be necessary to improve the quality of water in Wellington dam by reducing the salinity to the extent that the water would be of value to both irrigators and the IWSS. The first stage of this improvement work commenced in winter 2005 using funds provided by Harvey Water with support from Griffin Coal to implement the Collie River Salinity Recovery Project (CRSRP) being managed by Department of Environment under the National Action Plan for Salinity and Water Quality.

The project will see the diversion of the high salinity flows in the Collie River East Branch which brings in about 40% of the salt, but only about 10% of the water. The water will be diverted into empty coal mining voids owned by Griffin Coal. Modelling suggests that the salinity could be reduced to around 700 ppm TDS or 140 mS/m over 3 to 4 years depending upon the winter rainfall. Winter scouring of the saltiest water, which averages about 15 GL per year, will no longer be needed when the quality improves. The amount of saved water able to be traded to the State Integrated Water Supply System is estimated at 12 GL per year.

8.5 Meeting system requirements

Development of the above project progressed through the following stages:

1. completion of the preliminary design;
2. independent review of the technical, economic and environmental feasibility;
3. negotiations with the Government on the water trade and project funding;
4. approval of the project; and
5. planning for implementing the project in various stages. There are three stages in the Harvey District (Harvey South, Uduc and Logues) and two in the Collie District (Collie North and Collie South).

In undertaking the preliminary design, Harvey Water undertook modeling of the proposed piped system in order to determine the most cost effective pipe types, sizes and classes along with delivery volumes and pressures.

The new system is designed to replace the current supply points with four types:

1. 140 litres per second delivery that is open to the atmosphere for irrigation purposes;
2. 70 litres per second delivery as above;
3. closed supply suitable for stock and gardens;
4. a combination of open and closed systems.

Water supplied will be gravity fed. For example, the Harvey Dam operates with water between 57 and 72 metres AHD (Australian Height Datum). The top water level of 72 metres was used to determine the proposed pipe classes under maximum pressure conditions. Presently the pipe system from Harvey Dam to the Harvey Central area on Government Road where the Hanks' property is located is capable of delivering 400 ML per day.

The maximum demand is expected to be around 100 ML per day (1,160 litres per second). Total demand of eight 140 litre per second Dethridge Wheels (1,120 litres/second) operating together is presently catered for by Harvey Water. From this information a scheduling program of demands and suitable deliveries is being developed for the new pipe system.

As an example of an existing system, currently the demand to the Harvey North supply offtake is 130 ML/day, of which 35 ML/day of this volume can be attributed to water losses. Harvey Water expects to reduce the losses to 5 ML/day, thus reducing the total demand by the Harvey North pipe system to 100 ML/day.

The pipeline will be constructed in Western Australia with size ranges from 280mm to 1,200mm. Harvey Water has already constructed over 170 kilometres of this type of pipe which has contributed to water savings of 10 GL. PE 1000 with pressure class PN 6.3 pipe will be used instead of steel to keep the project cost down by limiting the static head pressure to 600kpa.

A minimum pressure of 250 to 300 kpa is required in the system when at its maximum draw so that centre pivot, solid set or trickle irrigation can be used in addition to surface irrigation.

The proposed system can cater for widespread adoption of centre pivot irrigation replacing a significant proportion of existing surface irrigation. If the new centre pivots are highly concentrated, scheduling issues will need to be addressed in future along with the possibility of installing larger pipes or irrigators installing in-line booster pumps.

Harvey Water planning system requirements (Arthur Mostead)

8.5 Conclusion

- The Harvey Water Irrigation Area (HWIA) has progressed a long way from the days of government ownership and control of the irrigation scheme. Privatisation of scheme assets and supply management in the hands of local irrigators provided the stimulus for change and diversity through greater participation of a wide range of stakeholders from the private and public sectors. The key players are now Harvey Water, irrigator members of the two cooperatives, and various government agencies that continue to have a direct role in irrigation regulation and water storage (Department of Environment as the licensor for irrigation water use and the Water Corporation as the owner of water storages and release points).

- The future development of the HWIA will capitalize on the water and energy efficiency of ta gravity pressure pipe system. This offers the opportunity of a complete re-think of the water/energy nexus in irrigation water supply and opportunities to investigate technical innovations. Many of these are not presently envisaged, but may include oxygen enriched water for irrigatin and small scale hydro-electricity generation.

- Harvey Water has now modelled and planned for a distribution system that will deliver water to meet the requirements of a multiple and growing number of outlets for varying pivot sizes, multiple sites per farm and scheduled supply to meet demand.

- The Project has provided data on the water delivery and pressure requirements for dairy farmers to successfully operate centre pivots of varying sizes. Baseline information has been provided on system capacity in millimetres per day, megalitres per hectare per year and appropriate pivot sizes for heavy brown loamy earths.

- The possibility of water trading within the Irrigation Area over the past 9 years has lead to the creation of an internal market of buyers and sellers and provides opportunities for additional investment in further developing irrigated agriculture. This also leads to closer connections between irrigators with service providers including agribusiness, farm advisors and providers of financial services.

- The proposal to fully pipe the Harvey Irrigation Area which is to be funded by a water trade of the resulting savings to the Western Australian Integrated Water Supply Scheme will create new opportunities for irrigators to invest in an expansion of irrigated agriculture and to change to more efficient spray and sprinkler systems such as centre pivot irrigation for pasture.

Gravity fed water from dams on the Darling Scarp (Arthur Mostead)

9. R&D PARTNERSHIPS IN IRRIGATION

9.1 Introduction

The development of the partnership approach to this case study, including key issues that have arisen and their resolution became an important part of this Project. A specific objective was included to:

Demonstrate a model of partnership research that engages the key decision makers in research design, conduct and evaluation, and leaves a legacy of understanding and learning that allows on-going research in the same or other areas (Objective 2).

The Project itself was a learning experience for the partners and adaptive management processes were used to respond to results and observations (eg, adjustments to irrigation scheduling, nutrition management or grazing rotations).

9.2 Project partners

Formation of a partnership that brought together the key commercial players supported by public sector experience in research and knowledge generation has been a successful feature of the Project.

The partners and their respective roles were:

- Department of Agriculture – the Research Organisation for the purposes of the Project with Waroona Research Officer, Mark Rivers, undertaking the research relating to issues of water and nutrient run-off and deep drainage, soil surveying and analysis and monitoring of surface irrigation during the 2004-05 season. He also provided links to the Dairy Catch project.

- Dale Hanks, who with his wife, Leanne, is the owner of Taylynn Farms. Dale managed the operation of the centre pivot and surface bay irrigation systems and collected pasture samples for measurement and analysis by Horizon Farming. Dale worked on farm planning issues in association with his financial consultant, Glenys Hough.

- Rob Kuzich & Co. who initiated the original proposal was responsible for overseeing and providing advice on centre pivot management. Rob Kuzich, the Principal, supplied the centre pivot and Sentek EnviroScans.

- Boorara Management was engaged to develop the original proposal into an application to the National Program for Sustainable Irrigation for funding. The Principal of Boorara Management, Ken Moore, became the independent Principal Investigator responsible for the overall management of the Project, the coordination of meetings, organisation of communication and adoption activities, maintenance of appropriate case study standards and preparation of project reports.

- Horizon Farming, WA through Dario Nandapi was responsible for the pasture analysis and reports.

- Harvey Water considered water distribution system issues relating to the adoption of centre pivot irrigation by farmers and installed the pipe necessary to connect the centre pivot to the distribution system.

The roles and responsibilities of team members were set out in a formal partnership agreement with the Department of Agriculture, Western Australia. As a result, the partners clearly understood their responsibilities and were able to establish effective working relationships for the duration of the project.

9.3 Outcomes of the partnership approach

The project partners achieved significant water management, pasture production and environmental results. The results and opportunities created were only possible through people, networks and connections with or engagement of communities of interest. Relationship building and management backed by knowledge and technology is the key to unlocking remarkable change.

This is important because Australian Government funding of R&D is increasingly emphasising commercially focused research that contributes to Australian industrial, commercial and economic growth. In addition, the Government is requiring the involvement of the private sector, particularly small and medium enterprises, in R&D so that it is directed to meeting market needs. Consequently, contracting and partnership agreements need to facilitate rather than constrain or even prevent meeting the Government's R&D objectives and intentions.

Iterative processes with the development of the Project involving the project team and the Steering Committee were essential features and improved the quality of project planning and outcomes. The partners held many meetings and spent considerable time and effort in implementing the Project. Their in-kind contribution of time in the development of the partnership, preparing the application and documenting the planning has far exceeded that originally expected. However, the team members regarded this Project as a learning experience for themselves in all aspects. While all are experienced and successful in their field, being involved in the planning issues, establishing a working team and implementing the actual case study provided major learning outcomes. It also provided opportunities for bringing in outside perspectives, varied experiences and new networks.

9.4 Role of the Steering Committee

A Project Steering Committee was formed to oversee the project and provide advice on approaches, methodology and achievement of required outputs and outcomes.

Membership included a number of key participants who could provide independent technical advice and oversight of the project. The members of the Steering Committee were:

- Andrew McCrea (Chair), Department of Environment
- Danny Norton, Chairman, Harvey Water

- Geoff Calder, General Manager, Harvey Water
- Murray Chapman, Coordinator, National Program for Sustainable Irrigation
- Joe Foley, National Centre for Engineering in Agriculture and CRC for Irrigation Futures
- Mathew Bethune, Institute for Sustainable Irrigated Agriculture, DPI, Victoria
- Wayne Bell, Harvey dairy farmer
- Adrian Nicholas, Industry Development Officer, IAA Western Australian region.

The terms of reference for the Steering Committee's was to:

- Provide external perspectives and expert guidance on all aspects of the project.
- Provide quality control and endorsement of key project documentation for approval of the NPSI Program Management Committee.
- Provide leadership within personal and organizational networks to promote the project and its outputs, facilitate contacts and assist in negotiations where this is necessary.

The knowledge, varied experiences and expertise of Steering Committee members added greatly to the development of the Project and the outcomes achieved.

Steering Committee meeting

10. LEARNING AND ADOPTION

10.1 Introduction

Objective 3 of this Project, was to:

> *Demonstrate and leave in place, a communication and learning strategy that ensures research results are effectively communicated to end users in a way which allows their application, and creates openness to learning from other areas.*

The overall goal was to bring innovation to irrigation systems and agronomy on-farm in the Harvey Irrigation Area by generating information through this case study. The aim was for farmers to use this information to increase water use efficiency and farm productivity, and reduce ecological impacts through factors such as water and nutrient seepage to the water table, downstream nutrient run-off and soil structural problems. The project's communication and adoption activities were directed at achieving this aim.

10.2 Achieving innovation and change though learning and connections

The Project's communication activities generated strong interest amongst Harvey Water irrigators and others outside the irrigation area. A number of producers have purchased centre pivot systems since the Project commenced and others are considering changes to their systems. This includes heighted interest in ways to improve the performance of surface irrigation through physical improvements such as automation, measurement of water application and movement and adoption of new practices based on results achieved.

We observed that farmer acceptance of research information is influenced by farmer involvement in the research and through the knowledge that the information was obtained in a real farming situation. Undertaking farming system trials, such as this one does not allow the level of scientific control that would be allowed in a purely research situation, but it does provide research results which are more meaningful to the farming community and which relate more to real farming practice.

It is important for future change in irrigation in the Harvey Water Irrigation Area, that locally derived data and information continues to be available to support such decisions. The Harvey Water irrigators' survey found that irrigators have a strong preference for receiving information via field days and field walks, hard copy newsletters and hard copy project reports.

Another achievement of this stakeholder initiated project was its drive to seek further connections and links both within the Harvey Irrigation Area and outside. This included its communication, education and learning activities involving other irrigators and an interested audience Australia-wide that has been promoted through articles, presentations, interviews and workshops. These networks have brought new knowledge and perspectives on opportunities and change.

A highly influential relationship was with the National Program for Sustainable Irrigation (NPSI) which not only provided essential funding for the Project, but provided national links and knowledge from its own partners and networks. Many suggestions and insights that broadened and strengthened the project were provided by the Program's Coordinator, Murray Chapman, and the NPSI partners.

Another crucial relationship was with the CRC for Irrigation Futures (National Centre for Engineering in Agriculture) which provided a level of expertise that opened new horizons for improving irrigation performance and farm profitability. Encouraged by the contact with the NCEA, and its links to the Cooperative Research Centre for Irrigation Futures, the project adopted a philosophy of learning from the best in relation to issues and problems which have arisen.

The Project sponsored visits to Harvey by Joe Foley of the NCEA in 2003 and Associate Professor Steve Raine in 2004 to advise on aspects of the Project and give presentations to Harvey Irrigation Area farmers on centre pivot and surface irrigation practices. This was followed by another visit in 2004 by Steve Raine and Professor Rod Smith to present a workshop on the '*Fundamentals of Irrigation: core skills training for irrigation professionals'* to irrigators, farm advisors and irrigation specialists and government agency extension and research staff.

The Project funded the participation of a group of six young south west dairy farmers in the Australian Dairy Conference in February and visits to innovative dairy farms with centre pivot and surface irrigation systems in the Shepparton area. It also funded a trip of six south west beef producers to the central west of New South Wales to observe and discuss with peers centre pivot irrigation of pasture and forage crops.

The Project also participated in the Western Dairy event, the Dairy Innovation Day, on 1 April 2005 and proposes to participate in the Dairy Discovery Day in September 2005. A further field day visiting a number of centre pivots in the Harvey Irrigation Area will be held in October 2005.

In its first year, the Harvey Irrigation Systems project was selected as one of 12 case studies from across Australia featured in Australian Government Innovation in Irrigation Showcase in Goolwa, South Australia in October 2004. It was also a finalist in the 2004 Western Australian Premier's Water Foundation Water Conservation and Management Awards and won a Special Commendation in the the SGIO 2004 Western Australian Environmental Awards. In 2005, the Project won the Water Conservation and Management Award.

The partners will continue to distribute information gained from the Project as part of the future development of the HWIA in a concerted effort to overcome constraints to change. Meeting the needs of irrigator members and recognising their capacity to change are critically important to achieving on-farm water savings. Capacity to change is influenced by a number of factors including the following.

- Due to their enterprise type and operations, some irrigators may be unable to afford the costs of implementing a new system.

- Change involves a level of risk that some may not wish to take, particularly those farmers reaching retirement age where they do not have succession plans in place.
- Change to more sophisticated technology often requires a high level of skill and knowledge that takes time or is difficult or costly to acquire.
- Uncertainty in policy (eg, environment flow requirements, property rights over water and regulation of environmental offsite impacts) can discourage investment in new systems.

Even with positive rates of return and payback periods for investing in improved irrigation systems, some farmers remain reluctant to invest. This risk aversion stems from non-economic factors such as industry uncertainties, life-stage, desired lifestyle and family business structures. For example, farmers with young families facing market and price uncertainty tend to be highly risk averse to large investments based on borrowing. The role of incentives to reduce risk and encourage investment in innovation needs further investigation.

Project field day

10.3 The Project's key messages

The essence of the Project evolved from the initial idea of an on-farm trial comparing sprinkler and surface irrigation; to a demonstration case study of the comparative performance of sprinkler and surface irrigation; to recognition that the greatest benefits will accrue from considerably improving the performance of both sprinkler and existing surface irrigation.

The crux of the Project was the demonstration of management practices whereby the optimisation of sprinkler and surface irrigation performance can be achieved. Results demonstrated the potential of sprinkler irrigation to bring about substantial increases in water use efficiency, pasture production and dollar returns on additional milk produced.

However, the Project partners have also recognized the potential for significant improvement in the productivity of existing surface irrigation through better irrigation measurement, monitoring and management practices.

Measurement and monitoring of water management were central to the project and it revolved around directly involving those participants with the greatest interest in the outcomes. The project was managed as a learning experience for the partners and adaptive management processes were used to respond to results and observations.

A key message flowing from the Project for irrigators is that if you are not measuring irrigation performance, then your ability to optimise your water management practices is limited. However, the Project found that farmers require clear information, back-up technical support and time to learn about the system's performance and become fully proficient in its use. Considerable knowledge is required in integrating water application and scheduling, and pasture, grazing and nutrient management. Identifying areas for improvement, learning new techniques and applying these on-farm are essential to innovation in water management.

10.4 Water policy development

It became apparent during the Project that even though its focus was on-farm water use efficiency and productivity, system-wide issues need to be brought together to fully understand and achieve or maximize wider benefits. Whole of system efficiencies result from improved water use efficiency or reduced losses through the system from the Water Corporation dam headworks via Harvey Water piping to farms and then via respective on-farm surface and sprinkler irrigation systems to the pasture and to surface water run-off and groundwater drainage.

Water savings from whole of system efficiencies can be used for piping the irrigation system as demonstrated by the Harvey Water project or when resulting on-farm for the expansion of production or water trading. More efficient irrigation practice also results in regional environmental benefits of reduced water and nutrient run-off and deep drainage. This is particularly important in environmentally sensitive areas in close proximity to inlets such as those on the South West coastal plain.

The Project's findings were available for consideration by the Western Australian Irrigation Review, the Department of Agriculture's Water Wise on the Farm program, Harvey Water's system planning, the Western Dairy Regional Action Plan and the South West Catchment Council natural resource management strategies.

In relation to Western Australia, learning from a whole of systems approach will provide major benefits in:

- strategies for development of irrigated agriculture in the Harvey Irrigation Area;
- further development and refinement of the WA Water Strategy (Irrigation Review);
- strategies for achieving greater water use efficiency on-farm and system wide;
- responding to water supply and quality pressures;
- responding to industry productivity and profitability pressures; and
- meeting the knowledge requirements of modern agriculture and natural resource management.

At an Australia-wide level, this Project highlights the potential for on-farm water use efficiency allied with productivity gains. It also demonstrates the success of private-public partnerships in R&D even on a small scale.

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APPENDIX 1: REVIEW OF COMMUNICATION ACTIVITIES

Project Communication Strategy

Stakeholder and information needed.	Desired Stakeholder Response	Actions/Outputs	Evaluation of success
Dairy farmers (and other producers) and agribusiness service providers – What irrigation and agronomy systems matched to local soil types, climate, land use and practical farm management will achieve best productivity, financial and environmental results, and how can these be effectively adopted into the farm business?	Evidence of analysis of best irrigation management practices on farms and adoption if justified	Field days at key times when data is available and meaningful to producers Field trips to other irrigation areas at strategic times in the project when outcomes can be maximised.	There was very good attendance at Project events and positive responses from attendees. Five centre pivots have been installed in the area since the commencement of the project and interest is at a high level. There have been many follow up inquiries from farmers following rural newspaper articles and radio interviews. Two field trips to irrigation areas in Victoria and NSW were held for groups of farmers.
Harvey Water (irrigation water provider) – What irrigation systems adopted on-farm and across the farming community will achieve the most effective and efficient use of available water resources, and meet the economic, social and environmental objectives of the Harvey Water Irrigation Area? What sustainable practices are required in present industries? What opportunities exist for the sustainable expansion of irrigated agriculture in the area? What are the energy efficiencies and energy balance of pressurised gravity fed piped irrigation systems and what are the lessons for other Australian	Strong support of board, executive and irrigator members to the project. Use of knowledge generated from the project in planning and services provided to members.	Provision of research reports at appropriate times addressing the issues of interest to Harvey Water.	Strong support for project has been provided by Harvey Water and results were used in their planning and system design for the pipe network.

Stakeholder and information needed.	Desired Stakeholder Response	Actions/Outputs	Evaluation of success
irrigation areas?			
NPSI – What models of research, extension and adoption will produce the best results for the commercial and community stakeholders involved? What changes in practices are required for the sustainability of present industries	Awareness and knowledge of details of project. Continued support for the project.	Involvement of Program Coordinator in project steering committee and project communication activities Submission of milestone reports.	Coordinator has visited the Harvey Irrigation Area twice. Milestone reports accepted and approved. PI has provided presentations on project to NPSI Investor Forums. Articles written for NPSI website and publications (eg Rip Rap)
Other researchers – What methodologies will produce robust and scientifically credible results? What are the findings of this research?	Awareness of project. Interest in project.	Writing of articles for relevant research publications.	Presentations to NPSI Investors Forums attended by other researchers. Joe Foley and Steven Raine (NCEA) and Matthew Durack (Vic DPI) have visited the HIA and discussed methodology and results.

APPENDIX 2: PASTURE MEASUREMENT, SEASON 2003-04

1. Methodology

The aim of this part of the case study was to analyse pasture yield and quality on the centre pivot and surface irrigation demonstration sites over two years. From this information, we were able to determine how much milk can be produced from grazing each site.

Protocols for measuring pasture quantity and quality

1. *Protocol for measuring pasture mass.*

- The amount of pasture grown is measured with an electronic rising plate meter. Measurements for pre-grazing and post-grazing pasture heights based on the approximate leaf stage of rye grass. The rising plate meter measurement is then converted to kg DM/Ha using equations that have been calibrated for the pasture species present and time of the year.

2. *Protocol for measuring pasture quality.*

- When pasture is measured pre-grazing a "grab" sample of pasture is collected. This "grab" sample is representative of pasture eaten by cows.
- These samples are frozen and once a month are pre-dried in an oven at 60oC and sent to a Feedtest laboratory in Victoria for analysis. [Feedtest is a commercial feed analysis service that allows both the producers and users of livestock feeds to make informed decisions on feeding strategies, based on objective measurement of feed quality]. Feedtest measures crude protein (CP), neutral detergent fibre digestibility (NDF) and metabolisable energy (ME).
- We are then able see if there is any difference in feed quality between the treatments.

3. *Combination of the two measurements*

- Using the two measurements above, we then calculate how many megajoules of energy are produced and tonnes of digestible dry matter rather than just tonnes of dry matter in the different treatments.
- Knowing the milk production of the herd when the various pastures are grazed and the energy content of the pasture and other feeds, we calculate the amount of pasture consumed on a megajoule basis. There can be variance associated with this calculation as cows can gain and loose weight to maintain constant milk, production and milk produced on a day-to-day basis can be "buffered" by the amount of digesta in the rumen from the previous day's intake. Cows' intake on a day-to-day basis and the management issues involved are examined.
- Milk components sent to the milk factory are available monthly. These are needed to accurately determine the amount of energy consumed by the cows each day they are grazing the trial sites so that, by reverse feed budgeting the amount of pasture consumed by the cows is determined.
- The electronic rising plate meter was calibrated by taking pasture cuts at various times of the year.
- A fertiliser budget was formulated for the pivot and surface bay sites and these were adjusted to optimise growth on both sites.

- Further to this, tissue tests of the pivot perennial site were carried out each second month to monitor the fertiliser budget.
- Grazing management and ration formulation were assessed monthly to ensure that grazing management is optimal for all sites and that the ration is set to optimise pasture use and milk production.

2. Results

2.1 Pasture growth rates

Measurements in both sites started in late November/early December 2003 and are presented here up to July 2004. The late start in 2003-04 was due to the pasture on the surface bay being established in autumn and the centre pivot site being established in spring. By December, the pasture on both sites had reached sufficient maturity to be compared.

The average pasture growth rate for the pivot site (paddock 42) over 14 measurements of pre-grazing pasture mass and post-grazing pasture residuals was 71.7 kg DM/Ha/day.

The average from the surface bay (paddock 29N) over 13 measurements was 44.9 kg DM/Ha/day. This is 26.8 kg DM/Ha/day (37%) lower than the pivot site.

The maximum growth rate for the pivot was 123.3 kg DM/Ha/day compared to 86.8 for the surface bay. The minimum was 28.8 kg DM/Ha/day for the pivot compared with the surface bay's minimum of 14.5 kg DM/Ha/day.

Figure 2 - Growth rates of the pivot site and surface bay

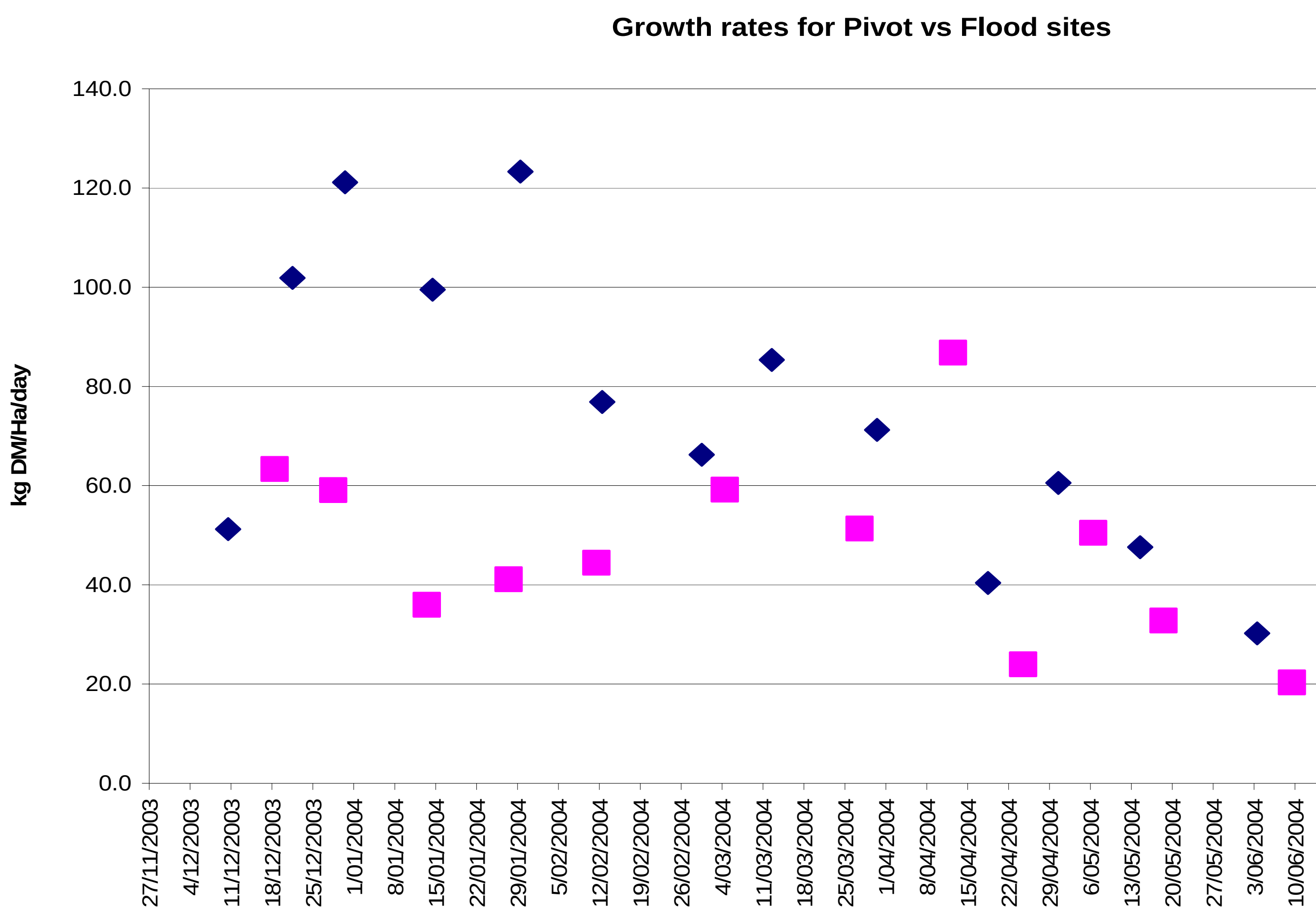


Table 1, Growth rates for pivot si

date	Paddock	Growth rat
27/11/2003	42	
10/12/2003	42	51.3
21/12/2003	42	101.9
30/12/2003	42	121.1
14/01/2004	42	99.5
29/01/2004	42	123.3
12/02/2004	42	76.9
29/02/2004	42	66.3
12/03/2004	42	85.4
30/03/2004	42	71.3
18/04/2004	42	40.4
30/04/2004	42	60.6
14/05/2004	42	47.6
3/06/2004	42	30.2
30/06/2004	42	28.8

Table 2, Growth rates for surface site

date	Paddock	Growth rate
7/12/2003	29N	
18/12/2003	29N	63.3
28/12/2003	29N	59.1
13/01/2004	29N	36.0
27/01/2004	29N	41.1
11/02/2004	29N	44.4
4/03/2004	29N	59.2
27/03/2004	29N	51.4
12/04/2004	29N	86.8
24/04/2004	29N	24.0
6/05/2004	29N	50.5
18/05/2004	29N	32.8
9/06/2004	29N	20.3
21/07/2004	29N	14.5

2.2 Pasture grown

Using the growth rate results from above, the amount of pasture grown over the same period was calculated

The pivot site grew 14.3 tonnes DM/Ha over 216 days compared with the surface bay site growing 9.3 tonnes DM/Ha over 227 days. This is 5.0 tonnes DM/Ha (35%) less pasture.

Table 3, Pivot pasture grown

date	Paddock	Growth rate	Pasture grown
27/11/2003	42		
10/12/2003	42	51.3	666
21/12/2003	42	101.9	1121
30/12/2003	42	121.1	1090
14/01/2004	42	99.5	1493
29/01/2004	42	123.3	1850
12/02/2004	42	76.9	1076
29/02/2004	42	66.3	1126
12/03/2004	42	85.4	1024
30/03/2004	42	71.3	1283
18/04/2004	42	40.4	767
30/04/2004	42	60.6	727
14/05/2004	42	47.6	666
3/06/2004	42	30.2	605
30/06/2004	42	28.8	778
		total	14272
		days	216

Table 4, Surface bay pasture grown

Date	Paddock	Growth rate	Pasture grown
7/12/2003	29N		
18/12/2003	29N	63.3	697
28/12/2003	29N	59.1	591
13/01/2004	29N	36.0	575
27/01/2004	29N	41.1	575
11/02/2004	29N	44.4	666
4/03/2004	29N	59.2	1302
27/03/2004	29N	51.4	1181
12/04/2004	29N	86.8	1389
24/04/2004	29N	24.0	288
6/05/2004	29N	50.5	606
18/05/2004	29N	32.8	394
9/06/2004	29N	20.3	447
21/07/2004	29N	14.5	611
		total	9322
		days	227

2.3 Pasture quality

There was also a difference in pasture quality measured in terms of crude protein, neutral detergent fibre and metabolisable energy. Averages for the 2 sites are as follows:

Table 5, Pasture quality for Pivot vs Surface bay sites

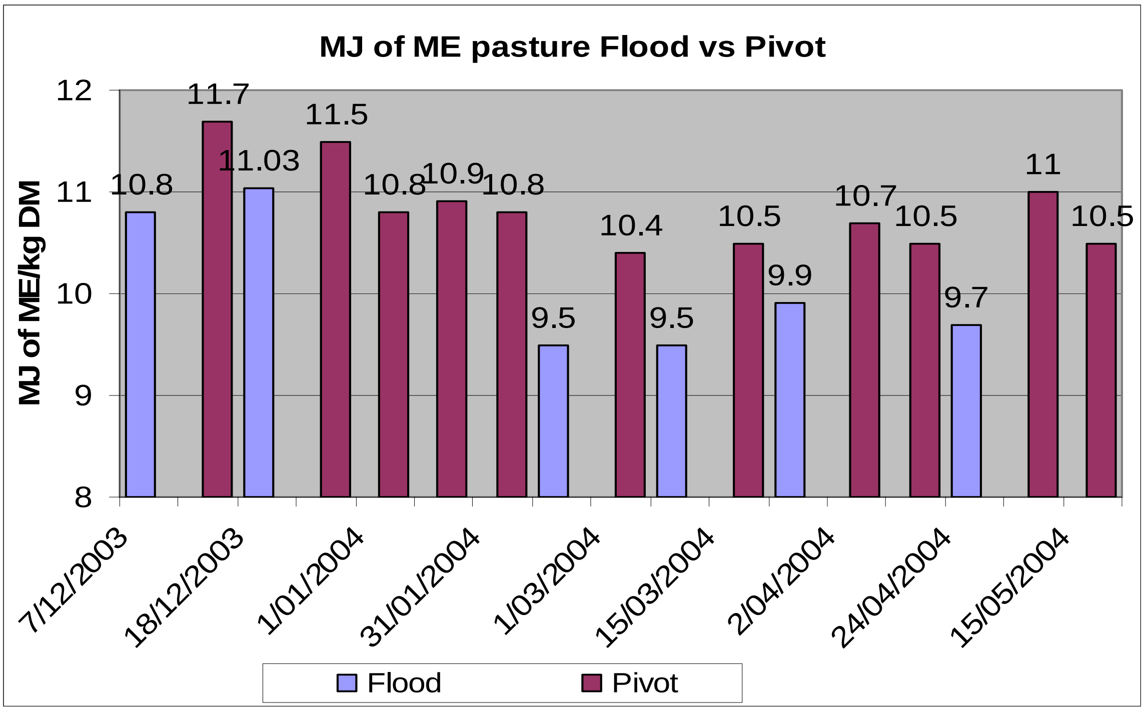
Sample description	CP	NDF	MJ of ME
pivot	23.75%	43.21%	10.8
Surface bay	19.4%	50.2%	10.1

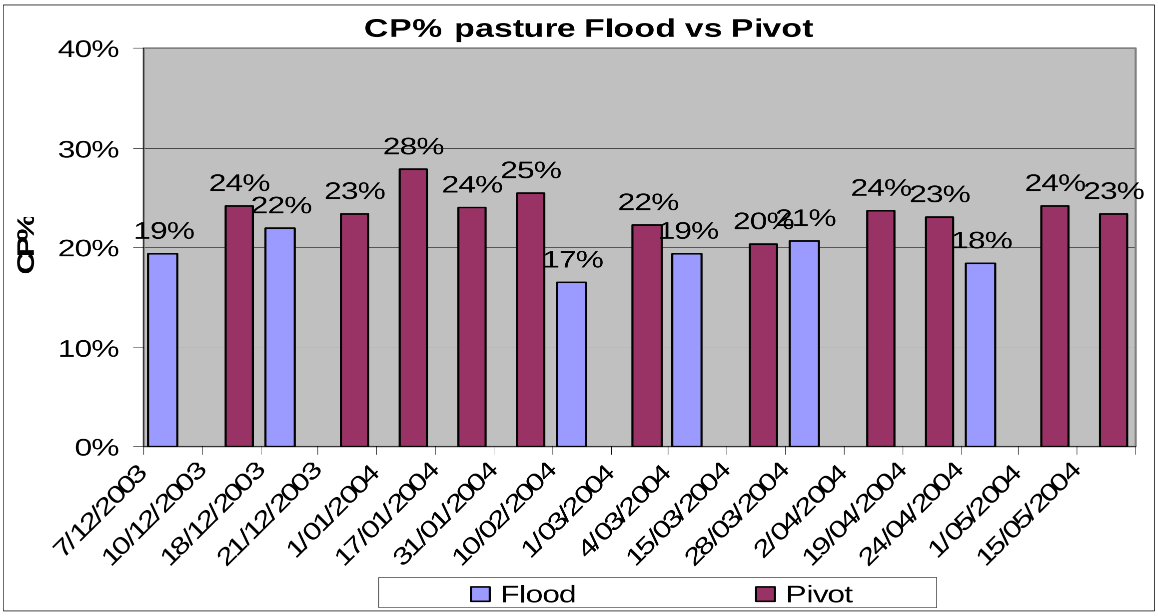
The data for the respective periods is outlined below:

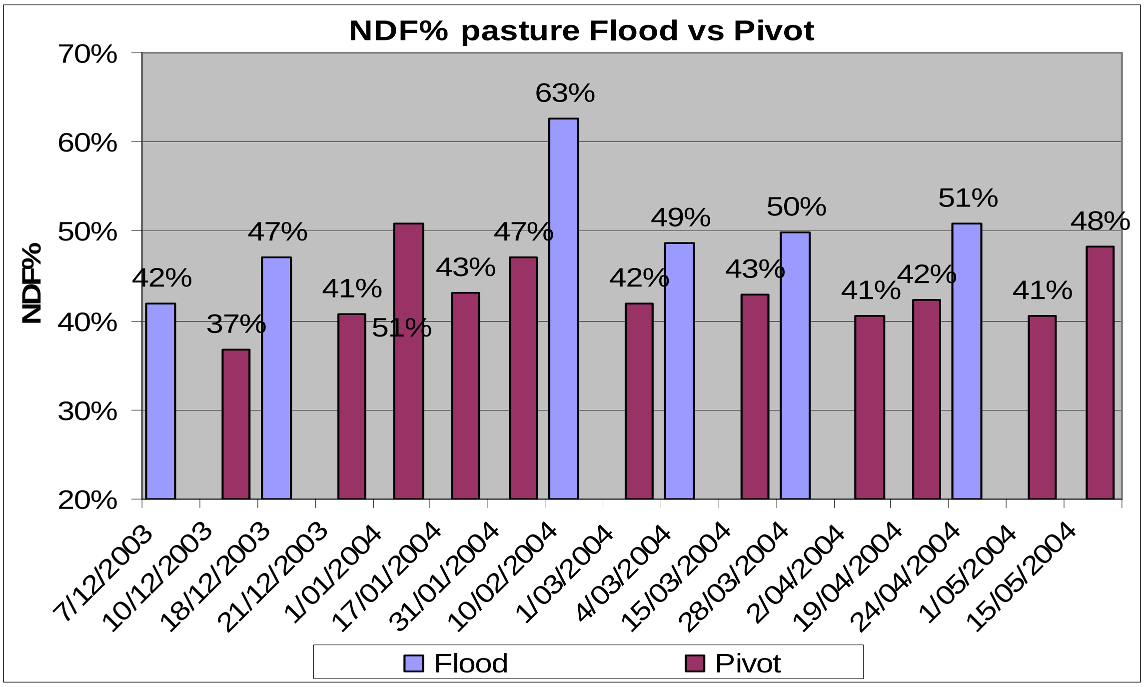
Table 6, feed test results from both sites

Sample description	Date	CP	NDF	MJ of ME
surface bay	7/12/2003	19.4%	41.90%	10.8
Pivot	10/12/2003	24.10%	36.70%	11.7
surface bay	18/12/2003	21.90%	47.10%	11.03
Pivot	21/12/2003	23.30%	40.70%	11.5
Pivot	1/01/2004	27.80%	50.80%	10.8
Pivot	17/01/2004	24.00%	43.20%	10.9
Pivot	31/01/2004	25.40%	47.10%	10.8
surface bay	10/02/2004	16.50%	62.70%	9.5
pivot	1/03/2004	22.20%	42.00%	10.4
surface bay	4/03/2004	19.40%	48.70%	9.5
pivot	15/03/2004	20.30%	43.00%	10.5
surface bay	28/03/2004	20.60%	49.80%	9.9
pivot	2/04/2004	23.70%	40.60%	10.7
pivot	19/04/2004	23.10%	42.40%	10.5
surface bay	24/04/2004	18.40%	50.90%	9.7
pivot	1/05/2004	24.10%	40.50%	11
pivot	15/05/2004	23.30%	48.30%	10.5

Figures 3 – 5: Pasture quality – megajoules of metabolisable energy, crude protein and neutral detergent fibre.







The reason for the difference in feed quality is probably a combination of four main factors:

4. The surface bay has far more weed as a percentage of the sward. As weeds are poorer quality than ryegrass/clover the resulting feed tests will be poorer.
5. As the surface bay puts more stress on ryegrass/clover due to its cycle of waterlogging and then drying out compared to the pivot, plants tend to lignify which increases the fibre level of the plant and reduces its digestibility and hence its energy content.
6. Also due to the waterlogging drying cycle, the surface bay plants did not take up as much nutrient (including nitrate) which resulted in lower crude protein level in the plant and also added to the stress on the plant as mentioned above.
7. Less nitrogen was used on the surface bay site so lower nitrate and, therefore, crude protein levels can be partly attributed to this. Less nitrogen could also increase stress on plants increasing lignin levels and enhance weed competitiveness.

Total metabolisable energy produced.

Due to time constraints on the farmer, pasture samples were not collected at every grazing. Therefore, the average figures above were used to estimate the total amount of energy produced on both sites.

The pivot produced 154,784 MJ of ME/Ha compared to the surface bay producing 93,883 MJ of ME/Ha. Assuming cows will utilise 70% of pasture grown they would utilise 108,349 MJ/Ha from the pivot site compared to 65,718 MJ/Ha from the surface bay. This is a difference of 42,631 MJ (39%). If we assume that each litre of milk takes 5MJ this is a difference of 8,526 litres of milk/Ha.

On average cows produced the same amount of milk solids (1.76 for pivot vs 1.77 for surface bay). However, the pivot was grazed 23 times compared to the surface bay being grazed 15 times. This happened because there was more pasture being grown on the pivot so the cows grazed half the area each night of the pivot (one Ha/night) compared to the whole surface bay (two Ha/night). As there was often not double the pasture available, cows had to eat other supplements or more daytime pasture to make up for this so the difference in quality between the pivot and surface bay could not be seen in the vat, especially as pasture intake from the pivot or surface bay averaged 4.4 kg DM/cow/day which is only 25% of the total ration.

2.4 Fertiliser use

The amount of fertiliser applied to both sites in kg/Ha are as follows:

Table 7, fertiliser use on Pivot and surface bay sites from october03 to July 04

Paddock 42 Pivot					Paddock 29 Surface bay				
Date	**N**	**P**	**K**	**S**	**Date**	**N**	**P**	**K**	**S**
13/11/2003	33	8	12.5	9	7/10/2003	33	8	12.5	9
12/12/2003	21	10.5	18.75	18	28/10/2003	35	4	12	5
23/12/2003	42	4.8	14	6	27/11/2003	21	10.5	18.75	18
23/01/2004	62				15/12/2003	21	10.5	18.75	18
16/02/2004	50	4		8	23/01/2004	14	7	12.5	12.4
23/03/2004	35	4	12	5	17/02/2004	50	4		8
6/05/2004	30	8	10	8	23/03/2004	35	4	12	5
8/06/2004	30	5	10	8	6/05/2004	30	8	10	8
19/07/2004	37								
total	**340**	**44.3**	**77.25**	**62**	**total**	**239**	**56**	**96.5**	**83.4**

The pivot site received 101kg/Ha more nitrogen, 11.7 kg/Ha less phosphorus, 19.25 kg/Ha less potassium and 21.4 kg/Ha less sulphur.

The pivot site was fertilised in July, but not the surface bay as it was deemed too wet to get an economic response to fertiliser. Also the surface bay, being already established, was fertilised in October 2003. If these two applications are taken out, as well as the July 2004 application on the pivot site (as the last grazing measured was 30 June), the results are as follows:

Table 8, fertiliser use on Pivot and surface bay sites from November 03 to June 0

Paddock 42 Pivot					Paddock 29 Surface bay				
Date	**N**	**P**	**K**	**S**	**Date**	**N**	**P**	**K**	**S**
13/11/2003	33	8	12.5	9					
12/12/2003	21	10.5	18.75	18					
23/12/2003	42	4.8	14	6	27/11/2003	21	10.5	18.75	18
23/01/2004	62				15/12/2003	21	10.5	18.75	18
16/02/2004	50	4		8	23/01/2004	14	7	12.5	12.4
23/03/2004	35	4	12	5	17/02/2004	50	4		8
6/05/2004	30	8	10	8	23/03/2004	35	4	12	5
8/06/2004	30	5	10	8	6/05/2004	30	8	10	8
total	**303**	**44.3**	**77.25**	**62**	**total**	**171**	**44**	**72**	**69.4**

The pivot site received 132 kg/Ha more nitrogen, 5.25 kg/Ha more potassium, the same amount of Phosphorus and 7.4 less sulphur.

Results of tissue testing from both sites are as follows:

Table 9, Tissue test results from both sites

date	pdk	CP%	N	NITR	PHOS	K	S	Na	Ca	Mg	Cl
2 Dec 03	pivot	25.3	4.05	43	0.37	3.52	0.39	0.44	0.6	0.32	2.15
13 Jan 04	pivot	26.9	4.3	145	0.43	3.903	0.489	0.662	0.425	0.334	2.98
30 Mar 04	pivot	24.1	3.85	451	0.317	2.649	0.352	0.582	0.522	0.387	2.07
3 June 04	pivot	28.3	4.53	810	0.52	3.845	0.377	0.507	0.39	0.336	2.26
	av	26.1	4.18	362.3	0.41	3.48	0.40	0.55	0.48	0.34	2.36

2 Dec 03	surf. bay	16.2%	2.59	43	0.255	1.70	0.245	0.63	0.576	0.33	1.615
12 Jan 04	surf. bay	21.8%	3.49	40	0.334	1.92	0.325	0.69	0.376	0.278	1.911
30 Mar 04	surf. bay	18.0%	2.88	38	0.317	1.54	0.368	0.39	0.47	0.42	1.529
3 June 04	surf. bay	21.3%	3.4	42	0.398	2.72	0.332	0.63	0.408	0.26	2.064
	av	19.3%	3.09	40.75	0.33	1.97	0.32	0.59	0.46	0.32	1.78

*Numbers in red indicate levels that are lower than recommended.

Nitrate and crude protein levels are higher for the pivot site which may be in part due to the higher rate of nitrogen application, but also due to better mineralisation occurring in the pivot site compared to the surface bay. This is mainly due to the surface bay going through a waterlogging and drying cycle, which restricts soil microbial action and hence mineralisation compared to the pivot site where readily available water is maintained in the soil through best practice irrigation frequency and application allowing for constant soil microbial action and mineralisation. Leaching may also be an issue as the surface bay will leach more nutrients.

Plant tissue levels of the other major nutrients (P, K & S) are all lower on average in the surface bay site compared to the pivot site, even though both sites received about the same amount of these nutrients. This again can be attributed to less mineralisation on the pivot site but would also be due to more leaching of these nutrients in the surface bay.

APPENDIX 3: PASTURE MEASUREMENT, 2004-05

Pasture growth rates
Measurements in both plots started in September/October 04 and continue to April/May 05. After discussions with Steven Raine it was decided that the surface irrigation site chosen was not the most suitable for measuring water flow characteristics so the more southern bay was to be monitored.

The average pasture growth rate from the pivot site (pdk 42) over 15 measurements of pre grazing pasture mass and post grazing pasture residuals was 121.6kg DM/Ha/day.

The average from the flood site (pdk 29S) over 14 measurements was 60.7kg DM/Ha/day. This is 60.9 kg DM/Ha/day (50%) lower than the pivot site.

The maximum growth rate for the pivot was 245kg DM/Ha/day compared to 110for the flood. The minimum was 38kg DM/Ha/day for the pivot compared to the flood's minimum of `25kg DM/Ha/day.

Figure 1

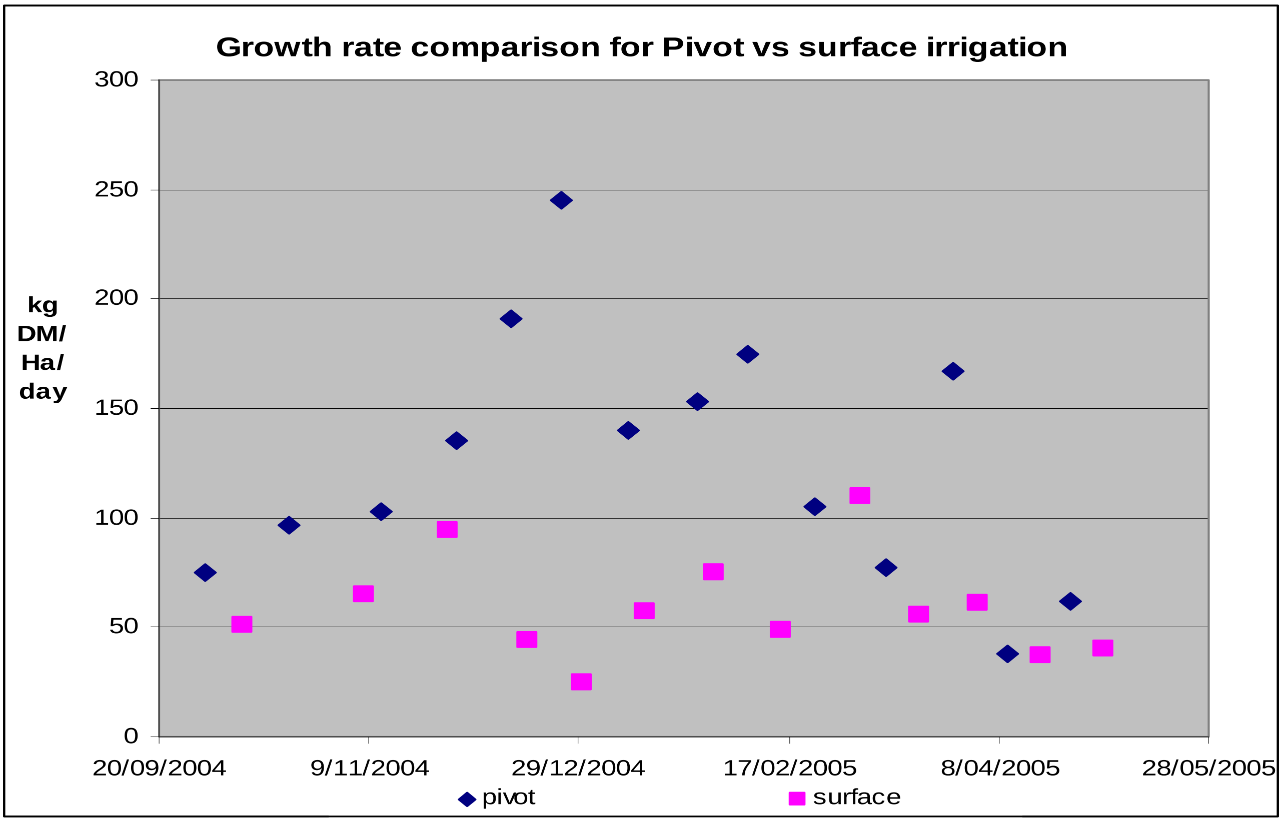


Table 1, growth rates for pivot site

Date	paddock	growth rate
12/09/2004	41	
1/10/2004	41	75
21/10/2004	41	97

Table 2, growth rates for surface site

Date	paddock	growth rate
20/09/2004	29S	
10/10/2004	29S	51
8/11/2004	29S	65

12/11/2004	41	103
30/11/2004	41	135
13/12/2004	41	191
25/12/2004	41	245
10/01/2005	41	140
26/01/2005	41	153
7/02/2005	41	175
23/02/2005	41	105
12/03/2005	41	77
28/03/2005	41	167
10/04/2005	41	38
25/04/2005	41	62

28/11/2004	29S	94
17/12/2004	29S	44
30/12/2004	29S	25
14/01/2005	29S	57
30/01/2005	29S	75
15/02/2005	29S	49
6/03/2005	29S	110
20/03/2005	29S	56
3/04/2005	29S	61
18/04/2005	29S	37
3/05/2005	29S	40

Pasture grown
Using the growth rate results from above, the amount of pasture grown over the same period was calculated

The pivot site grew 27.4t DM/Ha over 225 days compared to the flood site growing 13.7t DM/Ha over 225 days. This is 13.7 t DM/Ha (50%) less pasture.

Table 3, pasture grown on pivot site

Date	paddo	growth kg DM/Ha/	pasture grown kg DM
12/09/2004	41		
1/10/2004	41	75	1425
21/10/2004	41	97	1940
12/11/2004	41	103	2266
30/11/2004	41	135	2430
13/12/2004	41	191	2483
25/12/2004	41	245	2940
10/01/2005	41	140	2240
26/01/2005	41	153	2448
7/02/2005	41	175	2100
23/02/2005	41	105	1680
12/03/2005	41	77	1309
28/03/2005	41	167	2672
10/04/2005	41	38	494
25/04/2005	41	62	930
		total	**27357**
		days	**225**

Table 4, pasture grown on surface irrigation

Date	paddocl	growth kg DM/Ha/da	pasture grown kg DM
20/09/2004	29S		
10/10/2004	29S	51	1020
8/11/2004	29S	65	1885
28/11/2004	29S	94	1880
17/12/2004	29S	44	836
30/12/2004	29S	25	325
14/01/2005	29S	57	855
30/01/2005	29S	75	1200
15/02/2005	29S	49	784
6/03/2005	29S	110	2090
20/03/2005	29S	56	784
3/04/2005	29S	61	854
18/04/2005	29S	37	555
3/05/2005	29S	40	600
		total	**13668**
		days	**225**

Pasture quality

There was also a difference in pasture quality. The average of the 2 sites was as follows:

Table 5 Pasture quality for pivot vs. surface site

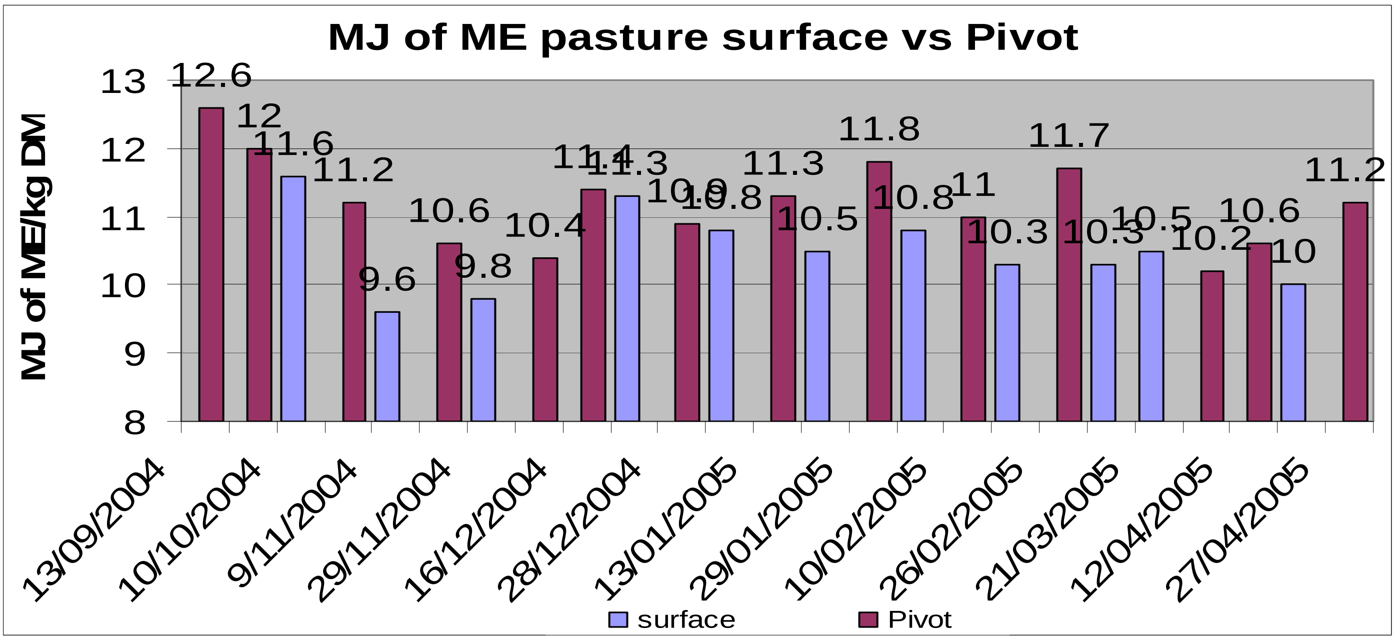
site	crude protein	acid detergent fibre	neutral detergent fibre	MJ of ME
surface	22.3%	24.8%	51.0%	10.5
pivot	23.4%	21.1%	48.9%	11.2

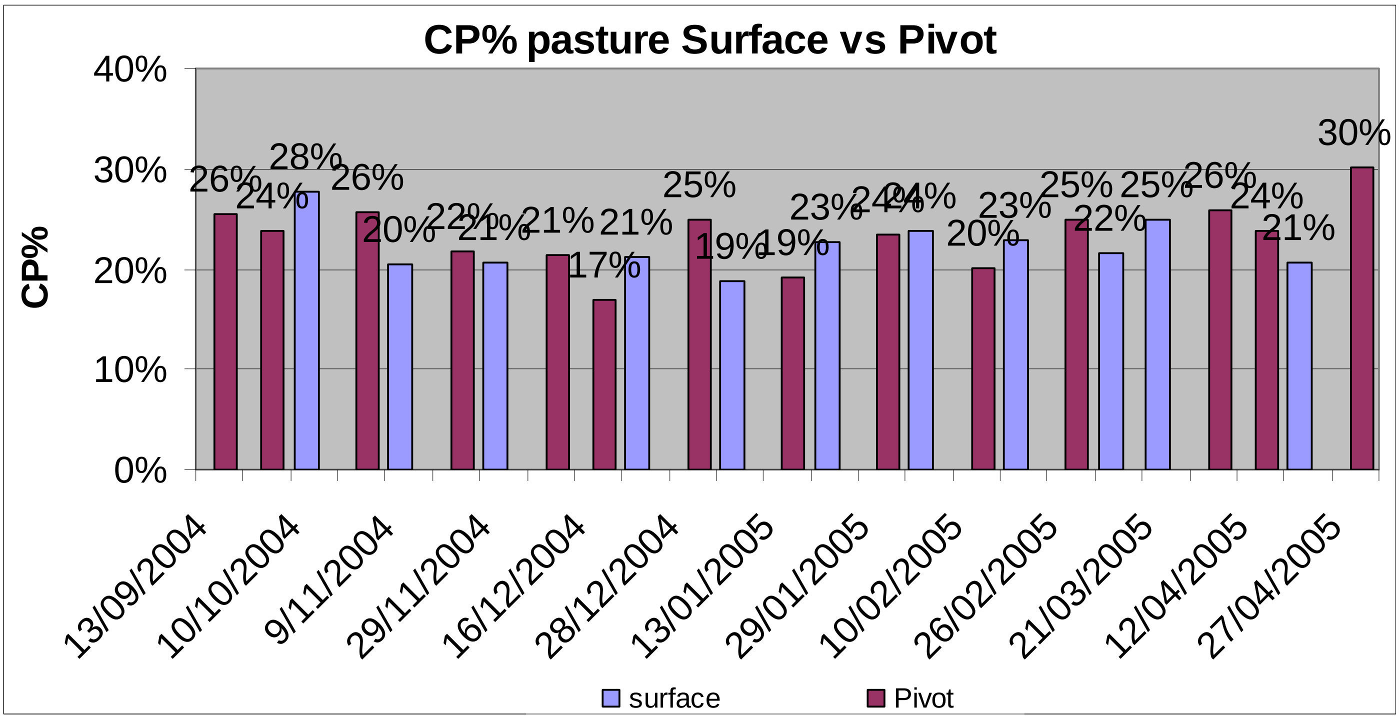
The pivot site, on average was higher in crude protein and energy and lower in both fibre measurements, which indicate better quality pasture.

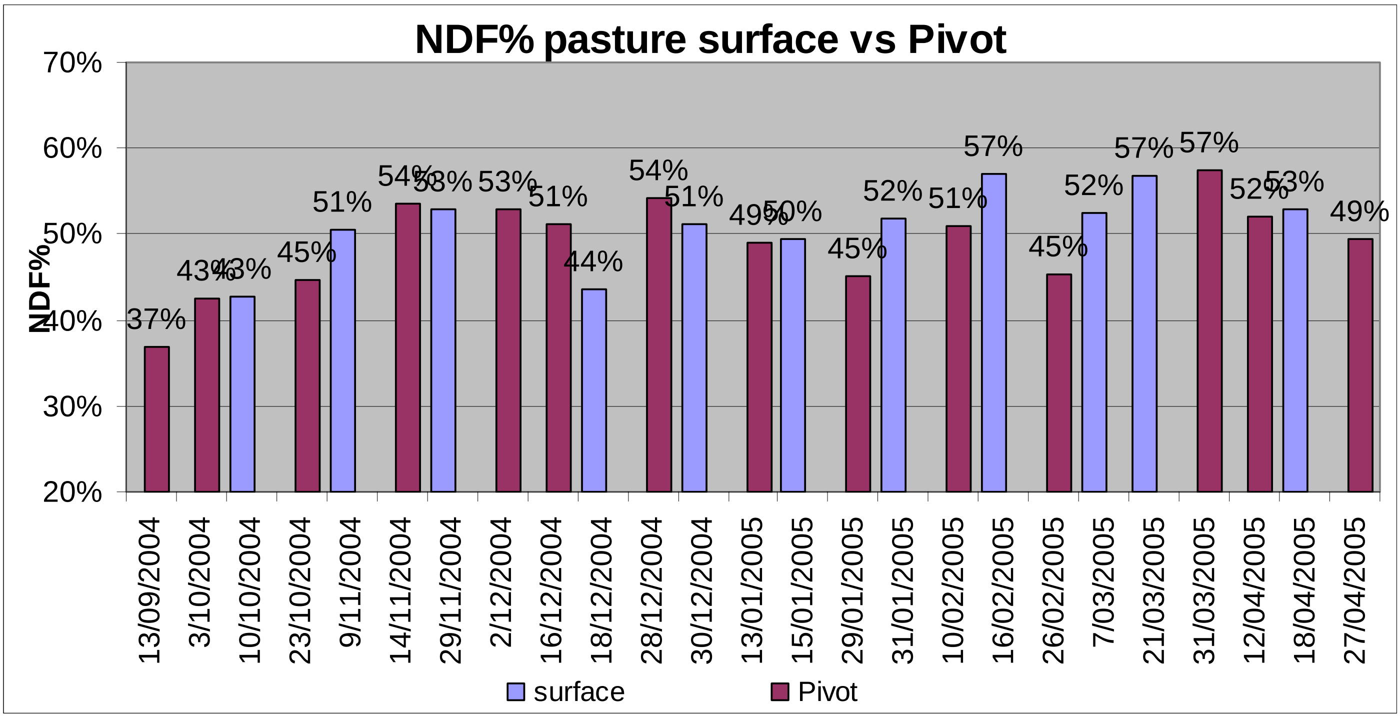
The data for the year is outlined below:

Table 6 Feed test results from both sites.

Sample description	Date	CP	ADF	NDF	MJ of ME
pivot	13/09/04	25.50%		36.80%	12.6
pivot	3/10/04	23.80%		42.50%	12
surface	10/10/04	27.80%		42.70%	11.6
pivot	23/10/04	25.70%		44.70%	11.2
surface	9/11/04	20.40%		50.50%	9.6
pivot	14/11/04	21.80%		53.60%	10.6
surface	29/11/04	20.70%		52.80%	9.8
pivot	2/12/04	21.40%		52.90%	10.4
pivot	16/12/04	16.90%	16.00%	51.10%	11.4
surface	18/12/04	21.20%	18.40%	43.50%	11.3
pivot	28/12/04	24.90%	23.30%	54.30%	10.9
surface	30/12/04	18.80%	21.20%	51.20%	10.8
pivot	13/01/05	19.20%	17.70%	49.10%	11.3
surface	15/01/05	22.70%	25.50%	49.50%	10.5
pivot	29/01/05	23.50%	16.00%	45.00%	11.8
surface	31/01/05	23.80%	23.60%	51.80%	10.8
pivot	10/02/25	20.10%	20.10%	50.90%	11
surface	16/02/05	22.90%	27.10%	57.00%	10.3
pivot	26/02/05	25.00%	17.70%	45.40%	11.7
surface	7/03/05	21.60%	26.80%	52.40%	10.3
surface	21/03/05	25.00%	27.50%	56.90%	10.5
pivot	31/03/05	25.90%	29.60%	57.40%	10.2
pivot	12/04/05	23.80%	25.60%	52.10%	10.6
surface	18/04/05	20.70%	28.00%	52.90%	10
pivot	27/04/05	30.20%	24.10%	49.40%	11.2


MJ of ME pasture surface vs Pivot
MJ of ME/kg DM
13
12
11
10
9
8
13/09/2004
10/10/2004
9/11/2004
29/11/2004
16/12/2004
28/12/2004
13/01/2005
29/01/2005
10/02/2005
26/02/2005
21/03/2005
12/04/2005
27/04/2005
surface
Pivot


CP% pasture Surface vs Pivot
CP%
40%
30%
20%
10%
0%
13/09/2004
10/10/2004
9/11/2004
29/11/2004
16/12/2004
28/12/2004
13/01/2005
29/01/2005
10/02/2005
26/02/2005
21/03/2005
12/04/2005
27/04/2005
surface
Pivot



The reason for the difference in feed quality is probably a combination of 3 main factors:

1. The surface site has far more weed as a percentage of the sward. As weeds are poorer quality than ryegrass/clover the resulting feed tests will be poorer.
2. As the surface site puts more stress on ryegrass/clover due to its cycle of waterlogging and then drying out compared to the pivot plants tend to lignify which increases the fibre level of the plant and reduces its digestibility and hence its energy content.
3. Also due to the waterlogging drying cycle the surface plants did not take up as much nutrient (including nitrate) which resulted in lower crude protein level in the plant and also added to the stress on the plant as mentioned above. (results will be discussed in fertiliser use).

Total metabolisable energy produced.

Due to farmer time constraints, pasture samples were not collected at every grazing. On these occasions the averages of the feed test results before and after were used to estimate the feed quality at the time. These energy levels were then used for each period to calculate the total amount of metabolisable energy produced per hectare for the trial period of 225 days. The estimated energy levels are shaded grey.

Table 7 energy produced on the pivot site.

Date	paddock	growth rate kg DM/Ha/day	pasture grown kg DM	MJ of ME/ kg DM	MJ of ME grown/Ha
12/09/2004	pivot				
1/10/2004	pivot	75	1425	12	17100
21/10/2004	pivot	97	1940	11.2	21728
12/11/2004	pivot	103	2266	10.6	24020
30/11/2004	pivot	135	2430	10.4	25272
13/12/2004	pivot	191	2483	11.4	28306
25/12/2004	pivot	245	2940	10.9	32046
10/01/2005	pivot	140	2240	11.3	25312
26/01/2005	pivot	153	2448	11.8	28886
7/02/2005	pivot	175	2100	11	23100
23/02/2005	pivot	105	1680	11.7	19656
12/03/2005	pivot	77	1309	10.95	14334
28/03/2005	pivot	167	2672	10.2	27254
10/04/2005	pivot	38	494	10.6	5236
25/04/2005	pivot	62	930	11.2	10416
				total	**302667**

Table 8, Energy produced on the surface site.

Date	paddock	growth rate kg DM/Ha/day	pasture grown kg DM	MJ of ME/ kg DM	MJ of ME grown/Ha
20/09/200	surface				
10/10/200	surface	51	1020	11.6	11832
8/11/2004	surface	65	1885	9.6	18096
28/11/200	surface	94	1880	9.8	18424
17/12/200	surface	44	836	11.3	9447
30/12/200	surface	25	325	10.8	3510
14/01/200	surface	57	855	10.5	8978
30/01/200	surface	75	1200	10.8	12960
15/02/200	surface	49	784	10.3	8075
6/03/2005	surface	110	2090	10.3	21527
20/03/200	surface	56	784	10.5	8232
3/04/2005	surface	61	854	10.25	8754
18/04/200	surface	37	555	10	5550
3/05/2005	surface	40	600	10	6000
				total	**141384**

The pivot produced 302667 MJ of ME/Ha compared to the flood producing 141384 MJ of ME/Ha. Assuming cows will utilise 70% of pasture grown they would utilise 211867 MJ/Ha from the pivot site compared to 98969 MJ/Ha from the flood site. This is a difference of 112898 MJ (53%). If we assume that each litre of milk takes 5MJ this is a difference of 22580 litres of milk/Ha.

On average cows produced slightly more milk solids (1.93 for pivot vs. 1.89 for surface). However, the pivot was grazed 15 times compared to the flood being grazed 14 times. On average 1.17 Ha was grazed each time the pivot was grazed compared to a slightly greater area of 1.29 Ha each time the surface irrigation was grazed. The slightly higher milk production per cow (27.1l for the pivot compared to 26.6 l for the surface) and better milk protein% (3.07% m/m for the pivot compared to 3.04% m/m for the surface) could be attributed to the better pasture quality and quantity but other variables such as the day paddock, hay and silage offered and eaten etc could also affect milk quantity and quality.

Grain feeding on average was the same for both paddocks (5.7 kg AF/cow/day) but on average 3.1 bales of silage and 0.6 bales of hay were fed to cows while grazing the pivot compared to the surface bay where 2.9 bales of silage and 0.8 bales of hay were fed. As silage was better quality than hay this could also have caused the difference in milk solids produced.

Table 8 average of hay and silage used during trial

forage	CP	ADF	NDF	MJ of ME
silage	18%	32%	50%	9.8
hay	10%	38%	57%	9.0

Fertiliser use

The amount of fertiliser applied top both sites in kg/Ha are as follows:
Table 9 fertiliser use in kg/ha on both trial sites from Sep 04 to Apr 05

Paddock 29 Surface bay					paddock 41 pivot site				
date	**N**	**P**	**K**	**S**	**date**	**N**	**P**	**K**	**S**
8-Sep-04	35	5	8	5	27-Aug-04	43.75	6.25	10	6.25
6-Oct-04	35	5	8	5	17-Sep-04	61.25	8.75	14	8.75
1-Nov-04	35	5	8	5	01-Nov-04	35	5	8	5
2-Dec-04	30	2	6	5	24-Nov-04	30	2	6	5
15-Dec-04	37.5	2.5	7.5	6.25	06-Dec-04	24	1.6	4.8	4
2-Jan-05	30	2	6	5	18-Dec-04	0	9	4	9
20-Jan-05	58	16	0	0	20-Jan-05	58	16	0	0
14-Feb-05	58	16	0	0	15-Feb-05	58	16	0	0
18-Mar-05	45	14	0	0	18-Mar-05	45	14	0	0
23-Apr-05	34.5	0	0	0	23-Apr-05	34.5	0	0	0
total	**398**	**68**	**44**	**31**	**total**	**390**	**79**	**47**	**38**

The pivot site received 8kg/Ha less nitrogen (2%), 11 kg/ha more phosphorus (14%) 3 kg/Ha more potassium (6%) and 7 kg/Ha more sulphur (18%).

These differences are not considered significant.
Results of tissue testing both sites are as follows:

Table 10, tissue test results from both sites.

date	**pdk No**	**CP%**	**N**	**NITRATE**	**PHOS**	**K**	**S**	**Na**	**Ca**	**Mg**	**Cl**
10/11/2004	pivot	27.8%	4.44	52	0.421	3.029	0.452	0.571	0.844	0.357	1.949
16/02/2005	pivot	26.8%	4.29	1906	0.339	3.56	0.373	0.469	0.397	0.324	2.161

date	pdk No	CP%	N	NITRATE	PHOS	K	S	Na	Ca	Mg	Cl
10/11/2004	surface	26.5%	4.24	53	0.464	2.978	0.438	0.624	0.494	0.348	2.151
16/02/2005	surface	21.5%	3.44	66	0.347	1.805	0.318	0.675	0.743	0.4	2.36

Of the major nutrients, only potassium and nitrogen levels differed markedly in the February test. The high nitrate level in the pivot in February may have been due to fertiliser being applied 2 days previously on the pivot site compared to only 1 day prior on the surface site. This could then have an influence on potassium uptake as the plant would have to take up a cation to balance the negatively charged nitrate. 1 day would not have been enough time for the nitrate to be taken up from fertiliser application.

Other reasons that Nitrate and crude protein levels are higher for the pivot site could be due to better mineralisation occurring in the pivot site compared to the flood site. This is mainly due to the flood site going through a waterlogging and drying cycle, which restricts soil microbial action and hence mineralisation compared to the pivot site where readily available water is maintained in the soil through best practice irrigation frequency and application allowing for constant soil microbial action and mineralisation.

Comparisons of different irrigation paddocks

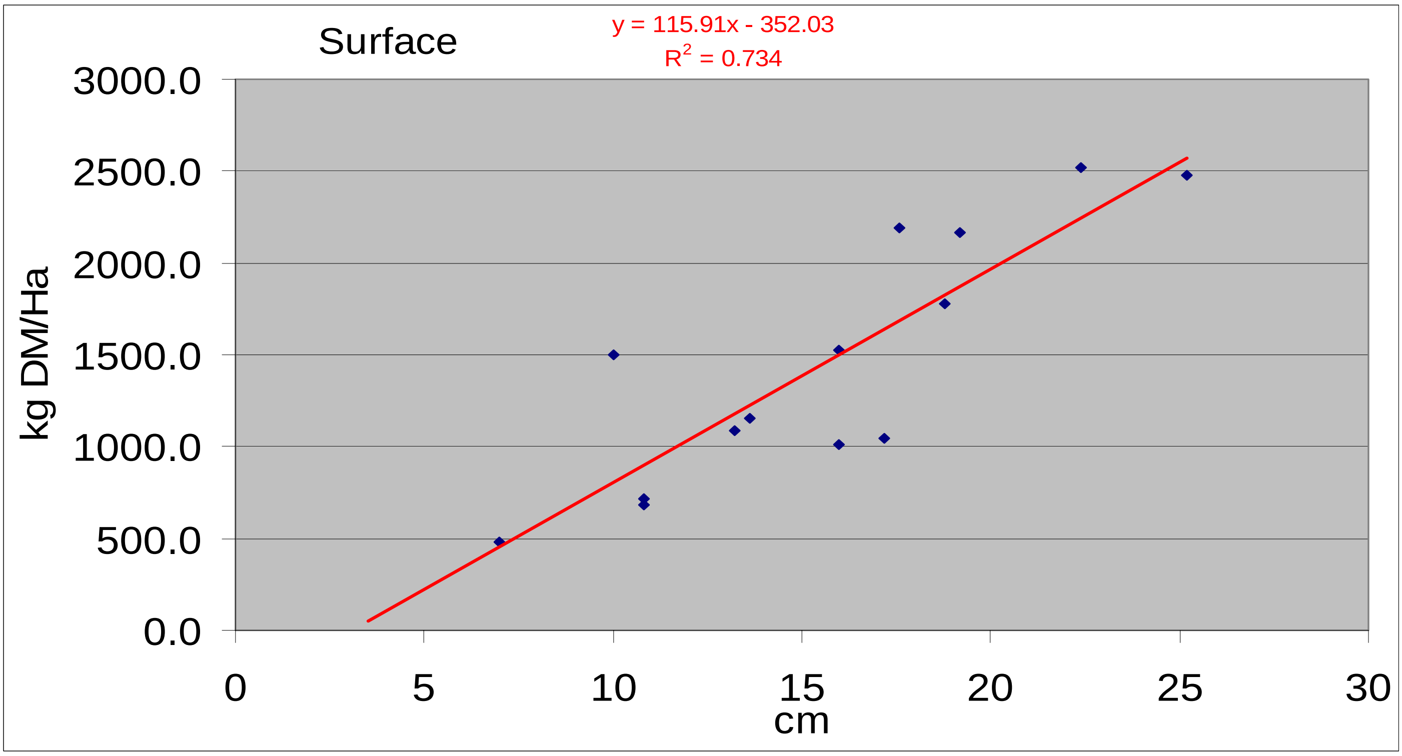
Table 11, growth rates of various irrigated paddocks in summer.

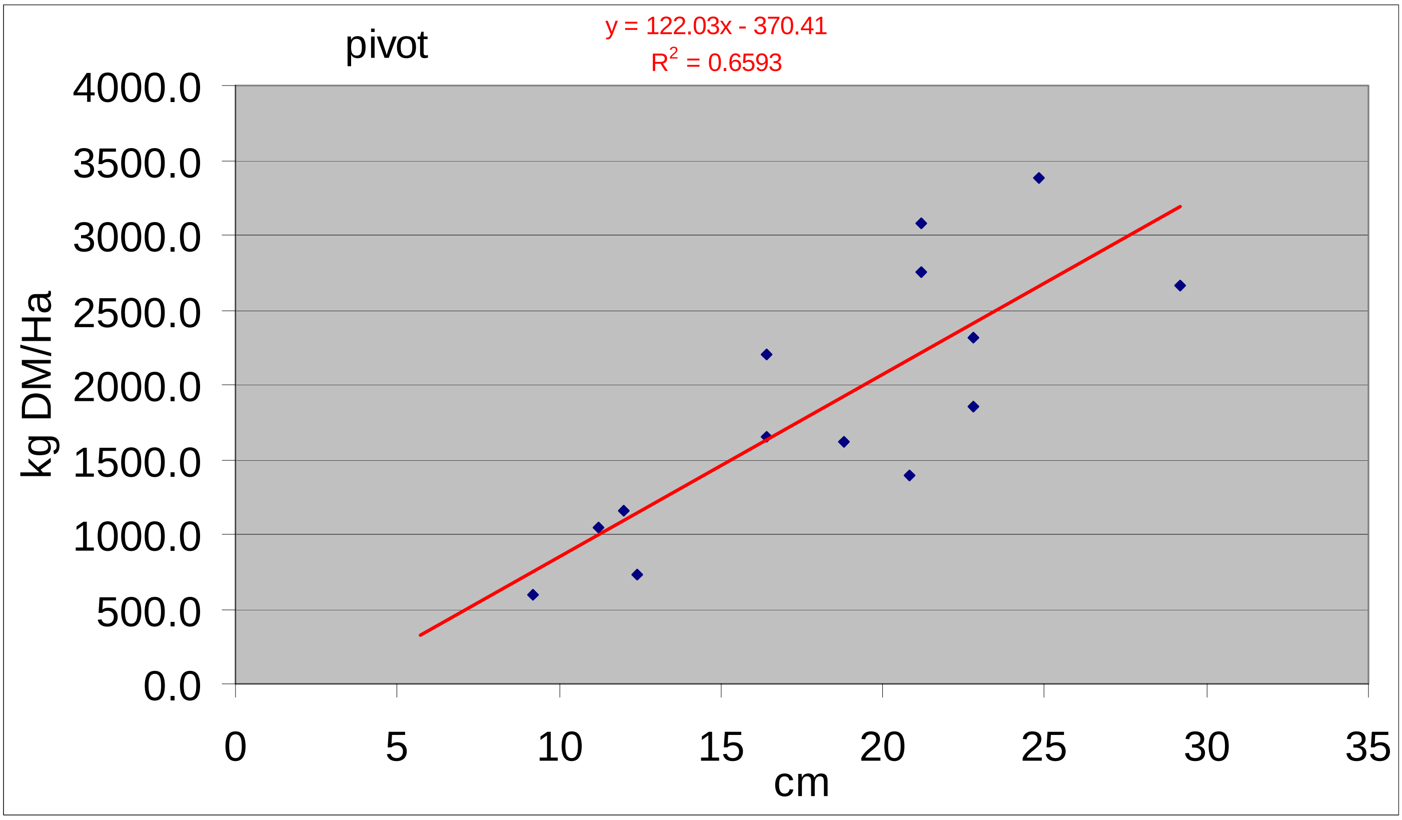
paddock name	predominai pasture typ	date of measuremei	date of measurement	GR	ranking
pivot	**ryegrass**	**29/01/2005**	**7/02/2005**	**175**	**1**
19	kikuyu	21/01/2005	7/02/2005	109	2
21	kikuyu	17/01/2005	2/02/2005	92	3
4&5	kikuyu	17/01/2005	27/01/2005	85	4
20	kikuyu	28/01/2005	7/02/2005	78	5
6	kikuyu	17/01/2005	2/02/2005	75	6
29S	**ryegrass**	**15/01/2005**	**30/01/2005**	**75**	**7**
10	millet	25/01/2005	4/02/2005	74	8
46	ryegrass	14/01/2005	25/01/2005	68	9
29N	ryegrass	25/01/2005	11/02/2005	52	10
29M	ryegrass	28/01/2005	11/02/2005	52	11
16	kikuyu	28/01/2005	7/02/2005	23	12
15	kikuyu	17/01/2005	2/02/2005	18	13

As can be seen from the above table the pivot site was the best performed paddock at the time. The surface irrigation site was ranked number 7 but was the best performed surface irrigation bay with ryegrass as the predominant pasture species. Kikuyu, being a tropical C4 plant, would be expected to have higher growth rates than ryegrass in summer. Kikuyu also made up a fair proportion of the pivot site which would have greatly contributed to the high growth rates achieved on this site.

Calibration of rising plate meter.

Bellow are the two graphs used for calculating the growth rates on the pivot and surface site.




pivot
y = 122.03x - 370.41
R2 = 0.6593
kg DM/Ha
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
0
5
10
15
20
25
30
35
cm

APPENDIX 4: RUN-OFF AND DEEP DRAINAGE, 2003-04

1 Methodology

The research protocols for this work were developed by members of the Department of Agriculture, Nutrient Management Project, who have extensive experience in the development of farm and catchment-scale research and monitoring programs for water and nutrients as well as in best management practice development. The research has also been subject to formal peer review and approval via the Department's Research Quality Management System.

1.1 Surface water quality and flow data

Surface water sampling at the site is being undertaken through the use of two ISCO 6712 automatic water samplers which were installed on the farm at the sites shown in Figure 1.

Sampler 1 is located on the tail drain of the surface irrigation bay and has collected runoff from eight irrigation events in summer and runoff from rainfall events during winter. Sampler 2 is located in a surface drain to the north west of both the surface and centre pivot irrigation sites and collects winter runoff from a significant portion of the farm as well as any excess irrigation from the centre pivot or early-germination irrigation from another surface irrigation bay (not monitored) on the farm. Both sites were set up with 6 inch Parshall flumes as flow control devices (see figures 6 and 7).

Water passing along the drains at the monitoring points adjacent to the autosamplers is forced through the Parshall flumes which have a stilling well attached. An air line is connected to the stilling well below the level of the water and runs to the autosampler. The autosampler records the pressure required to force air through the air line every minute and converts this to a water level reading using the on-board ISCO bubbler flow module. This data is then converted to flow data using an algorithm which considers the geometry and flow characteristics of the Parshall flume. Data is downloaded from the autosampler fortnightly using an ISCO 581 Rapid Transfer Device. Level data is then converted to flow data using the ISCO Flowlink 4.15 software.

The water level data which is being constantly monitored by the ISCO flow module is also used as the trigger for the initiation of water sampling by the autosampler. During irrigation events, 10 samples are taken by the autosampler at half-hourly intervals during the first five hours of the irrigation event, with 14 more samples then taken at hourly intervals. There have been some variations in hydrographs for different irrigation events, so sampling protocols have been somewhat adaptive over the course of the monitoring so far. Similarly, the sampling protocol to be used next season will be adapted from the results of this present analysis.

Samples are collected and chilled before shipment to the analytical laboratory for analysis for total nitrogen, total phosphorus and a range of standard physico-chemical parameters. Samples taken more recently are also being analysed for fractionated phosphorus (soluble and particulate).

It is also important to note that similar studies to those described above are being undertaken on three other irrigated dairy farms through the closely-associated DairyCatch Project and also at the Harvey Campus of the WA College of Agriculture.

Figure 6: 6" Parshall Flume installed at Sit (surface irrigation)

Figure 7: ISCO 6712 Automatic water sampler

These additional sites will provide essential comparative data allowing more detailed analysis of data from the Hanks' property.

1.2 In-bay surface irrigation water movement

In addition to monitoring of the runoff quality and quantity from the surface irrigation bay as described above, the progress of water across the surface of the bays was also measured and samples taken following the progress of the wetting front down the bay on two occasions.

1.3 Soil surveys

Detailed soil/nutrient surveys have been undertaken at the property by staff of DAWA's Natural Resource Assessment Group. This will allow mapping of nutrient distributions throughout the property, identification of locations of high nutrient flux and the development of nutrient budgets based on soil characteristics and plant requirements. Analyses of the soil samples are presently being undertaken by the Chemistry Centre of WA, following which a Technical Bulletin will be published discussing the analysis results, as well as the production of nutrient budgets and GIS overlays described above (see draft technical bulletin at Appendix 3).

As with the water quality monitoring described earlier, similar studies are being undertaken on other dairy farms through the associated DairyCatch project to provide comparative data.

Additionally, RAW values have been calculated for all soil horizons at all soil sample sites under the Centre Pivot. These are being used in planning. scheduling and modeling irrigation at this site and are shown in Table 10.

Table 20 : RAW values for soil samples under centre pivot irrigation

1.4 Groundwater monitoring

	DATA ENTRY IN THESE COLUMNS ONLY				Selected kPa 60 kPa		
Horizon	Lower depth	Texture	Gravel %	Root factor	corrected RAW mm/m	RAW (mm)	Cumulative RAW (mm)
	WCC1358 - CP1						
1	10	l	0%	100%	84.00	8	8
2	15	l	0%	100%	84.00	4	13
3	20	l	0%	100%	84.00	4	17
4	25	l	0%	100%	84.00	4	21
5	50	cl	1%	100%	64.35	16	37
6	70	lmc	2%	100%	55.86	11	48
7	95	mc	3%	100%	55.29	14	62
8	100	hc	5%	100%	38.95	2	64
9	110	hc	5%	100%	38.95	4	68
10			0%	100%			
	WCC1359 - CP2						
1	10	cl	1%	100%	64.35	6	6
2	20	lc	2%	50%	27.93	3	9
3	25	lc	2%	50%	27.93	1	11
4	50	mc	10%	100%	51.30	13	23
5	85	mc	10%	100%	51.30	18	41
6	100	hc	10%	100%	36.90	6	47
7			0%	100%			
8			0%	100%			
9			0%	100%			
10			0%	100%			
	WCC1360 - CP3						
1	10	scl	0%	100%	71.00	7	7
2	15	scl	2%	100%	69.58	3	11
3	20	lmc	5%	100%	54.15	3	13
4	25	lmc	5%	100%	54.15	3	16
5	40	lmc	5%	100%	54.15	8	24
6	50	mc	2%	100%	55.86	6	30
7	70	mc	0%	100%	57.00	11	41
8	100	mc	0%	100%	57.00	17	58
9			0%	100%			
10			0%	100%			
	WCC1361 - CP4						
1	10	cl	0%	100%	65.00	7	7
2	15	cl	0%	100%	65.00	3	10
3	20	lc	0%	100%	57.00	3	13
4	25	lc	0%	100%	57.00	3	15
5	50	hc	0%	100%	41.00	10	26
6	60	hc	0%	100%	41.00	4	30
7	80	hc	0%	100%	41.00	8	38
8	100	hc	0%	100%	41.00	8	46
9			0%	100%			
10			0%	100%			
	WCC1362 - CP5						
1	10	cl	0%	100%	65.00	7	7
2	20	cl	0%	100%	65.00	7	13
3	25	lmc	1%	100%	56.43	3	16
4	40	lmc	1%	100%	56.43	8	24
5	50	lmc	2%	100%	55.86	6	30
6	80	lmc	2%	100%	55.86	17	47
7			0%	100%			
8			0%	100%			
9			0%	100%			
10			0%	100%			
	WCC1363 - CP6						
1	10	lscl	0%	100%	74.00	7	7
2	15	lscl	0%	100%	74.00	4	11
3	20	scl	0%	100%	71.00	4	15
4	25	scl	0%	100%	71.00	4	18
5	40	scl	0%	100%	71.00	11	29
6	75	lc	1%	100%	56.43	20	49
7	100	lmc	10%	100%	51.30	13	61
8			0%	100%			
9			0%	100%			
10			0%	100%			

Equipment and staffing problems did not permit the installation of groundwater monitoring bores at the centre pivot site as was initially planned. This will be undertaken as soon as the site can be accessed and water tables drop at the conclusion of winter rains.

2 Results

2.1 Surface water quality and flow data

2.1.1 Flow data

Water level data recorded at the surface irrigation site during the course of the monitoring program can be seen in Figure 8. Figure 9 shows the data recorded during the irrigation season at the site.

Runoff from seven full irrigations was measured through the flume with the flume depth (400mm) being exceeded during one event (17 February 2004).

The taildrain downstream of the flume was occluded by weeds for much of the monitoring period due to problems in scheduling in the work required to clear these weeds from the perspective of both the research staff and the land manager. This may have resulted in the "submergence" of the flume at certain times (although not during the maximal flow periods following irrigation). Flume submergence occurs when water movement downstream of the flume is being retarded by an insufficient fall in the drain or (as in this case) occlusion of the drain by weeds or other obstructions. If water is not flowing freely through the flume and the downstream head is artificially elevated, then the flume geometry is not working as it should. This will influence the validity of level to flow conversions for the Parshall flume. As can be seen from Figure 9 periods between irrigation events still exhibit level data in the flume. This indicates either that water was still flowing through the flume, or that water remained pooled in the drain around the flume. It is more likely in most of these instances that water was pooling because of the downstream weed problem.

In order to compensate for the possibility of pooling around the flume and subsequent submergence, a series of alternative flow calculations have been made based on a series of level corrections for the level data. These are shown below in Table 11.

Table 11 : Drainage losses from surface irrigation site

Entire monitoring perio			
	Measured drainag (ML)	Irrigation input (Ml	Net loss
Uncorrected level data	98.59	94.75	104%
Corrected @ 0.013m	84.20	94.75	89%
Corrected @ 0.026m	71.47	94.75	75%
Corrected @ 0.038m	61.45	94.75	65%

This data highlights the sensitivity of flow structures such as flumes to the correct calibration of the base flow.

78.96ML +/-20% was applied as irrigation supply water to the surface irrigation site during the monitoring period.

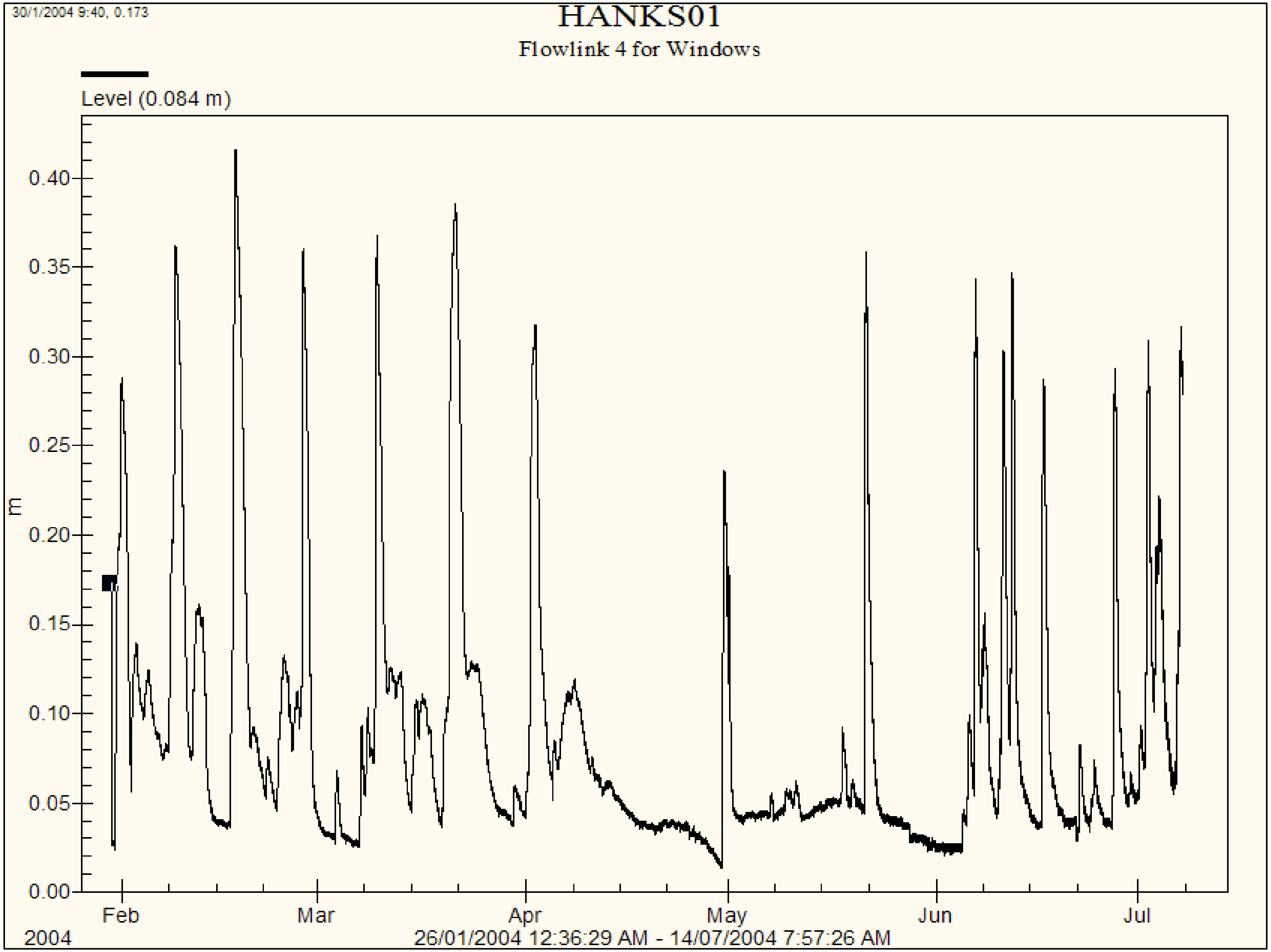


Figure 8: Water level recordings for surface irrigation bay

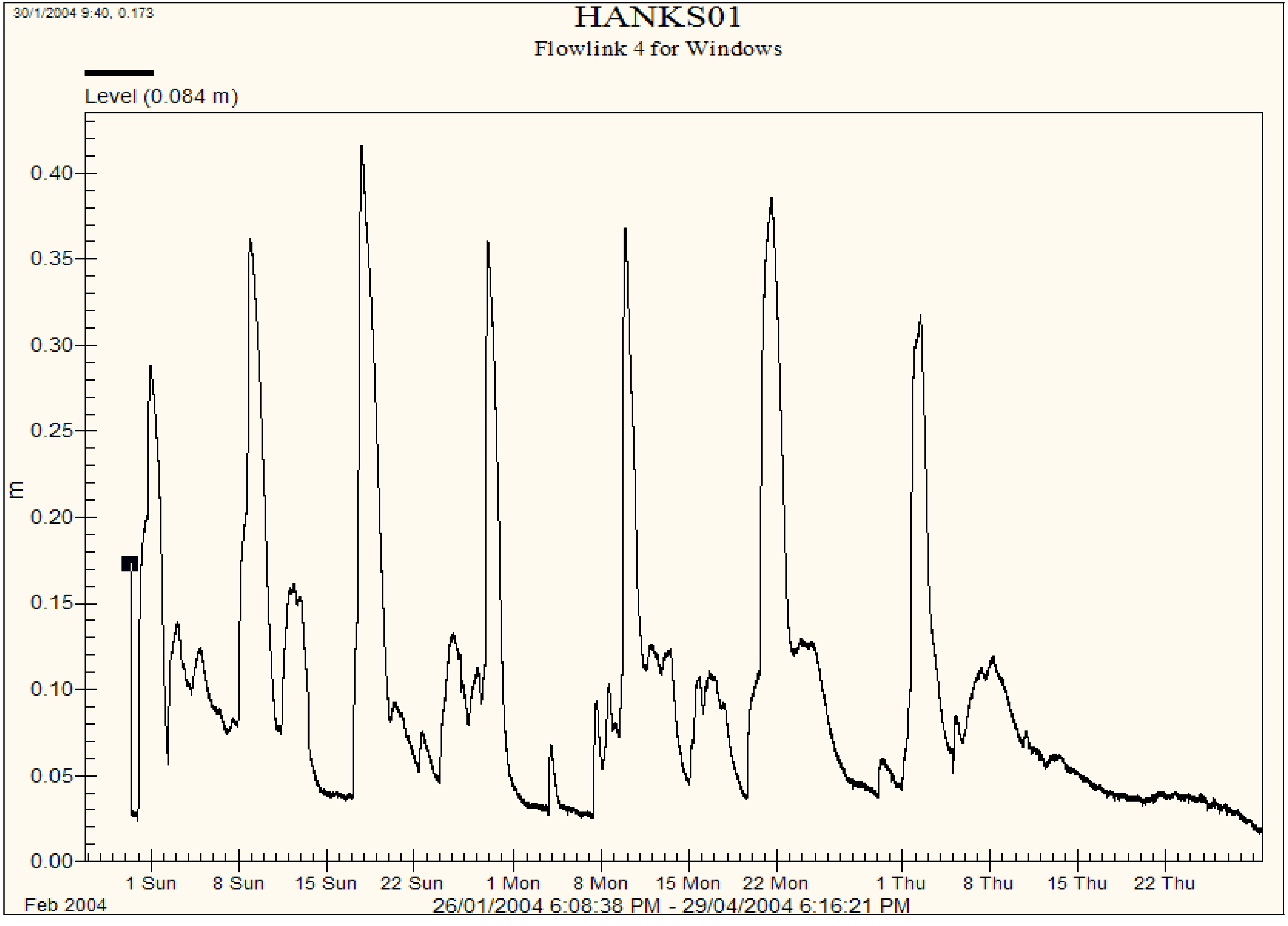


Figure 9: Water level recordings for surface irrigation bay

Data corrected at 0.038m effectively assumes that all non-peak flow during the irrigation event is affected by flume submergence and (in this case) is to be disregarded and there is no flow. (That is, all flow data is rejected when the water level is 3.8cm or less). Assuming this "worst case" scenario the seasonal efficiency of the surface irrigation system is 35%. That is, of a maximum of 95ML of water applied over the monitored period, 61ML left the study area as runoff. The uncorrected data actually indicates that more water left the study area than was recorded as being applied.

Other potential issues that influence the validity of this data are the accuracy of the data supplied by Harvey Water for irrigation supply volumes and the efficiency and condition of the water distribution systems. There are anecdotal reports of inaccurate Dethridge wheels and leaky channels, both of which will affect this data. Harvey Water have stated that the Dethridge wheels have an accuracy of +/- 20% when working efficiently and tend to err on the side of underestimating water flow.

An independent technical review of the surface irrigation bay by Dr Steven Raine (see Appendix 1) identified concerns with the accuracy of the measurement of inflow and its applicability for performance evaluation purposes.

However, in the "worst case" described above we can assume that the surface irrigation system at this property is 35% efficient at best. Again, anecdotal evidence supports this with reports that water enters the tail drain at almost the same time as irrigation commences at the top of the bays. This suggests a saturated soil profile with increases in hydraulic head at the top of the bays forcing water through the profile and into the taildrains.

The duration of the hydrographs for individual irrigations (Figure 9) also supports this. The typical duration of an irrigation event is 18 hours for the three irrigation bays measured together via the autosampler. However, the typical duration of runoff from these events is four days which includes a peak flow of approximately 12 hours with and extended "tail" of two more days. Also, each hydrograph also exhibits a further, secondary flow event of up to 5 more days duration.

2.1.2 Water quality data

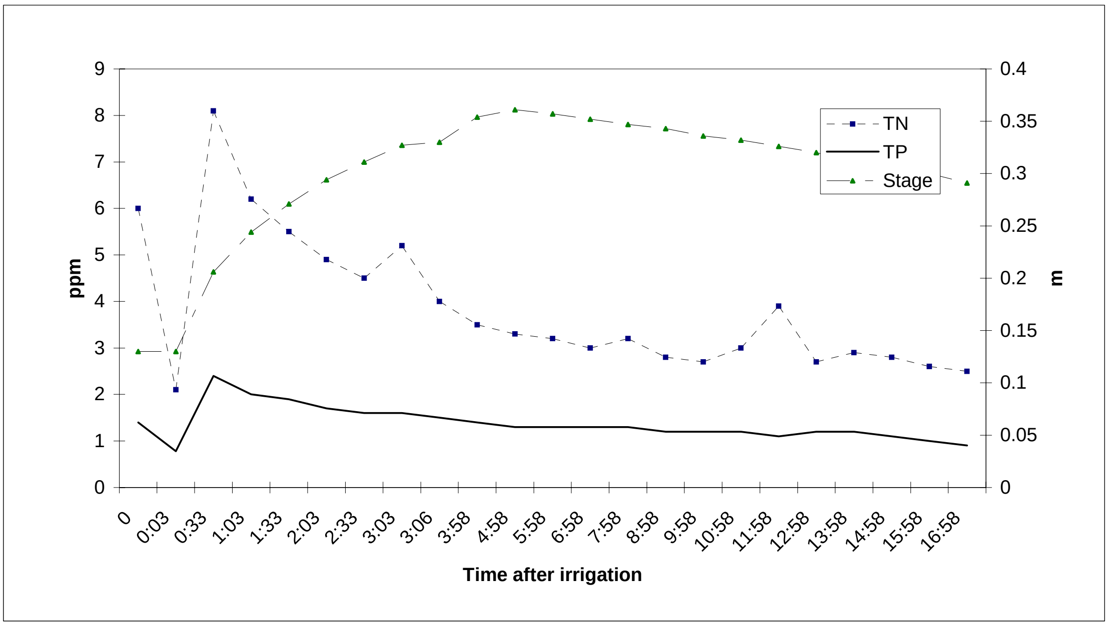


Figure 10: Water quality and flow through surface irrigation bay during irrigation

Only limited water quality data has so far been returned from the analysis laboratories, so no firm, overall conclusions are yet available. Figure 10 (above) however illustrates the nutrient concentrations in drainwater collected during an irrigation event. Peak water flows in this instance occurred approximately 5 hours after water first reached the drain measurement point. However, peak nutrient concentrations (8ppm and 2.5ppm for nitrogen and phosphorus respectively) occurred prior to this approximately 30 minutes after the start of drainage flows through the flume. This illustrates the importance of the “first flush” effect of irrigation-driven nutrient export from irrigated properties. Because of the submergence problems with the Parshall flume at Point 1 (mentioned previously) and subsequent flow-triggered water sampling issues, the actual first flush may still have been missed. To overcome this possible issue and to allow correction of the current data, a second automatic water sampler will be located at point 1 at the commencement of next irrigation season. Two samplers will then be used in parallel to allow long-term, high-frequency sampling over a full 10 day irrigation cycle.

Drain nutrient levels appears to be of the order of 3ppm nitrogen and 1.5ppm phosphorus with peaks of up to 8ppm and 2.5ppm measured for nitrogen and phosphorus respectively. These levels are not unexpected in drains of this type and are similar to nutrient levels expected in similar, dryland drains during winter. (Winter data is presently being collected and will be reported on subsequent to this report).

In-bay water quality data
Figures 11 and 12 show the concentrations of nutrients in water moving over the surface of the irrigation bay during two irrigation events.

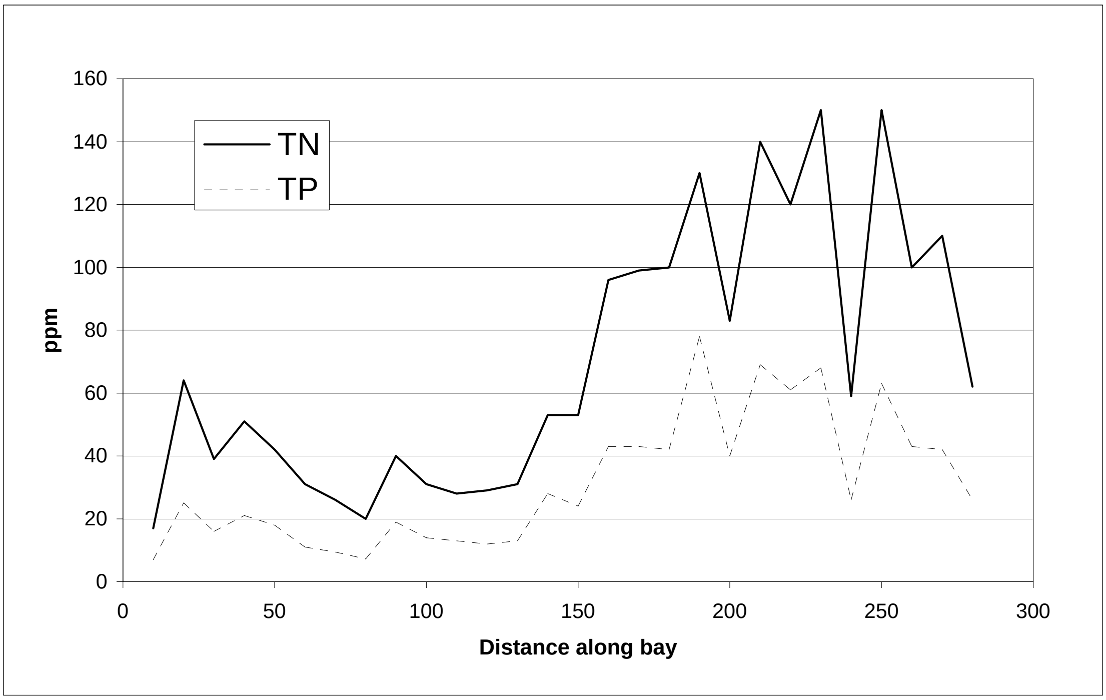


Figure 11: Bay nutrient concentrations, 8 February 2004 irrigation

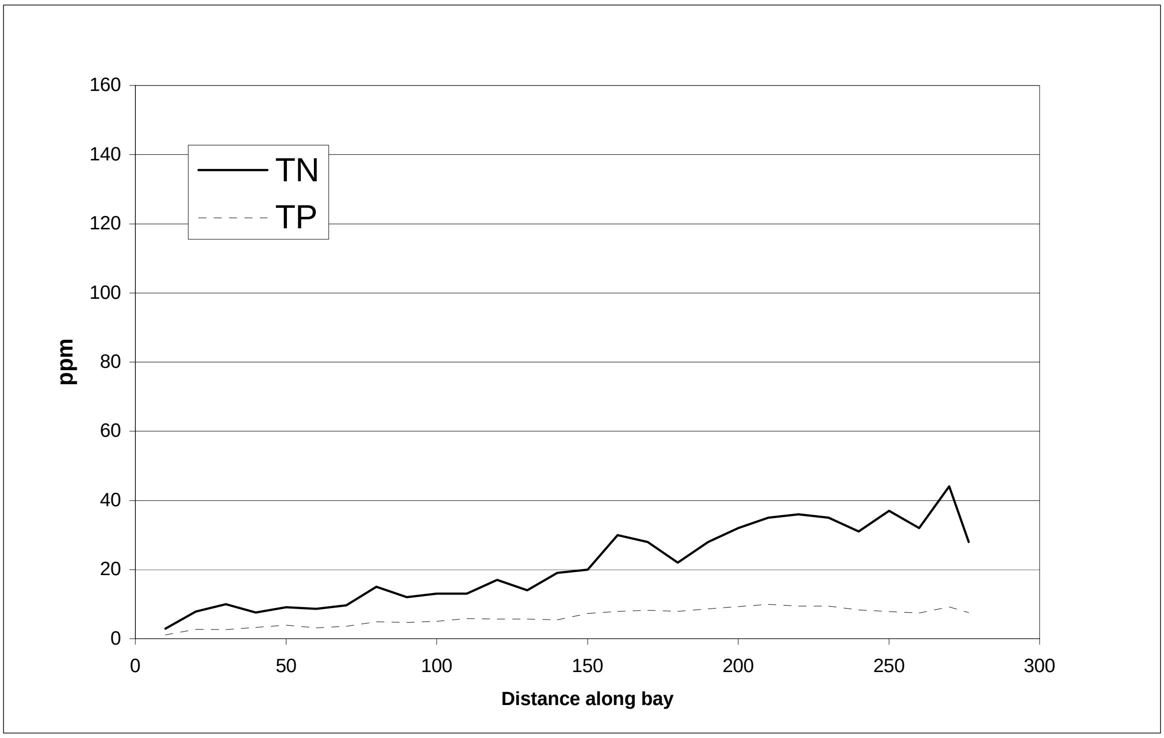


Figure 12: Bay nutrient concentrations, 9 March 2004 irrigation

Nutrient concentrations measured at the bay scale and in water moving directly over the soil surface exhibit very high nutrient levels which increase towards the bottom of the bays. Nutrient concentrations for the irrigation event monitored on the 8th of February, 2004 (Figure 11) exhibit maximum levels of 150ppm and 78ppm for nitrogen and phosphorus respectively. The concentrations for these two nutrients in water collected in March (Figure 12) show maxima of 44ppm and 9.9ppm. Fertilization of the bays took place 16 days before the February event and 20 days after the March event. Grazing data has not yet been examined to determine correlations between time of grazing and runoff water quality.

In the coming season, we will sample soil-water below the active root zone to evaluate nitrate losses into groundwater. Water will be sampled with piezo tubes and tested using nitrate strips. If the data indicates a significant difference in deep drainage (leaching) losses along the bay length, then soil nitrate measurements will be taken at various locations along the bay length. The measured soil solution concentrations and deep drainage losses will provide the basis for calculating the nitrate losses.

3. Conclusions

Although there are some difficulties with the first season's data, some conclusions may be drawn from the limited dataset available so far:

- Problems with flume installation and drain occlusion at the surface irrigation bay have compromised the water level and, therefore, flow data. This will be corrected for the next irrigation season.

- Despite these problems, and after a liberal correction for flume submergence, the surface irrigation site appears to lose approximately 65% of the applied irrigation water as drainage via surface flow. No surface runoff was measured from the centre pivot site during the same period.

- Drain water quality measured at the surface irrigation bay exhibits a typical "first flush" pattern of elevated nutrient concentrations following the onset of irrigation. Nutrient levels then return to levels which are typical of dryland drains in this region.

- Nutrient loads (expressed as kg of nutrient, or kg of nutrient/ha/yr) are currently being calculated. This will give some indication of the financial value of the lost nutrients as well as an indication of the nutrient loading supplied to the downstream receiving environment.

- Extremely high levels of nutrients have been measured in surface water flowing across irrigation bays. These increase towards the bottom of the bay as more nutrients are dissolved into or suspended by the advancing irrigation front. Although this dataset is limited, these concentrations appear to decrease with increasing time after the application of fertiliser to the bays.

- Similarly, although taildrain water quality is not as poor as water moving across the actual irrigation bays, taildrain water quality also improves with increasing time after the application of fertiliser to the trial site.

- These findings highlight the importance of in-paddock water and nutrient management practices in terms of improving water and nutrient use efficiency. Nutrients lost to excess drainage water are likely to be severely restricting agricultural production at the surface irrigation site as well as contributing to downstream eutrophication issues and wasting expensive fertiliser.

APPENDIX 5: INDEPENDENT REVIEW OF SURFACE BAY

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September 2004

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Background

Land and Water Australia, Harvey Water and other collaborators have provided funding for the Western Australia Department of Agriculture led project "Changing irrigation systems and practices in the Harvey irrigation area (SOU3)". At the request of the project team, a review of the current bay irrigation trial site and measurement protocol was undertaken by Dr Steven Raine. The surface and centre pivot irrigation trial sites were visited on the 1st September 2004. Discussions regarding the operation and management of the surface irrigation practices were held both at the site and as part of the subsequent review meeting with members of the project team.

Current Trial Site

The surface irrigation trial site consisted of three adjacent bays each 60 m in width and approximately 300 m in length. The bay length of this site is not excessive for the district but discussions with other growers indicated that average bay lengths would more typically fall within the 150-200 m range. However, the bay width at this site is not common in the district with a width of 30-33 m appearing to be almost universally adopted throughout the area. This difference in bay width is not regarded as serious as many irrigators commonly irrigate two or three bays at a time resulting in inflow rates per unit width similar to those likely to be achieved at the trial site.

Surface irrigation performance measurements had been taken on several occasions during the previous season by Department of Agriculture staff. These measurements were undertaken on the middle of the three bays which had been irrigated under commercial conditions. The site inspection revealed serious concerns regarding the accuracy of the measurement of inflow, and its applicability for performance evaluation purposes, the appropriateness of the bay selected for evaluation, and the nature of the supporting measurements being undertaken to evaluate irrigation impacts on pasture production and nutrient movements.

Inflow measurements had been taken using the dethridge wheel operating off the supply channel adjacent to the first bay. The dethridge wheel (with unquantified accuracy) discharges directly into the head channel which suffers from significant tunnel failure resulting in losses estimated at up to 20% by the operator. The middle bay selected for the irrigation performance measurements in the previous season is atypical in that it consists of two discrete sections of bay separated by a laneway. The first section of the bay is approximately 50 m in length and is connected to the subsequent bay section (~270 m) by four pipes (~225 mm diam). Advance measurements had been undertaken only on the second section of bay length and demonstrated a linear advance trajectory normally associated with an increasing rate of inflow during the irrigation event. An increasing discharge into the second bay section is most likely associated with an increasing head of water in the upstream bay created by the hydraulic resistance of the connecting pipes. These characteristics make this bay inappropriate for performance evaluation measurements.

Run-off measurements are currently taken using a tail-drain flume collecting run-off from the three bays. This measurement would be appropriate for calculating the volume balance from all bays but is inappropriate both for measurement of run-off from a single bay or inclusion in the calculation of the infiltration characteristics for the field.

Recommendations

Bay selection

Of the three bays currently being evaluated at the site it would seem that the bay closest to the water supply intake point is the most appropriate. Consideration should be given to more accurate measurement of the inflow discharging into the field. It is inappropriate to use the dethridge wheel measurements at the site while significant leakages are occurring from the head channel. Similarly, it may be difficult to accurately measure the discharge through the two bay inlet boxes.

This site does have access to the pressurised water supply pipeline immediately adjacent to the existing intake point. The most appropriate option would be to install an off-take point onto this supply line and use layflat fluming to supply the water across the head end of the bay. This could utilize either the existing metering at the site or alternatively involve the installation of a separate meter on the off-take line. It would be necessary to include appropriate pressure reduction (eg. a head box or pressure reduction valve) and flow control fittings consistent with the layflat fluming specifications. Based on some preliminary analysis it should be possible to use the available 14 inch layflat fluming to discharge 140 L/s via 50 mm outlets (ie flexiflume outlets with the variable black centre removed) spaced at 1.4 m along the fluming. A total energy head of approximately 1.8-2.0 m will need to be supplied at the inlet end which will transfer into approximately 1.5 m of velocity head and 0.35 m of pressure head within the layflat fluming on entry. Pressure head at the last outlet (60 m downstream in the layflat fluming) during operation should be ~ 0.3 m.

Water Advance Measurements

The advance of water along the bay length should be measured during each irrigation at a minimum of five evenly spaced locations along the bay. The first measurement should be taken within 20 m of the inlet. Consideration should be given to ensuring consistency of installation and measurement height due to the microtopographic variations within the bay. Measurements can be undertaken either manually or using a timed/logged sensor. If there is significant variation in advance across the bay width then consideration should be given to measuring advance at, say 3 points, across the bay at each measurement location down the bay length.

Depth of Flow
The maximum depth of water flow during the irrigation event should be measured within 20 m of the inlet end of the bay. This measurement is required as an input to the infiltration characteristic calculation. The depth of flow measurement also enables calculation of the hydraulic resistance to flow (mannings n) value which should be related to the length of pasture and unevenness of the surface.

Run-off Measurement
The location of the flume currently being used to measure the runoff hydrograph means that this data is not able to be used as an input into either the calculation of the infiltration characteristic or as a validation of the simulated irrigation event. While it is not essential, consideration should be given to measuring the runoff from the individual bay on which inflow and advance are measured. All of the outflow should be channeled through the flume and hydrograph recorded.

Soil-Moisture
The site is currently being monitored using Enviroscan capacitance sensors located approximately two-thirds of the distance down the bay length with sensors located at depths up to 50 cm. The Enviroscan should be located in the bay which is subjected to the irrigation measurements. As the trial progresses and depending on the irrigation performance evaluations, consideration should be given to relocating the sensors into sites which target either zones of excessive waterlogging (i.e. close to the inlet end) or moisture deficit (ie. towards the end of the bay) to enable comparison of the soil moisture extraction patterns with the pasture responses to these stresses.

Pasture Growth Measurements
Assuming adequate measurement of the irrigation performance, it is envisaged that it will be possible to accurately calibrate and simulate the surface irrigation model to enable comparisons of irrigation performance under a range of bay design and operating conditions. However, as a major driver to grower adoption of improved practices in this area will be the pasture production response and profitability implications, there is a need to collect some data on the impact of waterlogging, nutrient depletion and/or moisture stress on pasture growth responses. It is suggested that consideration be given to collected data which provides both the ability to benchmark the pasture performance of the current trial site as well as identify pasture growth response to the specific stresses imposed by bay irrigation. Measurements could include:

- Rising plate measurements taken on all (or a significant proportion of) bays around the farm at early, mid and/or late periods during the season. Measurements would taken both after cattle have been removed and prior to them going back into specific bays. This data would provide a basis for the benchmark comparison of the pasture performance between the trial site and other bays one the farm and provide an objective basis for comparison with the centre pivot pasture production responses.
- Rising plate measurements and growth rate observations taken at daily (or two/three daily) intervals during a single irrigation cycle on the instrumented bay. Measurements should be taken at multiple distances along the bay length (ie minimum top, middle, bottom of bay) to enable the identification of any differences due to variations in waterlogging, nutrient leaching or moisture stress. Ideally, at least one of the measurement points should be located near the Environscan sensors to enable comparison with soil moisture measurements. Consideration should be given to repeating these measurements at different times (ie early, mid and late) during the season.

Nitrate Losses

Some water sampling for nitrate has previously been undertaken to assess the movement of nitrate in the surface water flows across the bay. Consideration should be given to sampling soil-water below the active root zone to evaluate the nitrate losses into groundwater associated leaching due to irrigation practices. If a shallow perched water table is present at the trial site, water can be sampled directly from piezo tubes and tested using nitrate test strips. If a shallow water table is not present at the site, ceramic suction samplers can be used to extract soil-water for testing. If the irrigation performance evaluation indicates a significant difference in deep drainage (leaching) losses along the bay length then consideration could be given to taking soil-solution nitrate measurements at various locations along the bay length. The measured soil solution concentrations and deep drainage losses calculated from either the volume balance calculations (whole bay) or simulated irrigations (specific points along bay) will provide the basis by calculating the nitrate losses.

Shallow Groundwater Measurements

These measurements are not needed for the simulation of the irrigation events or performance evaluation but do provide direct confirmation of deep drainage losses due to irrigation practices. Measurements of shallow (<1.5 m) groundwater levels could be taken by installing peizo tubes either at a single or multiple points along the bay length. Manual measurements at regular intervals during the irrigation season will provide data to confirm the impact of irrigation practices on deep drainage. Logged measurements taken during several irrigation cycles would provide data on the rate of groundwater accessions and transmission rates within the soil and substrata.

APPENDIX 6: SOIL SURVEY, HANKS DAIRY FARM

Resource Management Technical Report:
SOIL SURVEY OF HANKS DAIRY FARM, GOVERNMENT ROAD, HARVEY

AUTHORS: Tilwin Westrup, Peter Tille
Research Officers, Natural Resource Management, Bunbury

April 2004

Disclaimer:

The contents of this report were based on the best available information at the time of the publication. Conditions may change over time and conclusions should be interpreted in the light of the latest information available.

Department of Agriculture
Government of Western Australia

Summary
A detailed soil survey was completed on Dale and Leanne Hanks' property at Harvey, Western Australia. This property is the Dairy Catch monitor farm for the Western Australian Farmers Federation Harvey Zone

The key results of the soil description survey are as follows; Approximately 140 hectares (98% of the property) is cleared and identified as being suitable for grazing cattle, though irrigation is necessary to maintain pasture production over summer. The dominant soils are loamy earths associated with alluvial flats.

The main mechanism for nutrient export from this property is through surface flow of water from the floodbays. Managing flood irrigation to minimise waterlogging and runoff from floodways will minimise this risk.

Context
The survey was conducted as part of the "Dairy Catch" project, with three key aims;

- To provide a detailed soil description to add to information associated with the environment in which the dairy industry in Western Australia is located.
- To collect soil samples at predetermined standard depths from documented locations on the farm for the purpose of nutrient analysis.
- To map soils with like characteristics based on the soil description and analysis.

This report describes, maps and documents the soils found at Hanks' dairy farm, Harvey, Western Australia, and provides technical detail of the methodology used during the soil sampling procedure. At the point of publication, nutrient analysis of the soils was not complete. The intention is to publish this information as an amendment to this document at a later date.

The nutrient analysis is of particular interest for areas to be treated with dairy effluent. The sample locations will be documented in such a way that similar samples can be taken in the future, and change in nutrient status can be identified.

This will provide an indication of the benefits, in terms of soil fertility and impacts on the soil environment associated with spreading dairy effluent on-farm in Western Australia.

Property Location
The property is located in the Shire of Harvey on the Swan Coastal Plain in Western Australia. It is situated on Government Road, 5 kilometers to the north-west of the township of Harvey. The Australian Map Grid coordinates (GDA94) for the centre of the property are 392300 m E and 6341940 m N.

Climate
The property experiences a mild Mediterranean climate with warm dry summers and cool wet winters.

The long-term average annual rainfall is approximately 1000 mm, though there has been a slight decrease since the mid 1970's. In an average year, 91% of the rain falls between the months of April and October. The average annual evaporation rate is approximately 1450 mm. The growing season at Harvey lasts for approximately 7 months, with November through to March being months where moisture deficiencies limit growth potential.

Rainfall in Harvey for the last two decades of the 20th century was 5% lower than the long term average (Tille *et al.*, in prep).

Mean maximum temperature in Harvey, for February (usually the hottest month) is approximately 31 °C. The coolest month is July, and mean minimum temperature is approximately 8°C. Frosts are rare, occurring once per year on average.

Geology, Geomorphology and Topography
The property is situated on the Guilford formation, characterised by alluvial sandy clay deposits, laid down during the Pleistocene period (Geological Survey of Western Australia, 1982).

The range in altitude over the property is from 22 to 24 m ASL. The property is situated on an alluvial flat, and there is minimal local relief on this location. Several padocks have been laser leveled in the past for flood irrigation purposes..

The property slopes slightly downward toward the west, at a grade of less than 1%.

Surface Hydrology
The Mangosteel Diversion Drain flows to the west of this property. A number of minor drains dissect the property and flow to the Mangosteel Diversion Drain. This then flows on to the Wellesley Diversion drain, the Wellesley River and the Leschnault inlet.

Several paddocks have been laser leveled in the past, and flood irrigated. The irrigation continues on parts of the farm today, and overflow is discharged into the minor drains and on to the Mangosteel Diversion drain.

Vegetation and Land Use
The property lies within the Drummond Sub-Region of the South-West Botanical Province (Beard, 1981). The loamy flats were originally dominated by woodland of paperbarks (*Melaleuca sp.*) Marri, (*Eucalyptus callophylla*), and flooded gum (*E. rudis*).

Approximately 2% (3.5 ha) of the property is covered by remnant vegetation. The remaining 140 hectares of the property have been cleared and is mostly used for grazing dairy cattle. Pastures planted include perennial and annuals such as kikuyu and clover.

A center pivot irrigation system has been setup in the southern part of the property. Twenty five hectares of pasture is irrigated under this system. Flood irrigation is used on several paddocks, sourcing water from the Harvey irrigation scheme. There are a number of effluent ponds associated with the dairy.

Land degradation

The soils in the flood irrigation bays remain waterlogged for extended periods of time. There is a risk that highly mobile nutrients such as nitrogen will not be incorporated into the soil under these conditions, and if excessive flood irrigation, or heavy rainfall occurs, may be exported from the property in overland flows.

There is a risk of salinisation of land in the flood irrigation bays. There are very low levels of salinity in the irrigation water (60 mS/m), but with extended periods of irrigation, and subsequent evaporation, without flushing may cause increases in salt levels in the soil profile.

Several soil samples tested indicated high levels of sodicity. There is a risk of soil structure decline when irrigating highly sodic soils. Structure decline on sodic soils may also occur with working up of the soil or heavy stock traffic.

Previous Surveys

The property lies within the Pinjarra soil-landscape system. The majority of the property lies within the P3 phase of this system, and this is described in the Department of Agriculture's map unit database as;

Flat to very gently undulating plain with deep, imperfect to poorly drained acidic gradational yellow or grey-brown earths and mottled yellow duplex soils, with loam to clay loam surface horizons.

An area of Pinjarra P6c intrudes into the south of the property, and this is described in the Department of Agriculture's map unit database as;

Very gently undulating alluvial terraces and fans. Moderate to moderately well drained uniform friable brown loams, or well structured gradational brown earths.

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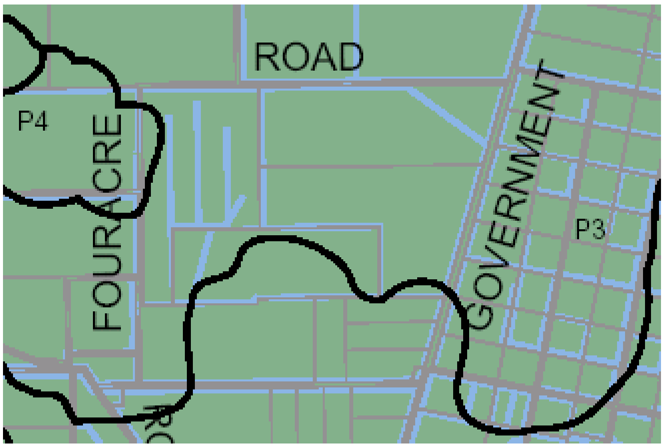

Survey Methodology

The starting point for the survey was the soil map drawn by the landowner, Dale Hanks. It identifies two soil types;

- Poorly drained Grey and brown duplex soils occurring throughout most of the property, and.

- Moderately drained Brown loamy duplex soil occurring on the southern edge of the property.

Soil profiles were examined at 17 soil sites on the cleared land. Soil samples were collected for analysis from 16 of these profiles.

Site selection was based on the “free survey” method (Gunn *et al.*, 1988), ensuring that profiles of each of the soil types identified by the landowner and each of unit mapped in Agmaps Land Profiler (2001) were described. Sampling was biased in favour of soils under the centre pivot,

The soils profiles were examined in pits dug using a shovel to about 40 cm, and then hand augered to 80–100 cm where possible.

Sites locations were recorded using a Garmin GPS 75 Global Positioning System (GPS) and marked onto an aerial photograph of the property. The site and soil profile were described using the terminology of McDonald *et al.* (1990). Site details recorded included landform element, surface condition and native vegetation.

Soil attributes recorded in the profile descriptions included: horizon depth, soil colour, mottling, field texture, structure and the presence of coarse fragments. Soil colours are described according to standard Munsell colour chart notation (Munsell Colour Company, 1994). Soil pH was tested using a indicator mixed with soil into a paste, and barium sulfate powder (Raupach and Tucker, 1959).

Site and soil profile data was then entered into the Department of Agriculture’s Soil Profile Database. Soil profiles were classified into WA Soil Groups (Schoknecht, 2002)

Samples for analysis were collected from standard depths in top 40 cm of the profile and also where changes in the soil horizons were thought to warrant sampling below this depth. The standard depths are listed in a table below:

Standard Sample Depth	**Comment**
0-3 cm	Most often an organic surface crust. Collected from 10-20 locations within 2.5 m radius of the sample hole, using hand-spade.
0-10 cm	Collected using a pogo stick from 20–25 locations within a 2.5 m radius of the sample hole.
10-20 cm	Usually collected from the cleaned wall of a soil pit, otherwise from a soil auger sample.
20-40 cm	Usually collected from the cleaned wall of a soil pit, otherwise from a soil auger sample.
Various	Samples were also collected from horizons in the soil profile which were judged to have the potential to impact on water and nutrient transport of root growth. E.g coffee rock layers in deep sands, or clay layers in gravel/ loamy duplex soils.

In some instances the standard depth was sub-sampled to avoid mixing material from different soil horizons. For example, where there was a major soil horizon change at 30 cm, a sample would be taken from 20-30 cm as well as from 30-40 cm. If a major horizon change occurred at 35 cm, the sample was collected at 20-35 cm only.

Samples were oven dried at 40^0C, and stored for analysis.

Laboratory analysis was conducted by the Agricultural Chemistry Laboratory at the Chemistry Centre (WA). The samples were process in two separate batches. The first batch consisted of 32 samples taken from 15 profiles. These were analysed for air-dry moisture content, pH (1:5 water and 1:5 0.01 M CaCl2), EC (1:5 water), organic carbon (Walkley-Black method - Walkley 1947), total nitrogen and phosphorus, phosphorus and potassium (Colwell method – Collwell 1963). In addition, particle-size analysis (sand, silt and clay fraction only), aluminium (extracted in M CaCl2), CEC, exchangeable cations and phosphorus retention index along with the previous analyses were recorded for a further 25 samples from these profiles. The results of this analysis was not available at the time of publication, and will be published as an annex at a later date. A further 16 samples from 0 to 3cm in depth were sent to Albany for total digestible nutrients (nutrients in OM)

These sites and the profile data, were used to produce a new soil-landscape map. The main soil types were identified and described. The map unit boundaries were drawn directly into a MICROSTATION design file using the site data, a rectified colour aerial photograph and a 5 m contour map. The map units incorporate soil types and landforms, as both have a major influence on the movement of nutrients.

Soil Types

The main soil type identified on Hanks' property was Brown Loamy Earth. These were either heavy, light or friable.

<u>Brown loamy earths (heavy)</u>

The soils have brown loamy topsoils grading into yellow or gleyed clayey subsoils within the top 20 cm. The soil reaction trend is neutral, though slightly acid in places.

A1 horizons are about 10 cm deep loams to clay loams with a brown colour. The coarse fragment fraction makes up less than 2% of the samples. They have high organic matter content and a crumb structure, and are usually non-wetting. The pH typically ranges from 4.5 to 6.

A3 horizons extend to depths of approximately 20 cm, greyish brown to yellowish red sandy loams, silty loams and loams. This horizon has weak sub-blockey peds with a rough fabric. Coarse fraction content (ironstone and quartz fragments) is usually less than 2%. The pH typically ranges from 5 to 5.5.

B1 horizons extend to a depth of 100cm and are brown light clay to medium-heavy clay. This horizon has weak sub-blockey peds with a rough fabric. Coarse fraction content (ironstone and quartz fragments) is usually less than 2%. The pH typically ranges from 5.0 to 6.5.

A total of 10 sites matched this soil unit (WCC 1359, 1361, 1362, 1370 1371, 1372, 1373, 1374).

<u>Variants</u>

There are some profiles similar to this, but there is a clear texture contrast between the loamy topsoil and clayey subsoil at 10 to 20 cm (brown loamy duplexes). Some of these profiles had acidic surface soil (pH of <5) (Acid shallow duplexes), or clay surface horizons (Non-cracking clay)

<u>Brown loamy earths (light)</u>

The soils have reddish brown loamy topsoils grading into yellow clayey subsoils at depths of 60 to 80 cm. The soil reaction trend is neutral, though slightly acid in places. These profiles are better drained the heavy brown loamy earths.

A1 horizons are about 10 cm deep loams to clay loams with a brown colour. The coarse fragment fraction makes up less than 2% of the samples. They have high organic matter content and a crumb structure, and are usually non-wetting. The pH typically ranges from 4.5 to 6.

A3 horizons extend to depths of approximately 60 cm, greyish brown to yellowish red sandy loams, silty loams and loams. This horizon has weak sub-blockey peds with a rough fabric. Coarse fraction content is usually less than 2%. The pH typically ranges from 5 to 5.5.

B1 horizons extend to a depth of 100cm and are brown light clay to medium-heavy clay. This horizon has weak sub-blockey peds with a rough fabric. Coarse fraction content is usually less than 2%. The pH typically ranges from 5.0 to 6.5.

A total of 3 sites matched this soil unit (WCC 1358, 1364, 1365).

<u>Friable red/brown loamy earths</u>
These soils have reddish brown loamy topsoils grading into reddish brown and reddish yellow clayey subsoils at depths of 40 to 80 cm.. The soil reaction trend is neutral, though slightly acid in places. The clay at depth is friable.

A1 horizons are about 10 cm deep loams to clay loams with a reddish brown colour. There are no coarse fragments in the A1 horizon samples. They have high organic matter content and a crumb structure, and are usually non-wetting. The pH is typically 5.

B1 horizons extend to depths of approximately 40 cm, an soils are brown to reddish yellow sandy clay loams. This horizon has weak sub-blockey peds with a rough fabric. Coarse fraction content is usually less than 2%. The pH is typically 5.

B2 horizons extend to a depth of 75cm and are reddish brown light clay. This horizon has weak to medium sub-blockey peds with a rough fabric. Coarse fraction content is usually less than 2%. The pH typically ranges from 5.0 to 6.5.

BC horizons extend to a depth of 100cm and are reddish yellow light medium clay. This horizon seems friable. Coarse fraction content is approximately 10%. The pH is typically ranges from 5.5.

A total of 1 site matched this soil unit (WCC 1363,).

Mapping Units
The above soil types were combined with landscape position and drainage characteristics to form two soil-landscape mapping units. The units are:

- Poorly drained brown loamy alluvial flat; and
- Gently undulating brown loamy alluvial fan mapping units.

Poorly drained brown loamy alluvial flats
This unit is found over most of the property. It is a broad aluvial flat, with slope grades of less than 1%, and is poorly drained. The area occurs at an elevation of 21 to 23 m AHD.

The soils are predominantly loamy earths**.** Loamy duplexes, Acid shallow duplexes, and Non-cracking clays may also occur**.** These soil profiles are poorly drained, and medium to heavy subsoils prevent rapid infiltration.The native vegetation is melaleuca-flooded gum woodland.

Gently undulating brown loamy alluvial fan
This unit is found in a small area along the southern boundary of the property. It is a broad aluvial fan, slightly undulating, but still with slope grades of less than 1%. It is well drained. The area occurs at an elevation of 23 to 24 m AHD

The soils are predominantly loamy earths, but unlike the above soil-landscape unit, the soil profile is moderately well drained.

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Glossary

Colour	Soil colour is defined in terms of hue, value and chroma using Munsell soil colour charts. Colours are classified by an alphabetical/numerical code. e.g. 10 YR 6/8: hue (brownish yellow) 6: medium high value 8: high chroma The classification makes it possible to distinguish slight differences in colour.
Gleying	Soil condition indicative of permanent or periodic waterlogging and is characterised by greenish, bluish and grey colours. Gleyed horizons are represented by the suffix (g) e.g. B2g.
Grade of Pedality	The degree, development and distinctness of peds. Soils without peds are divided into: Single grain – loose incoherent soil particles. Massive- coherent mass breaking into single particles or unstructured fragments. Pedal soils are divided into: Weak- peds indistinct or upto one-third of soil consists of peds. Moderate-peds well formed and evident with upto two-thirds of soil material consists of peds. Adhesion between peds is moderate to strong. Strong- peds distinct with more than two-thirds of soil material consists of peds. Adhesion between peds is moderate to weak.
Massive	A soil layer that appears as a coherent or solid mass that has no structure.
Mottles	Mottles are spots, blotches or streaks of colour which can be distinguished from the main background soil colour. Mottles usually indicate periodic waterlogging in the zone of its occurrence.
Pan	An indurated and/or cemented soil horizon. The nature of the dominant cementing agent is used to identify different types of pans. The most common types are:

	Silica pan - cementing agent is amorphous silica analogous to fragipan, silcrete, red brown hardpan and duripan.
	Sesquioxide pan - cemented by iron and aluminium oxides analogous to laterite, bauxite, bog iron ore.
	Iron pan - cemented by iron oxides, analogous to ferricrete.
	Carbonate pan - cemented by calcium and magnesium carbonates analogous to travertine, calcrete.
	Clay pan - concentrations of dense clays.
Ped	A natural soil aggregate.
Segregations	A soft to hard accumulation of minerals that have formed within the soil by the precipitation of cementing compounds. Some forms of segregation are: concretions, nodules and crystals.
Sodic soils	Soils that contain appreciable amounts of sodium within the clay fraction. High concentrations of sodium are associated with soils having poor structure and drainage.
Soil horizon	A layer of soil that is distinguished by the degree of alteration brought about by soil formation factors. Soil horizon are designated by letters e.g. A,B,C and D.
Soil units	Groupings of soils occurring in the landscape. They should: * contain soils with similar chemical and physical properties; * be sufficiently different to justify their separation at the published map scale; * meet the specified objectives of the soil survey.
Structure	The term relates to the arrangement of soil particles. Structured soils have soil particles orderly arranged in a recognisable shape. The forms are: crumb, granular, polyhedral, blocky, platy, columnar and prismatic.
Structure size	Refers to the vertical or horizontal dimensions of peds.eg. for angular blocky peds the size range is: Fine: 2-5mm diameter

Medium: 5-20mm diameter
Coarse: >20mm diameter

Texture

Soil texture is determined by the proportion of sand, silt and clay content. The descriptive terms fine, medium and coarse refer to the sand particle size, that is:

coarse sand - 2mm - 0.6mm
medium sand - 0.6mm - 0.2mm; and
fine sand - 0.2mm - 0.02mm.

APPENDIX 7: SOIL WATER IMPACTS OF IRRIGATION

Summary of discussions at irrigation trial site, 4 June 2004

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Cliff Hignett, Consultant (see full CV and publications list on www.soilwater.com.au)

- Certified practicing Soil Scientist by Australian Society of Soil Science at level 3 (most advanced level).
- Certified practicing Agriculturalist by Australian Institute of Agricultural Science & Technology at level 3 (most advanced level)
- 35 years with CSIRO Division of Soils, doing research on soil water measurement, water use efficiency and effect of soil strength and porosity on plants. Expertise in plant root systems as they interact with soil properties and soil water, soil salinity, water use efficiency, soil water measurement techniques.
- Five years as private consultant and farmer and TAFE educator

Summary of discussions at Irrigation trial site, 4/6/2004

Present at meeting: Rob Kuzich, Dale Hanks, Cliff Hignett, Soil Water Solutions

I was told that the purpose of this centre pivot trial is to demonstrate the benefits of irrigation by centre pivot over the flood irrigation method. Discussions centred on

- what changes in soil conditions might result from any changes in irrigation practice
- what measurements might be put in place to document those changes
- in what way could irrigation management be used to speed up, and enhance soil improvements

I believe that the project as planned seems to cover the demonstration of probable improvements in water use efficiency usually found in trials of this nature. By this, I mean that I would expect to see a rapid but small increase in productivity (10-20%) with less water consumption, and MUCH less drainage to groundwater.

The one small criticism I have of the trial as planned is that there is no provision for documenting changes to the local water table.

I noted that in WA there seems to have been very limited attempts to improve the physical condition of the soil on a farm. While most farmers accept that the soil chemical condition can be improved, (by addition of appropriate fertilizer), few have considered the soil physical condition is something which can also be improved by artificial means. Australian soils are usually many hundreds of thousands of years old which means they are not only leached of fertility but also have seriously degraded structure usually demonstrated by poor infiltration, high strength, high density and a tendency to disintegrate to dust if cultivated dry.

Improvement of soil physical condition is often expensive and usually a long term proposition, but it is usually possible and the benefits can be considerable. Such improvements are common practice in horticulture where high value crops pay for the process more quickly. However, techniques have been developed for lower productivity farming areas. Benefits of better soil physical properties include higher productivity, but the major benefit is more resilience or 'drought proofing' of a crop and less critical management decision making - the soils are less effected by weather and irrigation timing. In this case the major expense of an improvement program is already in place - the centre pivot.

In the context of management of an irrigated pasture, soil physical improvements mean that intervals between irrigations can be increased so that the pasture gets more time to grow in non saturated (ideal) conditions and produces more growth for less water consumption. Mechanical failures become less critical. This is of considerable benefit to the manager who can schedule irrigations 'any time in the next 4 days' instead of ' if the irrigator doesn't work tomorrow the crop dies'

What is a 'good ' soil vs a 'bad' soil?

In every district there are some soils which are better than others. By this I mean that if you selected a good soil and a bad soil and managed and fertilised, both soils the same way, the good soil would produce more, and would be more likely to produce reasonably in a bad year or if poorly managed. The bad soil may produce just as well in a good year but over a period of years would have more 'disastrous' events, there would be more years in which productivity fell seriously below that of the good soil.

A good soil means different things to different people. If you talk to an engineer, a 'good' soil packs down hard, sets like concrete when dry, and then does not let water into it. He wants to build a structure on it and wants a firm foundation. But farmers have different needs to engineers. A good soil for growing plants lets water into it easily and has plenty of aeration – even when wet. A farmer wants a soil which lets water in fast, stores as much water as possible in the root zone of the crop and then delivers that water back to the plant on demand. Ideally it also has little evaporation directly from the soil surface. A good soil for farmers also has to be soft enough for crops to develop a good root system – or else have lots of larger pores to allow root development between aggregates. A good farm soil neither sets like concrete nor blows away when disturbed.

Ideally a good farm soil is constructed of strongly bonded clusters of sand silt and clay around 0.5 to 3mm diameter , with only light bonding between the clusters. This means that the spaces (pores) between the clusters (aggregates) allow good aeration, rapid water infiltration and space for plant roots to grow, and the aggregates themselves hold water for delivery to the adjacent plant roots.

While various bonding agents produce a rapid improvement in soil condition and are commonly used in horticulture, they tend to be uneconomic for broad acre application. The cheapest bonding is provided by the organic glues produced by soil animals. A snail trail is one example - but all soil animals protect themselves and the cavities in which they live by such glues. These glues are easily produced by ensuring a healthy and active soil biological system.

A biologically active soil happens automatically if there plenty of organic residues on the soil (not a problem where there are animals) and when conditions are right for soil animal growth. The best conditions for soil animal growth are the same as for crop growth - warmth, moisture and aerated soil condition.

There are many residues dropped onto and left in soil , dead roots, animal droppings, dead leaves etc – all of these will decompose in some way. If there is plenty of air and space in the soil they will be consumed by soil animals (worms, protozoa bacteria etc.) which will die some 6 months later and return the fertility locked up in the litter to a form which plants can use (nitrates). If soil conditions are not right (not enough oxygen) then the waste materials will either not rot at all, or will be rotted by anaerobic bacteria which, instead of releasing nitrates, will release ammonia and methane - this is the 'sewer' smell which is usually obvious in 'waterlogged' ground.

There would seem to be several ways these technologies developed in dryland and horticultural fields could be adapted profitably to irrigated pastures.

What's wrong with flood irrigation (from a soils perspective) and how to maximise the benefits of pivot irrigation

The lack of water control implicit in flood irrigation usually involves the complete saturation of the soil for an extended period and the application of more water than is needed to wet the plant root zone. This has several effects

- Main effect is that water in excess of what is needed to fill the root zone soaks below the root zone and is wasted, or worse, turns up as saline groundwater somewhere else. I noted the deep drains running along the main road - to drain groundwater.
- The extended saturation time means that numbers of soil animals (from worms right down to aerobic bacteria) are severely depleted. The higher order animals simply drown and the lower orders are replaced by anaerobic bacteria. Sites with clay soils are particularly susceptible because of the longer period required for draining of surplus water. Presence of anaerobic bacteria is usually obvious by smelling a soil sample from a depth of around 20 cm – a smell of ammonia or methane is often present (smells like a sewer).
- The loss of soil animals means that any larger pores destroyed by animal trampling are not rebuilt and infiltration rates are progressively reduced over a period of years.
- The trial site has a high proportion of sodic clay – this type of clay disperses in water very quickly (the clay goes into suspension in the soil water and makes the water ‘milky’) which has (probably) reduces infiltration by blocking soil pores.
- As a consequence of poor infiltration, compacted soil, and anaerobic conditions the water evaporates quickly, roots do not penetrate deeply, the available soil water store is small and irrigations are required at ever smaller intervals.
- Trampling by stock in extremely wet conditions is probably a major contributing factor the substantial hard pan found at the mini pit dug at the centre pivot site. Interestingly, a similar mini pit dug in the flood irrigated site did not have a hard pan to nearly the same degree.

NOTE that a single pit at each site should not be taken as an indicator of anything beyond the fact that at least one instance of these conditions were found on site.

NOTE that BOTH sites in the trial suffer from these problems at the moment, probably due to past history. One effect of the trial will (hopefully) be a clear divergence of soil properties between the two treatments.

Is there anything which can be done to enhance the trial.?

At the moment, the main aim of the trial is to see what improvements accrue from use of the centre pivot alone. I have no doubt that such improvements will accrue and that the effects will be measured by the proposed productivity testing. However it may be several years before effects are obvious.

There are (a) a number of ways in which the progress of these changes can be hastened, and (b) a number of measurements can be taken to show the REASON why the centre pivot soils are becoming more productive. In my experience, if farmers are given reasons why something is happening, then the adoption of the methods is much more rapid and widespread. Everyone has an inherent distrust of 'black magic' solutions – especially when they involve the purchase of expensive equipment. Also, if farmers know what they are aiming for in terms of soil conditions, then they can better adapt the techniques for their own properties.

The trial also has a stated aim of community involvement and an experience in South Australia has shown that it is possible to involve even children – with very substantial benefits for the long term assimilation of knowledge.

Suggestions for treatments

- The presence of sodic clay at the site means that any improvement in porosity either by development of root channels, dug by soil animals or by cultivation will be hindered, as clay disperses and tends to block such channels. The use of soluble calcium is needed to change these sodic clays to calcic clays. This is usually done by application of gypsum (lime is less effective but also useful and has additional benefit of pH control), but by far the most effective treatment is calcium nitrate. This has the substantial benefit of penetrating the soil as fast and as deeply as the next irrigation or rainfall (gypsum may take years to affect the 200mm layer unless it is cultivated in) Once soil pores are coated with this material they remain stable for several years. Treatments with as little as 50kg/ha can have visible effects in days. (A proper trial would involve a similar plot with an equivalent amount of N as urea to account for the N effect)
- Long term saturation of the soil at the site and the effect of stock has (probably) caused a compacted layer which is probably restricting roots – if this layer can be disrupted then a deeper root zone will quickly establish. I suggest a sub trial where this layer is disrupted by a shallow 'ripper' (depth around 150mm) Ideally such a rip should be done when the soil is partly dry so that the soil 'shatters' – this may have to wait till the soil can be allowed to dry. The presence of sodic clay means that any such rip process would be short lived due to the soil pores collapsing again as clay disperses. Any rip trial should be associated with surface treatment with gypsum of calcium nitrate. In South Australia , spectacular results have been seen by dropping gypsum into the slot behind the ripper so that the cracks created are directly coated by the gypsum.

Suggestions for supplemental testing

1. A soil structure tests

1a. Infiltration

The expected improvements in productivity will be dependent on improvements in soil structure (the way sand silt and clay bond together to form aggregates and pores). The simplest structure test is a saturated infiltration test – a steel ring is inserted into the soil , water is added and the rate of infiltration of that water is measured. (A more sophisticated test yielding more information about the size of pores, would be using a suction permeameter – but I do not recommend this in the first instance due to the complexity of the test). I would expect to see significant differences in infiltration rate between the sites at the end of the first season. With the addition of calcium nitrate I would expect dramatic differences immediately – within minutes!

1b. Soil Aggregation and aggregate stability

These tests are more time consuming and usually involve sieving a soil by gently moving a sieve of soil under water and measuring how much remains on the sieve after (say) 10 up-down movements. I would recommend enlisting the aid of the local Agricultural college who may be looking for student projects. Sampling for this type of testing is simple. Go around each site using a core sampler to collect soil plugs which should then be air dried as quickly as possible (to arrest biological action). Then they can all be stored indefinitely until you are ready to do the testing. I would take the samples just on 'spec' – say every 6 months. Then they can be used or not as you decide later.

1c. Soil strength - pans

I demonstrated the use of a simple 3mm 'welding rod' penetrometer. I would recommend that once a year a transect of perhaps 50 such tests be done across each field recording the depth to which the rod could be pressed using the centre of the hand. (there are more sophisticated penetrometers available which measure the force required or there are laboratory tests also)

You could also set out a micro trial on the pivot site where stock are kept off the soil for at least a day (two days if possible) after the irrigation - this enables the pasture to get a ‘head start’ before it is eaten and prevents the animals from compacting the soil when it is wet. Cell grazing trials in dryland pastures - which try to do a similar thing, have produce double the productivity.

2. Soil biology tests

As noted above, the first casualty of flood irrigation is the soil animal population. There are two relatively easy tests which can establish differences in soil biota

2a. Worm counts – this only measures the 'top of the food chain in the soil', but is easy to do – so easy that children can do it. A few years ago, in South Australia, a kit was prepared for school children to go out to local areas (back gardens, farms, city parks ...) to collect soil and measure the number of worms per square metre. It was found that such projects met with a huge degree of cooperation from teachers who are especially keen to have children participate (and be seen to participate) in community environment projects. In several cases, the children generated so much interest that community meetings had to be organised to satisfy the curiosity of parents as to what the kids were up to. I am sure I could locate one of these kits if you want to try it.

2b. Lower order biota - the principle function of the lower orders of soil biota is to eat cellulose (old roots, bits of grass etc.) and so begin the recycling process. A simple test is to bury a known weight of cellulose (a strip of cotton cloth, a piece of paper etc.). After a short interval the paper is dug up, oven dried at 60 degrees, and weighed to see how much was eaten. You will have to experiment a bit to get the time and mass of paper right. As a stating point, I would expect a strip of office paper to halve in weight in 4 weeks in moist soil in winter and in one week in moist soil in summer in a bioactive soil. You will probably need to bury the measurement sheet between two other sheets to avoid soil contamination.

3. Estimate the actual transpiration (as distinct from evapotranspiration) to see if production is suboptimal.

Standard irrigation practice suggests that maximum productivity will result from supplying the plant with the amount of water equal to evaporation potential. This is, at best, an approximation of what needs to happen. For maximum productivity, the plant must be able to get, via its root system, sufficient water to prevent the leaves from wilting – even for a short time such as the hot part of the day.

The important difference between these two descriptions is that the first one only works if the root system is deep and spread evenly through the soil – which is rarely the case anywhere and is certainly not the case at the trial site. In the first pit we dug, 90% of roots were confined to the top 80mm – probably due to the hard pan at that location. The few roots at greater depths can supply water - but not quickly enough to prevent the plant temporarily wilting at (say) midday. (There are ways to measure the quantity of roots - and how they change down the soil profile - get I touch if you are interested)

At present roots occupy (say) 80mm of loam which should hold (80 x 2/10) =16mm of water. Daily demand in summer is 10mm – so the readily accessible water is only 1.6

days supply of rapidly accessible water. This means that the pivot needs to run virtually every day to keep up a full supply. As a consequence, animals must be allowed to graze on the field while it is being watered, with consequent compaction problems.

Yes, additional water could be added to fill the soil below the main body of roots, but there is insufficient roots here to extract the water fast enough to supply the demand in the middle of a hot summer day. The plant MUST go under stress while it accesses this water and of course, some stress will result and photosynthesis will be reduced right at the time of day when production should be at its peak. It is the improvement in the rooting depth allowed by better irrigation practice which will ultimately produce productivity gains with the pivot.

Consider what happens if the compaction layer is broken up and more root system is allowed to penetrate to (say) 300mm, which is about the maximum for most grasses. Water storage is now 300 * 2 /10 = 60mm or 6 days supply of water. Now more flexible management is possible – perhaps 1 day to water 2 days to drain and 3 days grazing. The soil (and plants) now get more time to benefit from the watering between grazing periods. The plants will not go into stress conditions so easily and overall productivity is improved. NOTE that the total water use is UNCHANGED as you would now supply 60mm per irrigation. The difference is that now the whole 60 mm will go through the plant. If you supplied 60mm to the current pasture, most would end up as drainage.

The project already will be measuring dry matter at regular intervals. There is a well established relationship that relates actual transpiration to DM production.

DM (kg/ha) = 40 x transpiration in mm
or, transposing this,
actual transpiration = DM / 40

I recommend that as a routine, the DM measures are divided by 40 and an estimation of actual transpiration be calculated for each sample period. For a full cover pasture operating at maximum efficiency, this figure and the amount of water applied should be similar. If transpiration is significantly smaller than water applied then this is a clear indication that the pasture has spent some period under water stress – and a clear indication that production is sub optimal.

Conclusion

- I have no doubt that the trial (as planned) will produce benefits in both water use and productivity.
- The addition of some soil measurements to the plan will help to document what is going on and will probably show differences between flood and pivot before they show up in productivity.
- The inclusion of children to do some measurements will have big community benefits
- Soil measurements will help to explain where the benefits of the pivot are coming from - and hence reduce the 'black magic' factor for farmers faced with the considerable expense of a pivot system.

Additional recommendation

I am including a copy of 'Better soils mean better business' which was produced in SA to introduce farmers to the relationship between their soils and their productivity. Note that the contents of this book are on the web site www.bettersoils.com.au