Australian Government
Cotton Research and Development Corporation

Cotton Catchment Communities CRC

FINAL REPORT 2006

I participated in the CRDC Final Report presentations this year, and sought permission to submit the final written report by 31st January, 2007.

Part 1 - Summary Details

CRDC Project Number: **NEC10C**

Project Title: Improving infiltration of irrigation water under Centre Pivots and Lateral Moves

Project Commencement Date: 01/07/04 **Project Completion Date:** 10/03/07

CRDC Program: Integrated Natural Resource Management

OR CRC Program:

Part 2 – Contact Details

Administrator: Erik Schmidt, Director
Organisation: National Centre for Engineering in Agriculture
Postal Address: University of Southern Queensland, Toowoomba, QLD. 4350
Ph: 07 46 311 347 **Fax:** 07 46 311 870 **E-mail:** Erik.Schmidt@usq.edu.au

Principal Researcher: Joseph Foley, Research Fellow
Organisation: National Centre for Engineering in Agriculture
Postal Address: University of Southern Queensland, Toowoomba, QLD. 4350
Ph: 07 46 311 559 **Fax:** 07 46 311 870 **E-mail:** Joseph.Foley@usq.edu.au

Supervisor: Professor Steven Raine
Organisation: National Centre for Engineering in Agriculture
Postal Address: University of Southern Queensland, Toowoomba, QLD. 4350
Ph: 07 46 311 691 **Fax:** 07 46 311 870 **E-mail:** Steven.Raine@usq.edu.au

Signature of Research Provider Representative: _____

Part 3 – Final Report

1. *Background*

Centre Pivots and Lateral Moves (CP&LMs) continue to gain favour across the irrigated cotton community, from Emerald to Hillston and Breeza to Bourke, as shown by the continued rapid uptake of this irrigation method (ABS 2005) in Australia. These machines continue to perform well on a variety of soils, using different water application techniques under the recent extremes of highly variable weather and water availability. CP&LMs are becoming renowned for their capacity to save water, reduce labour, germinate crops easily and produce excellent cotton yields.

Australian cotton growers are using the largest CP&LMs of any growers worldwide, both in term of irrigated area and system capacity (mm/day). Whilst growers are attempting to enhance their economies of scale with these larger machines, they are stretching the boundaries of acceptable performance; particularly regarding average water application rate (AAR) and the movement of irrigation water into the soil. Furthermore, most Australian cotton growers are placing water with LEPA heads/socks into soil cracks without the aid of furrow dikes, a significant departure from the original LEPA concept that involves smaller system capacities and soil reservoir tillage (furrow diking).

Consequently, growers are concerned about the ability of CP&LM machines to deliver water where it is placed, particularly under LEPA irrigation, sprinklers with high AAR and when soil moisture is not being fully replenished (deficit irrigation). Therefore a greater understanding of the placement and movement of irrigation water into the soil under CP&LMs was required.

Irrigation of cotton under CP&LMs is currently achieved using either; (1) overcrop sprinklers for germination followed by LEPA application, or (2) sprinkler application alone. Current issues include:

- Appropriate sprinkler selection
- Appropriate flow rate, particularly for germination
- Infiltration under high AAR water application
- Surface movement of water under LEPA irrigation without furrow diking
- Movement of water into cracks under LEPA irrigation, including potential movement below the crop root zone
- Redistribution of soil water under sprinkler and LEPA systems

In addition to this lack of knowledge regarding water placement and infiltration, growers still have concerns regarding the management of CP&LM systems. In particular, soil moisture issues such as those mentioned above, as well as soil moisture monitoring, probe placement, soil water deficit and average soil moisture are of concern. There is also a significant difference between management of CP&LM irrigated fields and furrow irrigated fields, and it is often difficult to grasp the change required to manage CP&LM machines to their potential.

A series of intensive soil moisture measurements was proposed to provide greater understanding of the fate of applied water for a range of soil types, application devices and soil moisture deficit/application depth combinations. Visual, simulation and decision support tools were created to allow the soil moisture and management data to be effectively communicated to CP&LM end users. Knowledge from this investigation will further improve CP&LM irrigation application efficiency, WUE (bales/ML_{irrig}) and management efficiency, and reduce the possibility of deep drainage, excess water application and poor crop uniformity.

The project specification including agreed objectives, outputs and outcomes was approved by the CRDC board on the 13th of September, 2004, following late final approval and re-negotiation of the original project's objectives with CRDC board members at NCEA, USQ.

This final report is delivered in a concise form containing hyperlinks re-directions to outcomes generated by the project. These links move the reader to the individual reports and stand-alone attachments. The final report is best viewed electronically on the provided CD, due to the visual and interactive nature of significant portions of the developed material. The nature and layout of this report are such that only the briefest of discussion has been included. Users will need Adobe Acrobat Reader configured with the navigation toolbar on, to easily access all components of this final report's "attachments". A number of the outputs will be delivered visually through Windows' Internet Explorer and movie player.

2. *Objectives*

The three agreed objectives of this project were as follows :

1. Investigate placement, movement and infiltration of irrigation water for a range of CP&LM characteristics under various field conditions.
2. Encourage adoption by creating visual tools that allow growers and consultants to understand soil water movement under CP&LM machines.
3. Increase awareness of management issues for CP&LM machines through development of decision support systems to demonstrate different management scenarios.

Further, these three objectives were to be delivered by this project through activities comprising eleven outputs or milestones, as provided in the Objectives, Outputs and Outcomes attached to this report. Outputs 1 to 4 are essentially against the delivery of the first objective, outputs or milestones 5 to 7 go to the second objective, leaving milestones 8 to 11 to deliver the third objective of this report.

3. *Methods*

The methodologies used throughout this project vary significantly from standard experimentally based projects, and reflect the broad range of activities centred on the production of extension material and information sources for use by growers and water extension staff in regard to the performance of CP&LMs across the Australian cotton industry. Methodologies for individual components are included with the material developed and are linked through hyperlinks.

The methodology for measurement and conversion of point source soil moisture measures into graphical soil moisture images has been provided in accurate and rigorous detail ; this process having proven to be challenging and time-consuming to develop over the course of the project. The methodology for the development of the 3D images is also provided in this same document, in addition to site selection and field installation of the measurement technology. Details of methodology for the water balance study of a lateral move irrigating cotton are provided in the stand-alone document discussing this work. Development of the sprinkler and probe placement guidelines do not warrant provision of a methodology.

4. Detail and discuss the *Results* for this project.

The results from the complete range of activities and eleven milestones successfully undertaken in this project will not be discussed in great detail here in this summary report and are detailed in the attachments. Suffice to say that substantiative measurement activities were undertaken at seven locations spread geographically across the industry, with over 60 access holes hand-augered, over 50 soil wetting events (irrigation & rainfall) recorded, over six hours of video footage recorded, over 300 soil moisture images developed, with extensive industry interaction via phone, email, site visits and field days. A range of publications and presentations at conferences have also been prepared and presented. Six key outputs of this project that will have the most significant impact for the cotton industry are discussed briefly here.

The six key outputs of this NEC10C project are :

1. The sprinkler selection guidelines document including equipment overview, performance measures and typical cases of sprinkler installations irrigating the two dominant soil types in the Australian cotton industry. These sprinkler guidelines successfully fulfil project Milestone 4 under the first objective listed in 2 above.

2. The soil moisture images contained within the html archive allow easy access to simple and accurate visualisations of soil moisture profiles of irrigation events on CP&LMs from a selection of soil type, sprinkler type, growing region, deficit and irrigation amount. The html archive also holds the video presentations of different sprinkler types and the 3D images of soil water movement in a cracking clay Vertosol site. This key output successfully delivers Milestones 1, 2, 3, 5, 6 and 7 and delivers across Objective 1 and 2.

3. The probe placement guideline which incorporate discussion of soil moisture measurement techniques and technology and provides guidance on probe placement both along the machine and within the machine's irrigated run for both centre pivots and lateral moves. The necessity for a combination of technologies including water and weather based ET measurement and calculation is discussed. This key output successfully fulfils Milestone 10 as part of project 3.

4. The Centre Pivot and Lateral Move Visualisation tool **OVER***Sched*, a web deliverable irrigation management tool successfully delivers upon Milestones 9 and 11 in the third project objective.

5. The water balance of a lateral move, encompassing the calibration of intensive soil moisture datasets, the development of an FAO56 ET calculation process, the interpretation and validation of irrigation and rainfall records, and the aggregation of crop datasets and crop model runs from project partners. This delivers upon Milestone 8 and project Objective 3.

6. Provision of substantial technical support to the Australian cotton industry, a selection of whom are mentioned in this provided document.

All milestones have been met and project objectives fulfilled. Each of the first five of these key outputs for NEC10C are discussed briefly below with the detail included in the attachments.

Sprinkler selection guidelines

The sprinkler selection guidelines for CP&LMs are provided in a document detailing sprinkler types and the important sprinkler performance measures of average application rate, uniformity, application efficiency and droplet impact energy. The performance measures and the discussion of them are critical in developing the cotton industry's understanding of sprinklers and their use. Important points to come from this review are :

- the necessity for soil surface detention capacity to be at least equal to the desired depth of application for the slow infiltrating soils irrigated in the Australian cotton industry,
- that sprinkler droplet evaporation loss is between 1 to 2% even under extreme heat, wind speed and low humidity conditions,
- that uniformity of applied water in the travel direction for LEPA socks will be improved with the use of dikes on spacings of 4 to 6 metres, and
- that CP&LM sprinkler irrigation packages can be designed to produce droplet impact energy levels less than most rainfall events, while still maintaining high system capacity.

In addition, this guideline highlights sprinkler package design issues typically encountered on hard setting red-brown earths, and on the cracking clay Vertosols, the two most prevalent soils in the industry.

Soil moisture visual images, three dimensional images and sprinkler action movies

Over three hundred images of soil moisture variation across the plant line down to a depth of one metre were developed from seven different CP&LM sites spread geographically across the cotton industry, from the Macquarie Valley to the Darling Downs. Each image was processed and handled through three different software packages from the data collected by 25 capacitance sensors. An html archive was assembled with a directory structure to allow users to choose images by soil type, region, sprinkler type and wetting event. Each wetting event typically contains three images of soil moisture before irrigation, after irrigation and the change over this 8 hr duration. The html file runs in the common Windows based web browser Internet Explorer, and allow users to access the movies of sprinklers in action, and three dimensional images of soil moisture change from 250 measured points in a cubic metre of soil. This is a highly significant collection of visual images that will strengthen the understanding of soil moisture change due to irrigation for many in the cotton industry. Discussion of the soil moisture visuals for typical crop, soil and sprinkler type combinations was developed and is presented as a stand-alone document.

Soil moisture probe placement guidelines

This guideline outlines the necessity for better soil moisture measurement for good irrigation management of CP&LMs, and recommends that a single point measure of soil moisture in a CP&LM irrigated field is insufficient, and that typically there is a necessity for additional measurement systems to ensure a reasonable understanding of soil moisture levels in the field. This document outlines the procedure to correctly position a soil moisture measurement zone within a CP&LM irrigation field, both with respect to the machine length and irrigation run, taking account of the irrigation cycle pattern and economically significant areas of light soil under the machine.

OVER*Sched* - a simple visual CP&LM management tool

A simple visual software tool was developed to assist new CP&LM irrigation managers come to understand the variation of soil moisture that will exist across irrigated fields. This package is web deliverable and operates with a minimum of user input, while providing graphics of the machine irrigated field and soil moisture levels from user determined probe sites. This package will prove to be of greatest use in assisting furrow irrigation growers to

understand the importance of system capacity in CP&LM systems and the way that it differs from that for a furrow irrigation system.

Water balance of a lateral move irrigating cotton

A water balance of a lateral move irrigated field was developed using aggregated data sets from soil moisture sensors and weather stations for a cracking clay soil site where a vacuum lysimeter had been placed at 1.5 metres depth. Data sets from other collaborative projects at this one site were collected, analysed and compared with results from a leading industry crop model to determine its performance for economic comparison of alternate irrigation management scenarios. Recommendations from this work highlight the requirement for improved soil water measurement for irrigation of cotton where amounts less than the predicted soil moisture deficit are applied. This exposed a significant weakness in the ability of the simulation model Hydrologic for this type of situation.

These six key outputs represent an impressive collection of informative images, guidelines, and software tools that will improve the understanding of CP&LM irrigation in the wider Australian cotton industry, and assist those already using this technology to improve their irrigation performance.

5. Describe how the project's outputs will contribute to the planned *Outcomes* identified in the project application. Describe the planned outcomes achieved to date.

All of the project's outputs have been detailed above and in the annexures. These deliverables provide a comprehensive resource for improving the understanding of best management of CPLM systems. The visual data, tools and recommendations will demonstrate to users the flow and soil water distribution characteristics allowing more appropriate management of these systems.

6. Please describe any:-

a) technical advances achieved (e.g. commercially significant developments, patents applied for or granted licenses, etc.);

b) other information developed from research (e.g. discoveries in methodology, equipment design, etc.); and

c) required changes to the Intellectual Property register.

Technical advances include a simple visualisation tool, **OVER***Sched* to assist new CP&LM users analyse alternate irrigation strategies to overcome common mistakes in the early few years of ownership. The novel mode of delivery for this tool allows complete delivery over the web. All IP associated with this project is by the NCEA. The CRC Irrigation Futures has contributed to further development of **OVER***Sched* following approval by CRDC. This has provided opportunities to extend its application and promotion.

7. Provide an assessment of the likely impact of the results and *Conclusions* of the research project for the cotton industry. What are the take home messages?

The results of this project go directly to the question that provided the seed for this project and that is "Where does CP&LM irrigated water go in the soil profile?" The results will assist growers, consultants and extension staff to understand the infiltration and water movement under CP&LMs. Key results and conclusions have been detailed elsewhere in this report.

8. Detail *Extension Opportunities* and activities or other steps that may be taken:
(a) to further develop or to exploit the project technology.
(b) for the future presentation and dissemination of the project outcomes.
(c) for future research.

This project has delivered a range of materials that can be used by the Cotton industry to improve the management of CP&LMs. The material can be delivered to wider audiences through the web using the resources being developed by the Cotton Industry, through future editions of WATERpak, via the CP&LM training package, and with the existing Cotton industry's water extension team and the federally funded Cotton and Grains Knowledge Management Project team. All of the numerous opportunities that this significant quantity of extension material provides can be discussed with Mr Erik Schmidt, Director, NCEA. All the extension material developed by this project is delivered here in the final report CD and can be easily extracted for immediate use.

Future research work should be conducted upon alternative field soil moisture measurement technologies used in conjunction with existing water and ET measurement systems to provide improved reliability and accuracy of soil moisture information for cracking clay soil fields where deficits are partially filled. In addition, improvements to the industry crop model are required, specifically to the irrigation and soil water modules, as these are essential before any economic modelling of alternate irrigation scenarios is possible. We strongly urge this work be conducted. Based on audience response at grower and researcher presentations, the

soil moisture imaging techniques should be used in deficit and re-fill type surface irrigations to assist irrigation communities understanding of where irrigation water has moved to in cracking clay Vertosols.

9. A. List the publications arising from the research project and/or a publication plan.
(N.B. : Where possible, please provide a copy of any publication/s)

A variety of publications have been developed by the NEC10C project team, and range from progress reports and guidelines, through to presentations, conference papers and popular press. A list of these publications is provided here, along with hyperlinks to them.

- Presentation to WaterTAPs, NCEA's weekly irrigation / water use discussion group,
- NEC10C Progress Report, January 2005
- NEC10C Progress Report, January 2006
- NEC10C Annual Report, September 2005
- Final Report presentation to CRDC, August 2006
- 13th Australian Cotton Conference paper, August 2006
- 13th Australian Cotton Conference plenary session presentation, August 2006
- Informed CP&LM Purchase Roadshow presentation, documentation & checklist
- SM Probe placement Suggestions
- 13th Australian Cotton Conference - Virtual Poster - Soil Moisture visuals
- 13th Australian Cotton Conference - Virtual Poster - **OVER***Sched*
- IAA Conference, Townsville May 2005 - Paper presentation & Extended Abstract
- IAA Conference, Townsville May 2005 - Workshop presentation & Checklist
- Australian Cotton Grower articles - Nine articles
- Irrigation Association of Australia Journal articles - Two articles
- Aust Cotton Outlook articles - Two articles

B. Have you developed any online resources and what is the website address?

NCEA management will remain in discussion with members of the "Cotton and Grains Irrigation Knowledge Management Project" regarding the on-line delivery of the visual outputs of this project. These possibilities were envisaged from the earliest phases of this project. CRDC will be made aware of these outcomes in due course through members of the Knowledge Management project team. The soil moisture visual images, the 3D graphics and the movies of operating sprinkler types are currently embedded in an html archive with a menu structure allowing users to access images by soil type, sprinkler type, and events for different sites. These are now most easily delivered in this format via the web. In addition the software package **OVER***Sched* was constructed specifically in a computer programming language best suited to development of software for web delivery. While this small visualisation tool is easily distributed via email and softcopy, it was always intended to be delivered over the web through the Knowledge Management project.

References :

ABS 2005, 'Water use on Australian farms 2002-03. Cat. No. 4618.0'.

Part 4 – Final Report Executive Summary

A project was funded by the Cotton Research and Development Corporation and conducted by the National Centre for Engineering in Agriculture to support the industry in the continuing successful uptake of Centre Pivots and Lateral Moves (CP&LMs) across the Australian cotton industry.

In particular, the cotton industry required assistance in developing their understanding of the way irrigation water from CP&LMs moves through the soil profile in some of Australia's most difficult and challenging soil types. These soils with their naturally low infiltration rates, and in some cases an additional propensity for surface crust and seal development, present sprinkler package designers with particular challenges not encountered elsewhere, especially in terms of uniformity, application efficiency and droplet impact energy levels. The high system capacity, large machine size and extreme weather conditions encountered in combination in the Australian cotton industry exacerbate these issues and require particular design considerations for these sprinkler packages.

To assist the cotton irrigation community understand where CP&LM irrigation water has moved to in the soil profile, over 300 images of soil moisture have been developed from a set of 25 capacitance sensors sited under seven different machines, on different soil types, sprinkler types and growing conditions. A set of video images of the different sprinkler types and their interaction with crop and soil under typical field operating conditions have been produced to assist growers in their understanding of the sprinkler options available.

In addition, a simple software package was developed to assist new CP&LM irrigation managers visualise alternate irrigation strategies, and their influence on the resultant soil moisture levels across the irrigated field.

A series of guidelines have been produced for sprinkler package design and soil moisture probe placement on CP&LMs. The sprinkler guidelines will assist the CP&LM irrigation community to understand the importance of sprinkler design and methods to reduce droplet impact energy levels to below that of natural rainfall to reduce surface crusting and sealing. The probe placement guidelines will aid growers and agronomists to work through the important factors in deciding the type and placement of soil moisture monitoring equipment in CP&LM irrigated fields.

To obtain further information on this work or related matters please contact the Director, National Centre for Engineering in Agriculture, University of Southern Queensland, Toowoomba on ph 07 46 311 871 or email on schmidte@usq.edu.au .