LAND AND WATER AUSTRALIA

PROPOSED RESEARCH PROGRAM FOR

BETTER CATCHMENT PLANNING & WATER RESOURCES MANAGEMENT

CASE STUDY

THE NORTHERN MURRAY DARLING BASIN

FINAL REPORT
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EXECUTIVE SUMMARY

Catchment, water resources and agricultural management are undergoing significant and difficult change in the Northern Murray-Darling Basin (NMDB).

(i) Recent Commonwealth, Murray-Darling Basin Commission and State water reform initiatives are redressing the balance between water for the environment and water for consumptive uses. This is having the effect of reducing water available for irrigation. Water pricing is also undergoing change.

(ii) The National Land and Water Audit and MDB Salinity Audit have indicated a significant risk of salinity developing in the dryland parts of the Northern Murray-Darling Basin (NMDB) which will have the effect of degrading stream salinities to the cost of the environment and downstream users. Implementation of the MDBMC's Basin Salinity Management Strategy is requiring catchments to develop end-of-valley (and in-valley) water quality (salinity) targets.

(iii) New information is suggesting that there is a significant risk of salinity developing under the irrigation areas where vertosols (heavy clay soils) predominate. This contradicts current understandings and should salinity occur, it is likely that impacts on land and water will be severe.

(iv) New State water legislation explicitly requires the avoidance of certain forms of environmental degradation including salinity, water logging and water quality impacts. Additionally there is a requirement for the development of Land and Water Management Plans and scope to declare protection zones.

(v) Irrigated agriculture is striving to increase water use efficiencies to increase farm profitability at a time of falling water availability and low commodity prices.

This Report has been developed following the interest of a number of investors who wished to understand the extent that current information will prevent the satisfactory implementation of these new policies, and of achieving sustainable natural resources and agricultural industry outcomes.

A primary aspect of the study has been to identify and appraise these policy, industry and natural resource management drivers and identify and evaluate information needs, identify gaps in understanding and their implications, determine the relative priority of information needs and, develop an R&D proposal to address them.

The conduct and results of this review has focussed on the management of the water balance and, in particular, measurement and management of deep drainage (DD) is emphasised for a number of reasons.

Until recently DD was thought to be close to zero in the vertosol soils of the Northern MDB. There are few studies however where the water balance and the DD component have been directly and accurately measured. Direct measurement is required as the magnitude of the DD term is often exceeded by the error in measurement of other water balance terms and relatively small changes in DD can be highly significant to the overall impact on groundwater and salinity. Recent, more accurate studies are indicating DD rates much higher than previously considered.

This has serious implications for the eventual development of salinity, its impacts on land and water quality as well as mechanisms required for the management of DD.

The structure of this report is to:

(i) Identify the policy, natural resource and industry drivers for better water balance and DD information and provide a prioritisation in order of significance (chapter 2).

(ii) Briefly evaluate a range of current and recent water balance and DD R&D projects and initiatives and identify the need for a catchment approach and coordination issues (chapter 3).

(iii) Identify and prioritise water balance and DD information needs and gaps (chapter 4).

(iv) Present a program proposal and identify and discuss implementation issues for the possible Program (chapter 5)

The Catchment Framework and Overview

A catchment outcomes framework for water balance and DD R&D has been proposed which considers 3 separate but interconnected zones. The Zones are:

- the Catchment level (water quantity and quality outcomes).
- Uplands Landscapes (irrigated agriculture, dryland agriculture and forests both natural and reafforested and, land condition).
- Plains Landscapes (irrigated agriculture, dryland agriculture, and forests both natural and reafforested and, land condition).

Analysis of the drivers for better water balance and DD information shows that there is a strong and urgent demand and justification for additional R&D into water balance and DD particularly for the Plains Landscapes zone. A R&D Program is proposed to address this need.

Policy, Industry and Natural Resource Drivers for Additional Water Balance and DD Information

From discussions with a large cross section of funders, researchers and resource managers (Appendix 2), 16 possible drivers for further water balance and DD information were considered and it was concluded that:

There is wide demand and support for better information on deep drainage. In particular, the need to understand the significance and probable extent of salinity was universally identified as an urgent need.

There is a critical need for better and credible water balance and DD information for:

- determining the significance and scale of the potential salinity problem,
- the effective implementation of NSW and Queensland Water Acts,
- end of valley and in-valley water quality target setting, and
- targeting vegetation retention licencing and revegetation programs.

An important need for better and credible water balance and DD information was also identified for several other high priority national, MDB and State policy and program and industry initiatives including:

- regional salinity planning,
- catchment health targets and monitoring,
- development and implementation of water use efficiency programs, and
- development of sustainable land management practices.

Other significant uses of better information are:

- groundwater licencing, and
- reducing groundwater pollution risk.

Current R&D Activity and Gaps

In reviewing current and recent R&D activities, a significant amount of R&D in Uplands (dryland) landscapes zone was identified. A need for better coordination and integration of these efforts was identified by some and, in passing, this was apparent to the consultants.

There is significant activity in both NSW and Queensland supported by the MDBC, in developing a suite of models from point scale to river and Basin scale in order to prepare end-of-valley and in-valley water quality targets. This work provides a potentially good overall linking mechanism between the water balance and DD R&D in the Uplands and Plains zones previously identified. This work is being funded by States and the MDBC and there is unlikely to be much need for further investment by other investors. There is a need however, for increased linkages with water balance and DD R&D in the Uplands and Plains zones so that results of the R&D is accessed and influenced by these catchment modelling initiatives.

By comparison, there is much less work in the Plains (irrigation and dryland) landscapes and it is here that there is most need for new investment in water balance and DD R&D. Coordination of DD/water balance R&D for the irrigated parts of catchments appears to be much less difficult as there is only the one significant irrigated industry and a small group of research providers.

There is a need for overall coordination and leadership at the catchment scale to ensure R&D effort is linked and contributes to overall catchment outcomes specifically to maintain and where possible improve land and water conditions.

The Program Proposal

A Program is recommended which has a landscape-based approach with 3 semi-independent Sub-Program elements and with overall Program coordination at the catchment scale. This arrangement is shown in the accompanying diagram.

Adoption of Results

There are 2 important aspects to the adoption of water balance and DD results. One is application of the findings through government policies and programs such as the setting of targets, salinity hazard maps, land and water management plans and regional plans. There is a high likelihood that this will occur provided the necessary connections and ownerships are made. The second aspect is that of adoption by industry. This is considered to be moderately high through the implementation of those government polices and programs but there is also good evidence of irrigators in the NMDB adopting practices to improve water use efficiencies once it can be credibly demonstrated that there are significant water balance and DD losses and possible gains.

Proposed Program Structure

GOAL:
Understand the Water Balance and Deep Drainage for Better Catchment Management in the Northern Murray Darling Basin.

CATCHMENT SCALE SUB-PROGRAM OBJECTIVES:
1. To understand the scale of water salinity problems in the NMDB.
2. To contribute to the setting of credible end of valley and in-valley water quality targets.

UPLANDS LANDSCAPES SUB-PROGRAM OBJECTIVES:
1. To understand the future scale of land salinisation.
2. To develop water efficient and profitable agricultural production systems.
3. To provide credible information to salinity hazard mapping and planning.
4. To provide credible information for vegetation polices and programs.
5. To provide credible information for setting of catchment health targets.
6. To provide credible information for the sustainable use of groundwater.

PLAINS LANDSCAPES SUB-PROGRAM OBJECTIVES:
1. To understand the future scale of land salinisation.
2. To develop water efficient and profitable agricultural production systems.
3. To provide credible information to salinity hazard mapping and planning.
4. To provide credible information for vegetation polices and programs.
5. To provide credible information for setting of catchment health targets.
6. To provide credible information for the sustainable use of groundwater.

Understanding Deep Drainage and the Water Balance: To undertake field and laboratory studies and computer modelling to understand the water balance and predict DD in vertosol soils.

Designing Solutions and Responses: Using field studies and computer-based simulations, identify, design and test solutions to reduce DD to within the assimilative capacity of groundwater systems.

Delivery to Stakeholders: To develop products and mechanisms so that Program findings are adopted by primary clients.

OUTCOMES
Effective Achievement of Government Policies / Salinity Managed Effectively / Profitable Agriculture

Sub- Program 1: Uplands (dryland) Landscapes:

This sub-program has two deliverables:

(i) Measurement and prediction of DD from land use and management practices for upland landscapes and, using this information as an input, developing hazard and risk maps as part of the third sub-program. Land uses would include both agricultural and forest (natural and reafforested).

(ii) Provision of DD estimates required by catchment scale groundwater models which can predict catchment impacts of changed DD.

The first of these projects is largely underway in a GRDC and other projects although there may be justification in expanding the 'forests' component of it. The second part is underway in the NSW, Qld and MDBC end-of-valley and in-valley target setting work. The main immediate need is to ensure consistency of methodologies, data standards and exchange, that the approach is comprehensive and resources adequate.

It should be noted that while there is some irrigated agriculture in the Uplands Landscapes this represents only a small percentage of activity and would not warrant R&D investment at this stage.

Sub-Program 2: Plains (irrigation and dryland) Landscapes:

This sub-program is the main area in need of additional R&D for several reasons, including:

- the various audits of salinity appear to have focussed on uplands catchments without recognising the significant risk and impacts from salinity developing in the (Plains) zone.
- the development of shallow watertables is likely to be accelerated due to the increased impact of irrigation on the water balance compared to other land uses.
- limited measurements of DD under irrigation are suggesting that DD rates could be much higher than previously considered likely.
- the cracking nature of vertosols pose special challenges for field measurement and computer modelling of DD. This will necessitate development of new and innovative approaches with a strong science underpinning.
- there is a likelihood that groundwater salinities in these more arid zones will be very high and salinity impacts severe should shallow watertables develop.
- credible information on DD and the farm-level water balance is required so that industry can design and implement targeted programs to raise water use efficiency.

The studies required in this sub-project are:

(i) Sub-regional groundwater modelling in the valleys where there is irrigation to:
   - reconcile any differences between DD measurements and previous estimates from groundwater modelling and watertable behaviour.
   - appraise impacts on land and water conditions if shallow watertables develop.

- estimate DD from common land uses in the zone including irrigated agriculture, dryland cropping, and pasture and forests (native and reafforested).
- investigate groundwater management options (necessary reductions in DD, groundwater pumping).
- evaluate sensitivity of results so that R&D is directed to the most beneficial information needs.

(iii) Measurement and prediction of DD to:

- estimate DD from a range of land uses including irrigated agriculture, dryland cropping, and pasture and forests (native and reafforested).
- provide input into hazard and risk maps of salinity (these are expected to be prepared as part of sub-program 3 but this needs to be confirmed and a commitment obtained).
- enable gaming (exploration of what-if scenarios) of alternative management and policy options.
- undertake sensitivity testing of results so that R&D is directed to the most likely productive information needs.
- input information into land and water management plans.

Sub-Program 3: Catchment hydrology:

This work aims to establish the risk of land and water salinisation by developing and applying models of surface and subsurface hydrology to set, monitor and refine end-of-valley and in-valley water quality targets. An added component of this sub-program will be to develop in partnership with the other sub-programs, catchment scale maps of salinity hazard and risk.

This work is underway as part of the NSW, Qld and MDBC initiative. There is a need to ensure that there is consistency and information interchangeability between this work and the other 2 sub-programs. In particular the other 2 sub-programs are expected to provide credible, field tested DD information for the catchment scale models.

Outline of Recommended Projects

The analysis of the policy, industry and natural resource drivers for DD information resulted in 6 priority projects for funding. These have been broadly scoped (Appendix 6) but need to be developed in detail once a decision to proceed with a program has been made. The recommended projects are:

a. Field studies and site characterisation of the water balance and DD under different land uses, water qualities, Land Mapping Units. A particular focus requiring new approaches is the difficult task of direct measurement of DD on vertosol (cracking clay) soils.
b. Development and testing of computer models for simulating DD from crops grown on vertosols.
c. Evaluation of the farm water balance and water use efficiencies including the impact of water storages and channels.

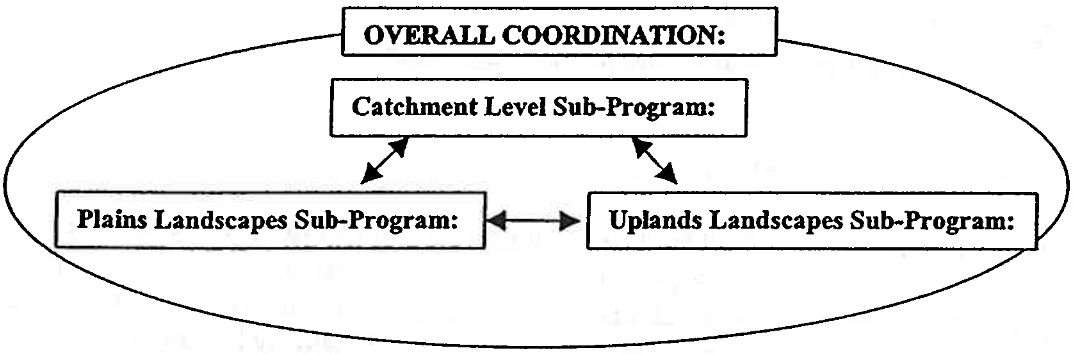
d. District scale groundwater models linking DD to watertable development and impacts.

e. Development of improved water use practices including evaluation of the economics of alternative land uses and of alternative policy and adoption options.

f. Development of catchment flow and salt routing models.

Program Coordination

A number of Program coordination options are considered and a preferred model suggested. An overall coordinating mechanism is recommended which is loosely based on the Pesticides model with sub-Programs being semi-independently coordinated. The recommended overall coordination approach is to ensure integration, consistency and compatibility between the sub-programs as well as deal with issues such as information sharing, standards, and ensuring a continual watch on emerging important information gaps. The suggested arrangements are shown in the following diagram.



Investors will need to review and negotiate the preferred management arrangements including who should take on the lead roles for overall coordination and of the separate sub-programs during the Program initiation phase.

We recommend initially a peak Management Committee to ensure the development, delivery and coordination of the overall Program of research. Initial membership of this body should have a strong representation of user groups and include representatives of funders, key industries, R&D providers, Catchment Management Boards / Committees, and organisations legally responsible for management of the water resource. An important need at this stage is to develop a partnership with shared ownership, clear responsibilities, and formal commitments to the Program.

The convener of this group needs to be an organisation with a Basin wide or national perspective and with a strong natural resource management and government policy perspective. It is expected that the committee will take a lead role in developing the overall strategic approach and consequent business/implementation plan, approving project proposals and ensuring projects focus on outcomes and user needs (eg. using the layout from Figures 4.2 and 4.3), setting of performance objectives and milestones, approval and oversight of budgets, and monitoring progress including adaptation of the approach as required.

Once commitment to the program is agreed, we strongly recommend Sub-Program Committees for each of the 3 sub-Programs. These would include representatives of specific funders, R&D providers, local CMB's, and the legal manager of the water resource. These sub-Program committees would ensure the execution of the respective sub-programs on a more day to day basis.

Co-Investors and Project Participants

Possible co-investors and participants in a future Program are identified. A preliminary list of possible participants is shown in the following Table.

Organisation	Potential Funder	Potential R&D Provider	Potential Information User/Client
State agencies	✓	✓	✓
CMB	✓		✓
CSIRO	✓	✓	
LWA/Industry	✓		✓
MDBC	✓		✓
GRDC/Industry	✓		✓
CRDC/Industry	✓		✓
RIRDC/Industry	✓		✓
ACCRC/Industry	✓	✓	✓
MLA/Industry	✓		✓
AHC/Industry	✓		✓
AWBC/Industry	✓		✓
Universities	✓	✓	
CRCCH	✓	✓	
CRCPBMDS	✓	✓	

Implementation Process

Following acceptance of this report, the following indicative process could be considered for implementing the Program.

STAGE	TASKS
Core management group (LWA, MDBC, CRDC, GRDC) agree whether to proceed	Core group agree whether to proceed and in-principle agreement to fund. Finalise the strategy and plan for developing the Program. Preliminary discussion of roles.
Investors agree interest and roles.	Discussions held with the range of possible investors and clients. Investors agree indicative levels of involvement, investment, roles, expectations /constraints to involvement.
Initial Program Planning Coordination Meeting **(Funders, researchers, end users)**	• Agreement of Program and sub-Program objectives. • Discussion of current R&D and R&D needs for sub-programs. • Consideration of end user needs, requirements and end products (using formats from Figures 4.2 and 4.3).

	• Agreement of scope of sub-program areas. • Identification of data sharing issues including protocols standards. • Adoption and communication planning. • Review of indicative roles
Detailed Planning through Separate Sub-Program Workshops **(Funders, researchers, end users)**	Detailed: • Review of current R&D initiatives. • Review of end user needs and specific product requirements. • Planning of R&D to meet end user needs. • Identification of data requirements, methodologies and data standards issues and resolution needs. • Identification of milestones, deliverables and products. • Further development of adoption and communication plan.
Program agreement.	Co-investors and R&D Providers review, negotiate and agree: • Overall Program ensuring any R&D gaps avoided. • Projects (including communication and adoption plans). • Funding contributions. • Administrative, reporting, project management arrangements agreed. • Providers identified by commissioning or tendering as appropriate. • Formal management agreements and MoU's.
Projects Implementation	
Progress Reviews	Annual (or more frequent) meetings at Program and sub-Program levels to review progress, share information, identify gaps and emerging needs, identify constraints and opportunities.
Program Completion	

Recommendations

1. There is a strong and urgent need as well as wide support for funding a significant R&D Program focussing on understanding the water balance and Deep Drainage for better catchment, water resource and agricultural outcomes in the NMDB.

2. Whilst this review has focussed on the northern MDB, it also has application to other areas in Australia where vertosol soils predominate.

3. There also appears to be a need to develop a similar program of user driven R&D for the southern MDB. The results of this recommended R&D Program however, do not transfer directly to the southern MDB bio-region due to different industry, policy and bio-physical conditions.

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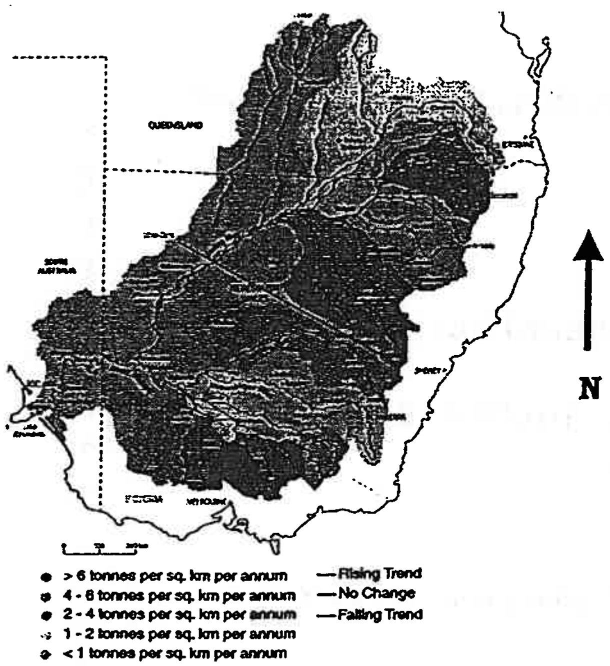
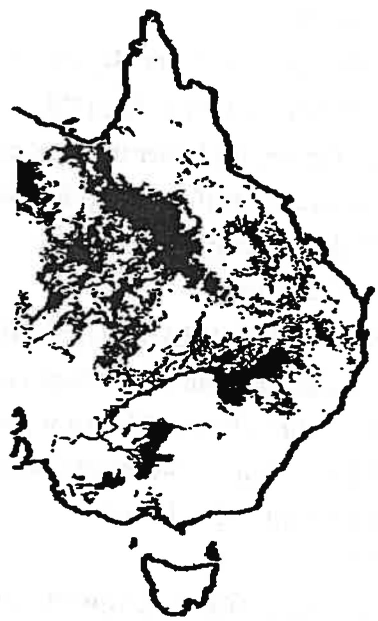
LOCATION AND SOILS OF STUDY AREA

The study area corresponds to the northern Murray Darling Basin and broadly corresponds to that area north of the line on the following map. The map also indicates the MDB catchments, their salinity generation risk rating, and estimated trends in water quality.

(i) Location of Study Area in Northern MDB



(ii) Vertosol soils in Eastern Australia



Location of Vertosols in Eastern Australia

The primary soils of technical interest in the study area are vertosols. The location of these soils in relation to the study area and more widely throughout eastern Australia is shown in the following map. These are the most important soils in Australian cotton growing areas.

These soils have strong shrink and swell characteristics and exhibit strong cracking throughout the soil profile as they dry. They also have well-developed internal structure (slickensides) and preferred flow pathways for water due to the strong cracking behaviour. Australia has the greatest area and diversity of cracking clay soils of any country in the world Isbell (1996). The cracking and structured nature of these soils are especially challenging to study either by indirect or indirect measurement or to model because of their cracking and structured characteristics.

ABREVIATIONS USED

ACCRCWG,	Australian Cotton Cooperative Research Centre
ACCRC	Cotton Cooperative Research Centre
AHC	Australian Horticulture Corporation
ARRIP	Research database on agriculture and natural resources research
AWBC	Australian Wine and Brandy Corporation
AWI	Australian Wool Innovation
BRS	Commonwealth Bureau of Rural Sciences
CMB	Catchment Management Boards, NSW
CRCCH	CRC for Catchment Hydrology
CRDC	Cotton Research and Development Corporation
CRCPBMDS	CRC for Plant Based Management of Dryland Salinity Corporation
DD	Deep Drainage
DLWC	NSW Department of Land and Water Conservation
ESIF	NSW Environmental Services Investment Fund
EC	Electrical Conductivity
GRDC	Grains R&D Corporation
ICM	Integrated Catchment Management
IQQM	Integrated Quantity and Quality Model developed by NSW DLWC
LMU	Land Mapping Unit
LWA	Land and Water Australia
MDB	Murray-Darling Basin
MDBC	Murray-Darling Basin Commission
MDBMC	Murray-Darling Basin Ministerial Council
MLA	Meat and Livestock Australia
NAP	National Action Plan for Salinity and Water Quality
NDSP	Land and Water Australia's National Dryland Salinity Program
NHT	Natural Heritage Trust
NMDB	Northern Murray-Darling Basin
NPIRD	National Program for Irrigation Research and Development
QDNRM	Queensland Department of Natural Resources and Mines
R&D	Research and Development
RD&E	Research, Development and Extension
RIRDC	Rural Industries R&D Corporation
SGS	MLA Sustainable Grazing Systems Project (1997-2002)
WB	Water Balance
WRDC	Wine Research and Development Corporation
WUE	Water Use Efficiency

1. INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Catchment Planning and Water Resources Management in the NMDB

Catchment, water resources and agricultural management are undergoing significant, rapid and difficult change in the Northern Murray-Darling Basin (NMDB).

(i) Recent Commonwealth, Murray-Darling Basin Commission and State water reform initiatives are redressing the balance between water for the environment and water for consumptive uses. This is having the effect of reducing water available for irrigation. Water pricing is also undergoing change.

(ii) Both New South Wales and Queensland have introduced new Water Acts in response to the COAG water reform agenda. Implementation of the legislation has the effect of requiring the avoidance of certain forms of environmental degradation including salinity, water logging and water quality impacts. Additionally there is a requirement for the development of Land and Water Management Plans and scope to declare protection zones.

(iii) The National Land and Water Audit and MDB Salinity Audit have indicated a significant risk of salinity developing in the dryland parts of the Northern Murray-Darling Basin (NMDB) which will have the effect of degrading stream salinities to the cost of the environment and downstream users including irrigators. Implementation of the MDBMC's Basin Salinity Management Strategy is requiring catchments to develop end-of-valley (and in-valley) water quality (salinity) targets.

(iv) New information is suggesting that there could be a risk of salinity developing under the irrigation areas where vertosols (cracking clay soils) predominate. This contradicts current understandings and should salinity occur, it is likely that impacts on land and water will be severe as groundwater salinities in this zone can be extremely high.

(v) Commonwealth and State policy initiatives are requiring the development of salinity and water quality management strategies in the catchments of the NMDB. In addition, States are implementing new community-based, catchment governance arrangements which require the development of broadly based catchment management plans.

(vi) Irrigated agriculture is striving to increase water use efficiencies to increase farm profitability at a time of falling water availability and low commodity prices.

Many stakeholders are concerned that soil-water processes in vertosol soils are not well understood, readily measured or modelled. This restricts understanding the cause of natural resource problems and how they might be better managed. This lack of information might also prevent implementation of new policies, and sustainable natural resource and industry outcomes.

Salinity as an Emerging Issue in the NMDB

The northern MDB is a highly productive agricultural area and is the centre of the Australian cotton industry. Irrigated cotton is the major user of irrigation water (mostly surface but also groundwater) in the region. Dryland agriculture includes cropping, livestock production and some wool production.

Salinity of land and water resources has been a significant problem in the southern MDB for several decades. However in the northern MDB, climate, soils and land use are significantly different. The heavy, swelling clay soils which exhibit symptoms of poor internal drainage, and the lack of extensive shallow watertables has led to the belief that there is little deep drainage and hence little risk of eventual salinity problems.

In recent years however, a number of technical studies of deep drainage as well as the National Land and Water Audit and the MBD Salinity Audit have indicated a strong likelihood of the eventual development of shallow watertables in some northern MDB uplands catchments with consequent land, water and environmental degradation.

In response to these findings the 'National Action Plan for Salinity and Water Quality' has identified several northern MDB catchments for attention. The MDBC is also instituting a system of end of valley water quality targets and is capping water diversions, whilst States have introduced new Water Acts reducing many surface and groundwater licences. The impact of this will be to reduce water availability for irrigation in many regions and probably require changed land management practices to meet end of valley water quality targets. It is noteworthy that these targets and initiatives have not considered development of shallow watertables and salinity in the irrigation areas of NMDB to be an issue.

There is now evidence of more extensive shallow watertables and salinity in the irrigated regions of Macquarie valley and the Darling River near Bourke. Isolated and apparently localised areas of saline soils have been identified in other irrigated areas. Groundwater salinities in some of the cotton growing areas are very high (seawater) and so any outbreaks of salinity will have severe consequences of land and water conditions.

The key factor determining the emergence of salinity problems is the balance between groundwater recharge (deep drainage) from all land uses and the capacity of the groundwater system (and abstractions), at local and regional scales, to cope with increased recharge without significant land or water salinisation impact.

Groundwater is widely used for irrigation in the NMDB. In many areas, groundwater pressures and yields are falling suggesting that shallow watertables and salinity will not become endemic. However, there are differing views on the degree of connectivity between shallow and deep groundwater systems and monitoring is concentrated in the deep (water supply) aquifers. There is some evidence in different regions of the development of shallow, perched watertables above depleting or static aquifer pressures.

Deep drainage needs to be recognised as part of the overall hydrological system and balance where, depending upon local conditions, changes in one component, such as deep drainage, can have either positive or negative impacts on other components such as run-off, stream baseflow, groundwater storage and quality, plant water use or evaporative losses from watertables.

Catchment and Water Resources Management and the Understanding of the WB & DD

Catchment, water resources and agricultural industry outcomes are heavily influenced by management of the water balance. In particular, the so-called leakiness of current farming systems is a most important determinant of salinity development and water quality outcomes.

Until recently, it was believed that the leakiness (DD) of dryland and irrigated farming systems on vertosol (cracking clay) soils was negligible. This conclusion however was not based on the direct measurement of DD but rather as DD being the parameter required to close water balance studies. The risk from this approach however, is that errors in the measurement of the other components of the water balance can be of the same or larger magnitude than the DD term itself. In addition, relatively small changes in DD can be significant to groundwater response and hence the significance of any salinity problem.

Some recent investigations have questioned these previous understandings of DD.

Relevant technical investigations of DD under irrigation in the northern MDB have occurred so far, at a relatively limited number of sites for limited periods. A number of recent but limited studies have shown that DD is significant and much higher than previously believed. For example Silburn and Montgomery (2001, in progress) cite a number of direct and circumstantial estimates of DD and suggest that DD under irrigation is typically of the order of 100mm to 200 mm/year (and up to 700 mm/year on some light soils) compared to less than 10 mm/y from similar non-irrigated sites. This has obvious implications for land and water salinity risk (and groundwater pollution) in these areas and also suggests that the current focus on dryland salinity needs to be broadened. As a consequence, the suite of Land Mapping Units (LMU) (soils, land use, geology) and climatic events (particularly large episodic events) have not been studied or integrated sufficiently at a catchment scale to give an adequate picture of system behaviour.

Ideally our capacity to model DD for various land uses and climates would enable ready and reasonably confident prediction of DD for various LMU across the catchments. However, the highly cracking nature of vertosols does not conform to conventional models of soil-water movement. As well, direct and indirect measurement of DD difficult is difficult where soils are highly cracking.

A national workshop was held recently on 'Modelling Water Movement in Cracking Soils (Bethune and Kirby, 2001). The workshop identified:

- the poor ability of current models to simulate DD from cracking soils,
- a lack of field studies on cracking soils with closed water balances,
- the need for standards and guidelines for datasets.

The need for a multi-pronged approach to determining DD is exemplified by a number of separate studies in the NMDB where there are significant differences in estimates from different approaches. For example, estimates of DD using root zone hydrology methods versus estimates arising from regional groundwater models are significantly different, and some partial water balance studies have suggested high DD losses which have not been consistent with observation.

Previous Formulation of a Water Balance R&D Program for Cotton Growing Areas

Concern with the water balance in the northern MDB has existed at least since the mid 1990's. At this time Brian Hearn's work "Benchmarking Water Use on Farm – If you don't measure it, you can't manage it" highlighted the lack of reliable data and the need to identify the magnitude of all the components:

- Inputs (rain, irrigation etc.)
- Consumptive uses (eg domestic, crops, stock, etc)
- Deep Drainage
- Evaporation and,
- Run-off

A "Cotton Water Balance Workshop" was held in Toowoomba in October, 1999 in recognition of the risks and potential economic and environmental gains of managing the water balance well. This workshop agreed that a joint research program was required to:

(a) understand the processes involved, and
(b) better measure each of the components of the water balance.

A meeting with potential research providers was held in Sydney in May, 2000 on "Water Balance Research Coordination". Four main elements of the potential program were suggested:

(i) A comprehensive research program to address generic water balance research needs.
(ii) A fine tuning of the terminology and science used.
(iii) Monitoring and measuring the impact of irrigation on a landscape scale.
(iv) Measurement and improvement of the uptake, adoption and consequences of relevant irrigation technology.

Following this meeting, a Working Group was formed within the Australian Cotton Cooperative Research Centre, Narrabri. This Working Group then formulated an integrated research program proposal "Managing Deep Drainage in Agricultural Systems in Northern New South Wales and Southern Queensland." A number of projects have resulted from this initiative including this scoping study.

The benefits of such an approach would ultimately include sustainable agricultural industries that avoid the environmental consequences of shallow watertables with substantial benefits to regional conditions and communities and the regional environment.

1.2 Review Terms of Reference

The study is to:

- Scope the inter-relationships between deep drainage, catchment water balance and a range of natural resource management issues in the Northern Murray Darling Basin. The study should include consideration of possible impacts from different landuses (eg irrigation, dryland farming, native vegetation and forestry) and different agricultural management practices, on processes likely to be affected by deep drainage (such as soil and water salinisation, surface and sub-surface water quality, and river health). It should review the effectiveness of associated tools, models, management guidelines and planning provisions in managing those potential resource impacts and identify short-comings due to a lack of understanding of deep drainage.

- In consultation with research purchasers, research providers and service providers, (primarily those associated with irrigated production, dryland production or with natural resource management) identify gaps in the understanding of deep drainage and the implications of these gaps, determine their relative priority and develop a R&D proposal to tackle them.
- Propose a suitable structure for the administration of a program(s) that will address these priorities and a model for investment in them.

1.3 Methods

This report was developed by the consultant team in consultation with the LWA project Manager and with assistance provided by the Steering Committee. The Steering Committee comprised representatives from Land and Water Australia, Murray-Darling Basin Commission, ACCRC, NSW Agriculture, New South Wales Department of Land and Water Conservation, Queensland Department of Natural Resources and Mines, Queensland Department of Primary Industry, Cotton RDC, and CSIRO. A smaller Management Committee met twice by teleconference, once at the start to review and refine the approach proposed and a second time to review and early draft of this Background Report. The members of each group are identified in Appendix 1.

Over 40 stakeholders were interviewed to determine:

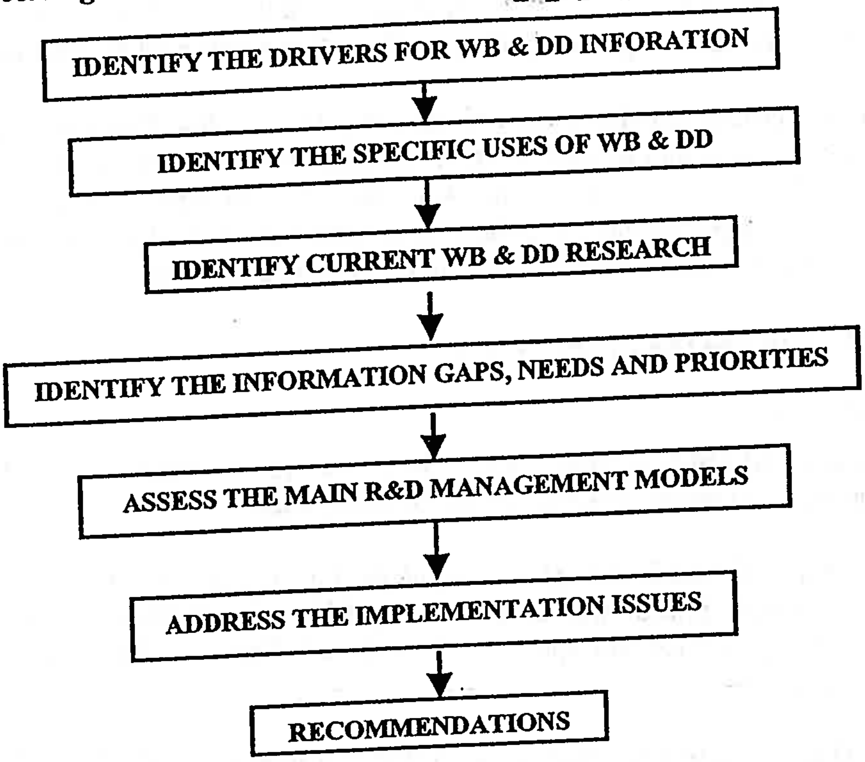
- Drivers for water balance and DD research;
- Specific impacts of lack of water balance and DD information;
- Specific information needs to address issues identified;
- Potential management models; and
- Administration issues for each potential management model.

People consulted are identified in Appendix 2. A copy of the interview format is included in Appendix 3.

1.4 PROJECT LOGIC AND REPORT STRUCTURE

The project logic for this study is shown in Figure 1.2. This report also broadly follows this structure.

Figure 1.2: Project Logic and Report Structure



2. POLICY, INDUSTRY AND NATURAL RESOURCE DRIVERS FOR WATER BALANCE AND DEEP DRAINAGE INFORMATION

A wide range of stakeholders were consulted to identify and prioritise the issues and drivers where improved information on deep drainage and the water balance is important to end users.

Key policies and other uses of WB & DD information are described in the following sections and our view of the relative importance of DD information needs summarised in Figure 2.2.

Many government policy initiatives and reforms, target the sustainable use of land and water resources so that use is within the assimilative capacity of the natural environment. Effective implementation of many of these initiatives require at least some understanding of deep drainage, including implications for policy objectives (and catchment outcomes) and the feasibility of improving natural resource outcomes by managing deep drainage.

2.1 DRIVERS FOR BETTER INFORMATION

MDBMC ICM Policy

As the overarching MDBMC strategy, the ICM Policy is an important and fairly specific indicator of future government policies and funding priorities.

The Policy '*Integrated Catchment Management in the Murray-Darling Basin 2001-2010-delivering a sustainable future*' was agreed by the Ministerial Council in mid 2001. The policy identifies the priorities and approach for future MDBC activities including research and on-ground action.

Strategies and Targets are to be developed according to a specific timetable for Water Quality, Water Sharing, Riverine Ecosystems, Terrestrial Biodiversity and Catchment Health (Figure 2.1). Targets will be set on the basis of assets to be protected, involve all partners, use reasonable timeframes, have clear accountabilities, and be integrated.

Figure 2.1: MDBMC ICM Policy Targets

ISSUE	TARGET TIMEFRAME
Water quality, (surface water and groundwater)	End-of-valley targets for in-stream salinity in each major catchment by 2001 (Basin Salinity Strategy).
	Nutrient targets for each major catchment by 2003
Water sharing, including surface water and groundwater	Cap on diversions agreed for NSW, Victoria and SA in 1995. Interim targets for environmental flows for River Murray by 2002.
	Targets for each major catchment by 2006
Riverine Ecosystem Health	Work to determine appropriate targets to be undertaken by 2006. Targets in place by 2006.
Terrestrial biodiversity	Work to determine appropriate targets to be undertaken by 2006. Targets in place by 2006. Interim targets for native vegetation in each major catchment by 2002
Catchment Health	Framework for catchment health to be in place by 2008

Change will be achieved and monitored through stronger institutional arrangements and accountabilities, integrating land use planning and catchment planning, targeted use of market mechanisms to drive change, accreditation of catchment strategies and plans, reporting to the MDBMC and Australian public.

MDBC Cap on Water Diversions

The purpose of the Cap is to:

- establish long-term diversion caps from rivers within the Murray-Darling Basin, in order to protect and enhance the Riverine environment;
- set out action to be taken by the Ministerial Council, the Commission and State Contracting Governments to quantify and comply with annual diversion targets; and
- prescribe arrangements for monitoring and reporting upon action taken by State Contracting Governments to comply with annual diversion targets.

Implementing the cap is the responsibility of the different States (see State Water Policy Reform). At a Basin level, DD information is considered to be of low importance for implementation of the Cap.

State Water Policy Reforms

Implementation of the Cap (and the associated COAG water reform initiative) is the responsibility of the States. NSW and Qld are at different stages of the reform process for historical reasons such as heavier diversion licence commitments on NSW streams and the Queensland Water Allocation Management Planning (WAMP) process.

Both States have introduced new Water Management Acts and are undergoing a difficult period of reform because diversion licences on many streams and groundwater systems will be significantly reduced. The Acts have a number of aspects relevant to DD and Catchment Planning. The NSW Act separates irrigation licences into 'access' and 'use' components. The 'use' component is tied to the land parcel and will identify acceptable water management practices. The Act lists a number of forms of land degradation to be avoided including salinity, waterlogging, deep drainage and water quality impacts. A key requirement of the Act is that new (and some existing) developments will require a 'Water Use and Works Approvals' which includes the need for a property based plan. The Act also provides scope for declaration of protection zones. Although the process for providing licence approvals is currently being developed, a crucial requirement will be salinity and waterlogging risk assessments and hazard maps (eg. soils, groundwater conditions, risks of undertaking certain land use practices) as well as understanding management and cultural practices that can reduce this risk. Credible information on DD and the links to acceptable and unacceptable impacts (cause-effect) will be essential for effective implementation of these aspects

The Queensland Act also targets reform of its rural water industry. Development of water sharing bulk allocations between users (including the environment) at a valley level are being developed by the WAMP process and are expected to lead to declining access to water. The allocation and revision of individual licences will require more detailed study. The new Act requires new licences and trading of water to take place within the context of a farm-based Land and Water Management Plan and adoption of BMP's which must take into account salinity, groundwater and water quality impacts. Again, reliable information on DD is essential to the effective implementation of this aspect.

Salinity and End of Valley Targets

This MDBC Strategy is the first MDBC Strategy to be rolled out within the new ICM Policy and sets a Basin level framework for managing water quality (salinity). The objectives of this Strategy are to:

- maintain the water quality of the shared water resources of the Murray and Darling Rivers for all beneficial uses—agricultural, environmental, urban, industrial and recreational;
- control the rise in salt loads in all tributary rivers of the Basin and, through that control, protect their water resources and aquatic ecosystems at agreed levels;
- control land degradation and protect important terrestrial ecosystems, productive farm land, cultural heritage, and built infrastructure at agreed levels Basin-wide; and
- maximise net benefits from salinity control across the Basin.

The means of achieving these objectives are the development and application of targets (less than 800 EC for 95% of the time at Morgan) for the shared (River Murray and the Darling River downstream of Menindee) water resources, end of valley targets for each main tributary valley (salt load and flow) and targets for other Basin-wide values and assets (State within-valley management targets).

The principal responsibility for developing and implementing the targets rests with the respective States with the MDBC taking a monitoring and auditing role in addition to the management of the shared resource.

Whilst there are interim end of valley targets, the information underpinning these targets for the northern MDB is believed by many to be scant. Major shortcomings include limited understanding of groundwater systems, current watertable levels, their rate of change, rates of recharge under current or alternative land uses, and limited predictive capacity for translation of shallow watertables into salt affected land and salt discharge to streams.

Revised end-of-valley targets are to be finalised for NSW by March 2002 and for Queensland by 2004. Both NSW and Qld have studies in place to develop these targets. Current studies at both MDB and State levels are focussed on the uplands part of catchments and have not yet factored in possible salt loads from the plains (irrigated and dryland areas). It is essential that risks to stream water quality from these areas be considered because of their close proximity to streams and possibly high salinities (of the order of sea water) that could enter streams.

NSW has commenced a large State funded computer modelling initiative to support development of maps of recharge potential for regional and property planning, and for setting of water quality targets. More detail of this is given in the section dealing with R&D.

In Qld, investigation and characterisation of catchment groundwater systems including installation of bore networks in deep and shallow systems are being made to determine the risk of groundwater salinity. This information will be used in a suite of models to develop end–of-valley and in-valley targets in a similar way as in NSW.

Irrigation areas are important sinks for salt through the water diverted for irrigation. These sinks will become more important in order for valleys to meet end-of-valley and in-valley targets. There are important questions regarding the long term sustainability of irrigation areas in these circumstances. Issues include whether the soils can meet the increased leaching requirement (DD) as water salinities increase; and, the implications for district salt and water balances and sustainability.

As river salinity becomes more saline, there is a strong likelihood, due to electrolyte effects from more saline irrigation water, of increased DD from fields and water storages. For similar reasons it is likely that DD will be higher where groundwater is used. Studies of the extent of this effect and then extrapolation into district scale studies of watertable and salinity responses are important. Whilst laboratory studies are important, it is essential that these effects be studied on undisturbed, structured soil profiles.

Developing reliable DD information and calibrating models is important to the development of targets, and district salinity management plans as well as giving greater confidence to community interest groups.

Catchment Health Targets

The Catchment Boards in NSW are currently developing their catchment strategies/ blueprints. It has been common for the Boards (as well as in other states) to identify 'reduction in recharge' as a catchment target and performance indicator. However lack of information on current / base rates of recharge (DD), and its importance and the significance in particular catchments or parts of catchments, means that the practicality of using this as a target is problematic. Better information and mechanisms are required to:

- Provide the catchment context (surface and groundwater systems; quality and quantity issues)
- Confidently predict DD under current land management systems.
- Confidently predict DD under alternative land uses and management.
- Design landscapes for integrated land and water objectives (for example the current paradigm of mimicking natural systems may exacerbate water quality degradation and flows in some circumstances)

Catchment planning and catchment health targets could proceed in the absence of better DD information. However reliable DD information and a capacity to apply it across the landscape is an important requirement for better plans and more meaningful catchment health targets.

Regional Salinity Planning

Development of Salinity Management Plans is a priority activity under the Commonwealth NAP and MDBC and State Salinity Programs.

An essential input into these Plans is the development of salinity hazard (groundwater levels, quality, trends, and salt storage); and risk maps (DD for current and alternative land uses and management practices) as well as an understanding of the costs, benefits and feasibility of the alternative management options. An understanding of the levels of uncertainties in such mapping and analysis is important.

Understanding DD under various land uses with models that enable DD simulation will provide the basis for evaluating management and policy options.

Improving Farm Water Use Efficiency and Water Use Efficiency Programs

Improving water use efficiency is a relevant consideration to improving farm profitability and environmental outcomes (reduced recharge and/or reduced tail-water runoff) as well as indicating an industry's responsible environmental credentials. It was also suggested that improving irrigation efficiencies will result in greater environmental flows although this is unlikely to eventuate unless government or a third party steps in to purchase or claw back water saved.

The current average irrigation application efficiency on cotton farms (Hamilton, in discussion) is of the order of 70% whilst best practice is 90% and with trickle irrigation 92-93% is thought to be possible. Other studies (eg. Tennakoon, also Dalton see Project 4, Section 3.1) have found farm efficiencies of less than 60%. Increasing the average industry from 70% to 85% is considered a realistic goal. This translates into an increased irrigated area of about 20% for a given quota of water. Other likely benefits include reduced freely available water in the hydrological system which can carry pollutants and raise watertables.

Both NSW and Queensland water reform processes will result in less water for consumptive uses. In order to assist farms make adjustments to a more water limited environment both governments have water use efficiency programs. These WUE Programs are ready end-users of the results of DD research.

It is essential for these programs, that it is understood where losses are occurring on-farm (eg. field, channels, storages, particular soil types and management practices). This information can readily feed into established cotton industry Best Practice Guidelines. Better DD information is an important input into improving farm WUE and the effectiveness of farm WUE Programs.

Improving Farm Profitability

Agricultural productivity per unit of water will increase as water is used more efficiently and water losses decrease. Adoption of more water efficient practices will normally follow subject to the investment needed being less than the value of the increased production.

The industry is currently striving to increase farm profitability and water use efficiencies because of the decreasing availability of water from water reforms as well as current low commodity prices.

DD information is considered to be of moderate importance as a driver of change in relation to farm profitability. The availability of economic, convenient and labour saving technology are probably more important factors to adoption of improved practices by irrigators. The key issue that will drive adoption however are practices which lead to significant reductions in production costs.

Groundwater Licencing

Groundwater licences are being revised in the northern MDB. In some catchments, they are to be reduced substantially (eg. by 80%). Licences are being based on determinations of the sustainable yield of the aquifers using pump tests, groundwater modelling and monitoring of the supply aquifer. Knowledge of deep drainage rates is important to developing these licences. However the ultimate licencing levels will be based on groundwater behaviour observed by direct monitoring. An understanding of the likely impact of extensive land management changes to groundwater recharge would provide an early signal of possible emerging problems to the resource base and a need for licence revisions.

Groundwater Pollution

Until recently, groundwater pollution has not been considered to be a major risk. In the absence of extensive groundwater sampling programs, this was based on the belief that DD was small and that most chemicals used were absorbed onto soil particles. If however DD is much higher than previously thought, then the risk of pollution becomes higher. There is enough evidence (nitrates- apparently from feedlots and urban septic systems and atrazine in some places) to suggest the need for a detailed risk analysis and risk management plan even in the absence of DD information.

Vegetation Clearance Policy, Plans and Licences

Both NSW and Queensland have native vegetation retention policies and licences. Along with bio-diversity considerations, consideration of salinity risk should be a primary input into decisions about vegetation clearance plans and licences. A key input (along with factors such as groundwater salinity and hydrogeology) into the salinity risk assessment will be the change to groundwater recharge (DD) following clearing. It is important that there be better DD information to clarify the importance and level of risk from vegetation clearing.

A significant concern identified during interviews was that an excessively cautious approach is taken in issuing licences because there is no DD information to objectively identify high value vegetation from a salinity perspective.

Targeting Revegetation Programs

There are a number of government policy initiatives including funding programs such as NHT, Greenhouse Abatement, market/tender systems which target revegetation to high impact parts of the landscape, and vegetation banks, which aim to increase the area of forest in the landscape. Information on DD under different land management units, climatic conditions and land uses is required for these schemes to be most effective. These initiatives are expected to focus on upland, dryland salinity catchments where rainfall is higher and where dryland salinity is of concern into the foreseeable future.

River Health and Riverine Health Targets

Improving river and riverine health is a priority of government funding programs. Under the MDBMC ICM Policy, targets for riverine ecosystem health are to be set throughout the MDB. Water, watertables and stream water quality are important in the following ways:

- Streamflow is one of the most important factors determining stream condition where bed and bank are still in reasonable condition. Knowledge of DD is unimportant here as more efficient irrigation is unlikely to result in more water for the environment without government intervention to purchase or 'claw back' water.
- Shallow watertables if saline, will degrade riparian vegetation and also cause saline seepage into the river. In some circumstances, this can result in highly saline pools beyond the capacity of freshwater fish to survive.

Overall we consider that better information on DD is of relatively minor importance to achieving this outcome.

Terrestrial Bio-diversity targets

Terrestrial biodiversity targets are to be developed as part of the MDBMC ICM Policy. An understanding of salinity risks to high bio-diversity value stands of vegetation could be an input into the setting of bio-diversity targets. As such, DD information could be indirectly relevant to setting these targets and to implementing strategies to reduce the salinity risk.

Knowledge of DD is not considered to be of major importance or immediacy to the setting of these targets.

Sustainable Land Management Practices

Sustainable land management is of major importance to the industry as evidenced by their on-going development of the Cotton BMP manual and interest in Environmental Management Systems. Sustainable management of the natural estate is also important for regional and national communities. Indicators of sustainable land management are likely to be included when targets for catchment health are developed as outlined earlier. DD is likely to be a main determinant of the classification of the sustainability of agricultural systems.

Some interviews also identified the need for industry to demonstrate that it is meeting its duty of care obligations. Again DD would be an important input into meeting this need.

Demonstrating the Significance and Scale of Salinity and Water Management Problems

A number of the interviews indicated that until recently it was believed that DD was not a problem for the vertosol soils of the Northern MDB. Whilst there is now the recognition that DD may be a possibility, it will only become accepted as a problem by industry and the wider community if it is proven by rigorous technical study. Similarly it was indicated that community acceptance of computer generated results will only be accepted if they can be shown to be consistent with direct field measurement. Credible estimates of DD and credible computer models of water and salt movement are therefore crucial to demonstrate to the community, the scale and scope of the problem so that the community is then willing to participate in salinity management planning and implementation.

2.2 Overview of Interview Responses

Salinity Management: The most common and important reason for having better DD information was for salinity management purposes (ie. will salinity be a major problem), and the development of salinity hazard maps for planning purposes. This issue was identified as a high priority by virtually all people interviewed.

Farm Water Use Efficiency Programs: It is widely held that better information is required so that better education and extension programs can be developed in order to improve industry performance and duty of care and that these programs are an immediate end user of the R&D results. Whilst the focus here was on field performance, the need to understand DD at a farm level (dams and channels) was also identified.

Optimising Farming Systems to Maximise Production and Minimise Environmental Impacts: A better understanding of DD under land use systems (forestry, grazing, dryland agriculture and irrigated agriculture) will greatly assist the development of production systems with minimal environmental impact both on and off-farm. New simple and reliable DD measurement and prediction methods are required to develop and optimise such systems.

Nutrient and Pesticide Accessions to Groundwater: There is both an environmental and production element to this concern. Again better DD prediction and measurement under various management options is required.

State Water Reforms (Water Acts): The need for salinity hazard maps to enable the development of land and water management plans in order to meet the requirements of the legislation resulting from these reforms was identified as an important priority need by those people interviewed who were aware of these changes and what would be required.

Development of End of Valley Water Quality Targets: This was seen by most people interviewed as an important issue that requires better DD information.

Native Vegetation Management: There were mixed responses to this issue. For those not involved in vegetation planning there were relatively few unprompted responses that identified a better understanding of the changes to deep drainage under native vegetation to be important. Once prompted it was agreed that understanding the baseline was important as well as consideration of DD in preparing vegetation clearing plans, licences and land use planning. For those involved in vegetation planning, this issue was seen as of great importance. Some expressed a major concern that lack of DD information has meant that excessively conservative (precautionary) decisions were being made in issuing licences.

Riparian Health: This was generally not seen as a significant issue other than that water quality and the condition of riparian vegetation will be casualties of shallow saline watertables if and when they become endemic.

Industry Duty of Care: Some responses indicated that it was important for the industry to demonstrate its duty of care for water use and that this would be best achieved by it undertaking DD research to include in its Best Practice Manual.

2.3 Importance of Drivers

Figure 2.2 lists the issues that were identified as important users of WB & DD drainage information during interviews.

Figure 2.2: Importance of DD In formation to Drivers as Requiring Better DD Information (5= highly important, 1= unimportant). The relative priority placed against each is based on the consultants' subjective integration of interviewee responses and knowledge of the various drivers.

Driver Identified	Importance of DD information
MDBC Cap/water sharing	2
Implementation of State Water Reform	5
Salinity Strategies- End of Valley Targets	5
Catchment Health Targets	4
Regional Salinity Planning (eg. salinity hazard maps, land use)	4
Improving Field Water Use Efficiency and Water Use Efficiency Programs	4
Improving Farm Profitability	3
Groundwater Licencing	3
Groundwater Pollution	3
Vegetation Clearance Policy and Plans	5
Targeting Revegetation Programs (GAP, Vegetation Banks, Auction Systems)	4
Riverine Health Targets	2
Terrestrial Biodiversity Targets	1
Sustainable Land Management Practices	4
Demonstrating the significance of the salinity and water management problems	5
Demonstrating and Industry Duty of Care	2

2.4 CONCLUSION

There is wide support and demand for better information on deep drainage. We conclude that there is a critical need for better and credible WB & DD information for:

- determining the significance and scale of the salinity problem.
- the effective implementation of NSW and Queensland Water Acts.
- end-of-valley and in-valley water quality target setting.
- development of sustainable land management practices.
- targeting vegetation retention licencing and revegetation programs.

An important need for better and credible WB & DD information is also required for several other high priority national, MDB and State policy and program and industry initiatives including:

- regional salinity planning.
- catchment health targets and monitoring.
- development and implementation of water use efficiency programs.

Other significant uses of better information are:

- groundwater licencing.
- reducing groundwater pollution risk.

3. CURRENT WATER BALANCE & DEEP DRAINAGE R&D AND R&D INITIATIVES

3.1 CURRENT STUDIES AND PROPOSALS

Information on pertinent current and immediate past R&D was collected during interviews and from a search of research databases. Interviews included relevant project/program managers responsible for R&D that was thought to be highly relevant to this scoping study.

The ARRIP, NDSP, MDBC and NPIRD project databases were searched. Some of these databases did not appear up-to-date or comprehensive as some activity, particularly in regard to dryland salinity, catchment classification and catchment modelling was not identified. Also some of the databases provide fairly limited information. There appear to be a large number of relevant projects in the uplands dryland catchments but many fewer for the plains area where there is irrigated and dryland agriculture. A listing of some of the most relevant projects identified from the database search as well as information subsequently supplied by some researchers is listed in Appendix 4.

This section does not aim to provide an exhaustive identification and review of water balance R&D in the northern MDB as these reviews have been undertaken elsewhere. For example, thirty R,D&E projects relevant to water balance in cotton were identified at a major workshop held in Toowoomba in 1999 (Cotton Industry, 1999) and Hearn (1998) reviewed irrigation related cotton research in Australia. Similarly the ACCRC as part of its proposal for an integrated research program on DD has reviewed past work (ACCRCWG, 2001). Silburn and Montgomery (in progress, 2001) are reviewing the current state of knowledge regarding DD research and information in the northern MDB. Several of the reviews also note that a lack of national and state focus on salinity and environmental problems is reflected in the number of small projects that have often been poorly integrated and technically under resourced.

The purpose in this Chapter therefore, is to focus on <u>those major and key pieces of work relevant to this study</u> and build on what has already been done. The key current R&D and R&D technical initiatives relevant to this study are (initiatives dealing policy, economics, bio-diversity etc have not been investigated):

Project 1: Catchment Modelling of Salt Loads and Salinity Hazard

Both NSW and Queensland government agencies are undertaking substantial technical studies substantially driven (and supported) by the MDBMC 'end-of-valley' water quality (salinity) target setting. The projects involve hydrogeological investigations linked to a suite of computer models ranging from root zone up to a catchment scale flow routing model which will have a water quality component added later. Some details of the NSW approach are given in Appendix 5.

The NSW project will produce maps of recharge potential across the State for regional and property management planning, end-of-valley and in-valley salt loads for target setting. The project is primarily focussed on dryland, upland catchments. This project will also support monitoring at the NSW Environmental Services Investment Fund model sites (where a tender process is being used to target grant funds to best benefit sites).

The project will instrument 4 dryland sites (paired sites at each) in the NSW (Murray, Namoi, Lachlan and North Coast) using lysimeters and intensive water balance monitoring to obtain water balance closure and to assist model calibration.

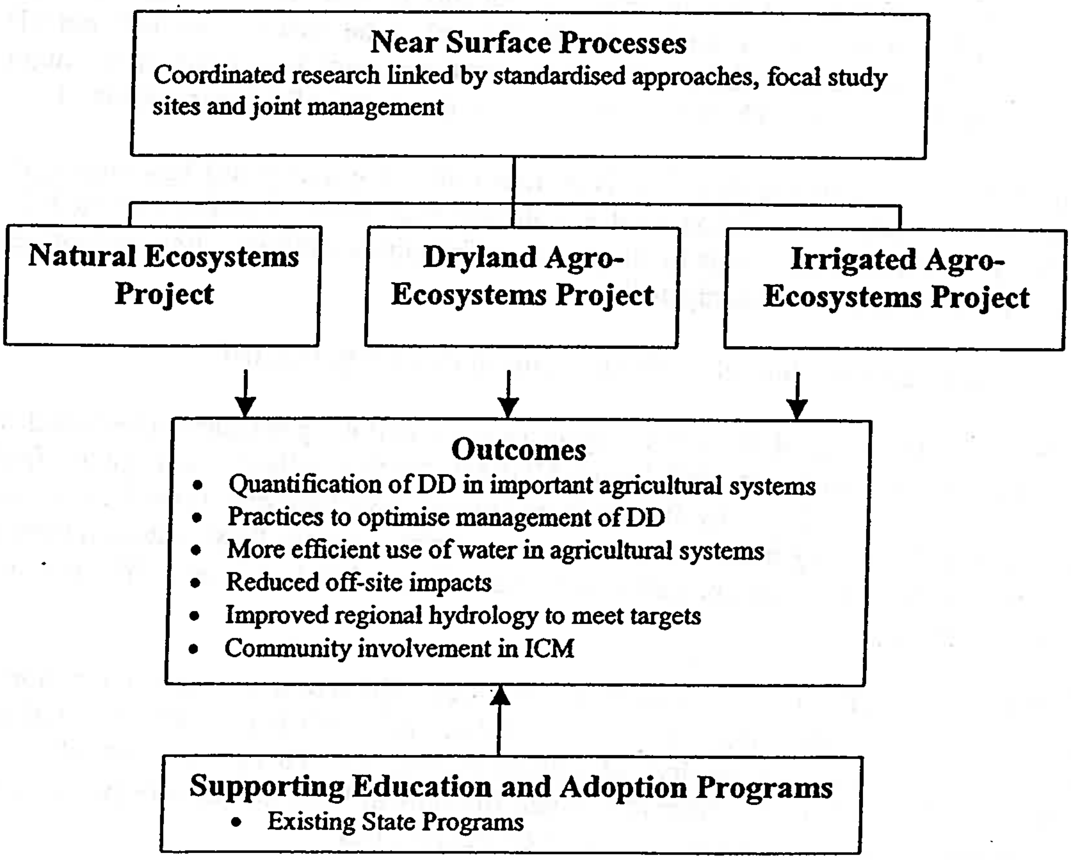
Initial steps (exchange of letters) have been taken to share information and approaches between similar activities in NSW, Queensland and Victoria.

Project 2. Managing Deep Drainage in Agricultural Systems in Northern NSW and Southern Queensland: Integrated Research Program Proposal.

This proposed program of research comprises 3 major project modules: irrigated agro-ecological systems (centred on cotton), dryland agro-ecosystems (centred on dryland cropping) and, natural ecosystems. It was proposed that the 3 major project components would be loosely coordinated so that there were links between standardised approaches, focal study sites and sharing of information. The dryland agro-ecological systems project has been developed further with the GRDC and is now funded (refer to brief project description below). The irrigated agro-ecological systems project has been developed into a project proposal which is on-hold whilst this scoping study is conducted. A more detailed project proposal has not been developed for the natural ecosystems project component.

The proposed Program Structure was:

Figure 3.1: Program Structure for the Previously Proposed DD Project

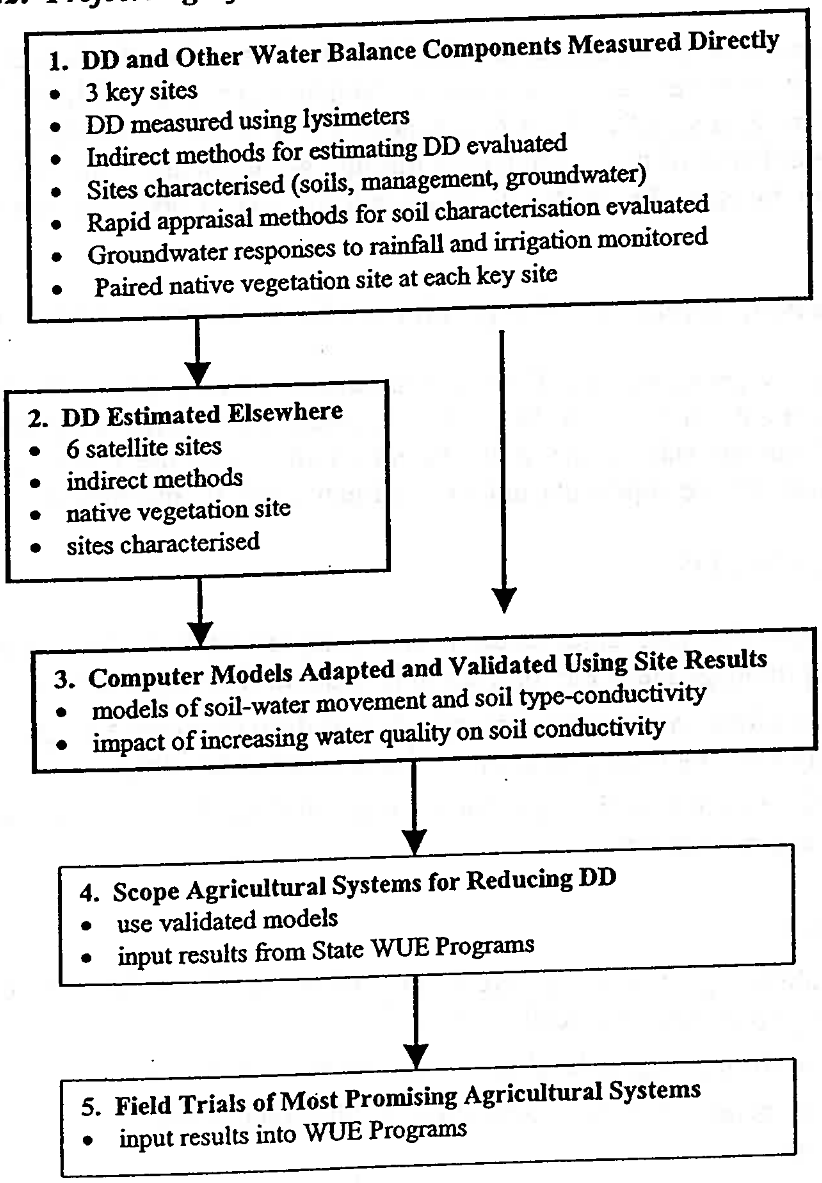


Project 3. Minimising Drainage from Irrigated Agricultural Systems in Northern New South Wales and Southern Queensland'

This proposal is the Irrigated Agro-ecosystems project of the above Program. The genesis of this proposal was the recognition by Brian Hearn of the CRDC in the mid 1990's and the subsequent series of workshops convened by the ACCRC which reviewed relevant research and culminated in the above project proposal addressing "water balance / deep drainage". The proposal was prepared by the ACCRC Working Group with membership from QDNR, NSW Agriculture, CSIRO Land and Water and Primary Industry, and the University of Sydney.

The project logic for the irrigated agro-ecological systems is broadly as follows:

Figure 3.2: Project Logic for the Previously Proposed Project



The project is proposed to be implemented over 5 years.

Project 4. Whole Farm Irrigation Efficiency Project

The Cotton RDC funded this project conducted by Paul Dalton from 1998-2001. The project evaluated water use efficiency at a farm level and found farm efficiencies of 30% to 75%, with water storage efficiencies of 50% to 80%, distribution efficiencies of 80 to 95% and field application efficiencies of 50% to 95%. The project also investigated best management practices to improve on-farm water use efficiency.

Project 5: Regional groundwater modelling the lower Namoi Valley

The UTS (Merrick) has been undertaking regional groundwater modelling of the lower Namoi Valley over the last two decades. A 3-layer model (the shallow layer is 30-40m thick) balances groundwater inputs (recharge) with groundwater outputs (groundwater flow, discharge to streams/water bodies and groundwater abstractions) and change in storage as measured by monitoring bores.

The current recharge rates used in the model are significantly lower than the higher, more recently measured DD. Possible explanations include watertable perching not identified by the monitoring, a different balance of dryland to irrigation induced DD or incorrect recent estimates of DD. Reconciliation of these differences through more intensive modelling and observations is important to meet the needs of the drivers for DD information previously identified.

Project 6. Water Leakage from Dryland Agriculture- Measurement and Solutions

This project is funded for 3 years by the GRDC and approximately corresponds to the dryland eco-systems project described above. Similar to the irrigated ecosystems proposal, this project will measure all components of the water balance rather than the more common practice of measuring some of the components and then estimating DD by difference.

The objectives of the project are to:

1. Measure drainage below the root zone directly and compare with indirect methods (solutes, modelling and drainage meter etc) on clay soils under dryland agriculture.
2. Improve capabilities for direct and indirect determination of deep drainage and <u>prediction</u> of water balance on clay soils, including estimation of associated uncertainty.
3. Assess the relative risk of excessive drainage for different dryland farming systems and soils, and propose management solutions.

Expected project outputs are:

1. Drainage and water balance quantified, by direct and indirect methods, for contrasting practices (eg. fallows v. perennials) on cracking clay soils.
2. Drainage risk assessment for farming system/soil combinations in Qld MDB.
3. Interpretation of project results and communication to different audiences, especially growers and governments

There are two components of the project; one in Queensland and one in NSW. Project methodologies are similar but on a more modest scale to those proposed for the irrigated ecosystems project and comprise measurements on two soil types with fallow, perennial pasture and native vegetated land use. All components of the water balance are measured with DD measured with both direct and indirect methods. The results will be used to improve and calibrate 1-D models which are then to be used to predict risk of excessive drainage and runoff. Hydrogeological monitoring and modelling is to support the project although few details of this are provided. In Queensland the work is carried out by the units involved with the end-of-valley target work.

Project 7. Sustainable Grazing Systems Project

Meat and Livestock Australia (with support funding from MDBC) has funded this major national initiative over the past 4-5 years. The project has investigated the sustainability issues (water, nutrients, pastures, animals, bio-diversity) seen to be important to the livestock industry at 6 national dryland sites (site selected according to different climatic and conditions). Three sites are in NSW (Wagga, Tamworth, Carcoor). Treatments included pasture types (annual, perennial, native) with a range of grazing systems.

The project included water balance measurements at each site although DD was not measured directly (inferred by difference). A soil-water model is being used to analyse the data and its implications. The project includes a common database which was designed at the start of the project with considerable effort to ensure that common methods were used across all sites. The project results are currently being written up. The database is said to be potentially valuable and relevant to catchment scale hydrological studies. The MLA Program Manager believes that the MLA would consider that enough is known about DD from these studies to satisfy the industry's needs.

Project 8. Sustainable Grain & Grazing Systems

Grains RDC, MLA, Australian Wool Innovation and LWA are scoping a research and development program targeting the needs of grains, livestock and wool producers in the cereal/sheep and high rainfall areas of Australia; and the systems they manage.

Project 9. The Landmark Project

The MDBC Landmark project is researching the sustainability of dryland systems in the MDB. Its objective is to identify the need for land use and land management change and investigate policy responses to facilitate change in the broad acre dryland regions of the MDB.

The research is based around identifying the current BMP's for dryland agricultural use (cropping and grazing), investigating the sustainability of these land uses and practices and, identifying policy options for governments, industry and the community to enhance the sustainability of land use. One of the 3 sites is the Upper Condamine catchment, Queensland - summer cropping landscape. The 3-year project commenced in 1999 and there are links between the project and the GRDC program via a shared project coordinator.

Project 10. Redesigning Agriculture for Australian Landscapes (RAAL)

This project was a joint 6 year initiative between LWRRDC and CSIRO which finished its first phase in 2000. The project focussed on water (including DD) and nutrients in dryland agriculture and natural systems at 3 sites (2 in WA and one at Wagga). The project worked at the point/paddock scale and used some of the modelling approaches (eg. APSIM) currently used in the NMDB. One of the issues involved was the scaling up of results to a catchment scale. Future directions (whether there should be a Phase 2 for instance) are under consideration.

Project 11. Heartlands

Heartlands is a MDBC, CSIRO and NSW and Victorian government agencies and regional Catchment Management Authorities/Boards project conducted at 2 dryland sites in northern Victoria and 2 dryland sites in southern New South Wales. It comprises R&D with targeted on-ground works. The project objectives are to:

- Develop new systems of land use that are more resource efficient than current practices
- Deliver spatial landscape design strategies that provide multiple environmental benefits and are socially acceptable.
- Understand the social and economic mechanisms and impediments associated with land use change.
- Identify policy instruments or strategies to help achieve implementation of the necessary land use change strategies.
- Verify the effectiveness of the landscape design strategies through long-term monitoring of catchment function.
- Support and facilitate implementation of the above landscape design strategies.
- Design and support implementation of adaptive catchment management processes.

3.2 Approaches for Measuring and Estimating Deep Drainage and Water Balance

DD is difficult to measure for a variety of reasons including field variability (soil, aspect, slope, surface depressions, land cover, areal and temporal rainfall, etc), it is generally only a small part of the overall water balance and most if not all methodologies have limitations. For this reason a range of approaches are often used. The main methodologies relevant to estimating DD and catchment impacts are:

a. Lysimeters which provide a direct measure of DD.

b. Indirect methods of estimating DD include soil solute profile analysis, mass balances, and tracer studies.

c. Water flux below rootzone can be estimated from knowledge/measurements of the hydraulic gradient and estimated soil properties below the rootzone.

d. Water Balance- field. Rainfall, irrigation, runoff, and evapotranspiration are measured and DD estimated by difference. The problem with this approach is that often the magnitude of DD is less than the error of measurement of other water balance components.

e. Water Balance- farm is especially important for irrigation farms where there are structures such as water storages and canals which contain water for extended periods and so represent possible concentrated sources of DD.

f. Water Balance- district. Similarly there are often significant water features where recharge (and for that matter discharge) are more significant than local/field recharge.

g. Radio-metric and Electro-magnetic methods for determining soil, salt and hydrogeological conditions are often (EM methods) used to delineate salt levels within the soil or deeper strata and under some conditions can be used to infer soil/sediment type and identify aquifers. Extensive ground-truthing and calibrations are required for these methods.

h. Computer models of salt and water movement in the rootzone. There are many models ranging in levels of sophistication that are used to predict salt and water movement through and beyond the unsaturated root zone. The modelling approaches mostly use relatively easily measured soil physical properties to infer soil hydraulic properties (pedo-transfer functions) to capture the differences between soil types.

i. Groundwater Response. Monitoring watertables and groundwater levels provides a direct measure of the groundwater balance and whether shallow watertables may eventually become a problem. There may be a significant time (eg. 50 years) however before there is a watertable response in semi-arid climates and where watertables are initially deep.

j. Groundwater Models (3-D) using monitored groundwater response. There are a number of 3D computer models that simulate saturated and unsaturated flows and use groundwater responses to calibrate the model. These models include spatial distributions of land use and hydrogeology. DD for different land uses can be a model input (eg. from field measurements) or an output (assumed values which are balanced to achieve model results calibrated against groundwater behaviour).

k. Catchment Models of surface and subsurface flow (2-D). In sloping landscapes in particular, local lateral flow is an important determinant of the catchment water balance, the apportionment of water between the various components of the water balance and, between the local and regional components of the groundwater system.

l. River Basin surface flow routing models. These models route surface flows accounting for floodplain conditions, climatic events, diversions and drainage returns through river systems. The models (eg. the NSW IQQM) are being extended to include water quality so that water quality targets can be developed and evaluated on a more quantitative basis.

Virtually all methods suffer from problems of variability (soil, aspect, slope, rainfall, land cover, distribution of aquifers etc) which results to uncertainty of results. Judgement based on sensitivity analysis is required to decide the level of measurement precision required. There appears to be the need for more of this important analysis.

3.3 Adopting a Catchment Context for R,D&E

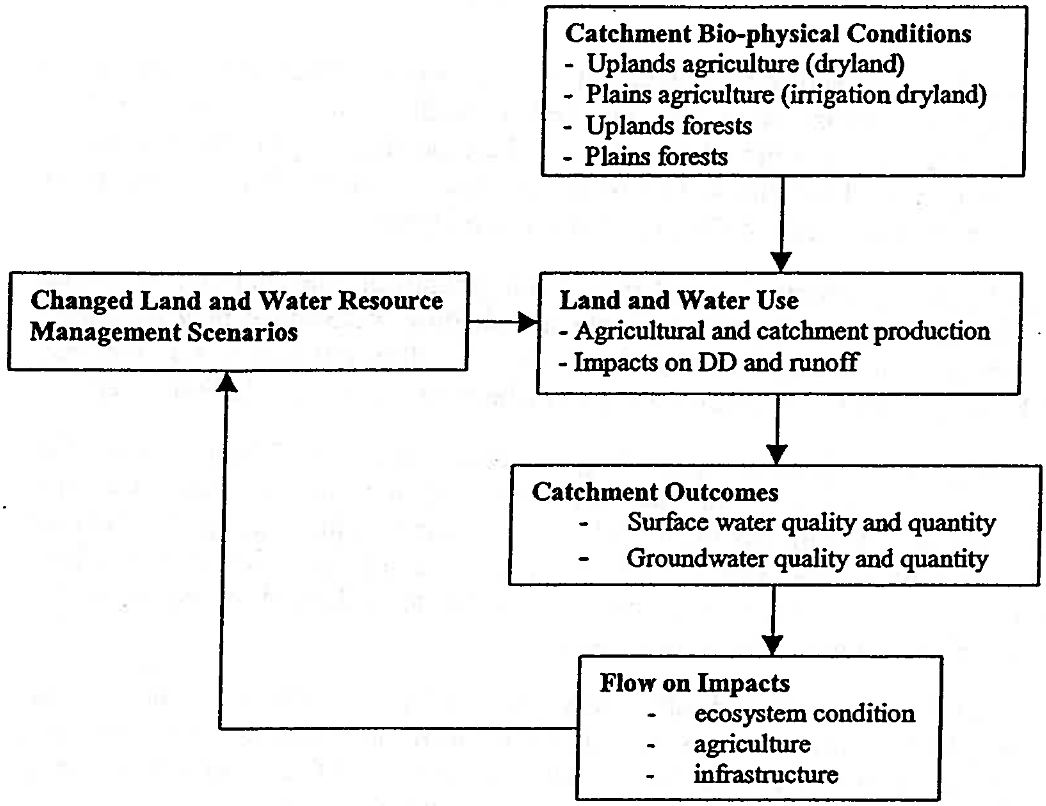
It is important that DD and water balance R&D is placed in an overall catchment context so that the work delivers sufficient information and in a form that will enable appreciation and exploration of:

- Current processes and trends.

- Impacts of management options on catchment outcomes (water quality and quantity, landscape condition).
- Impacts of management options on economic and social conditions.
- Targeting effort to where risk is highest and benefit greatest.

A simplified diagram showing these interactions is given in Figure 3.3

Figure 3.3: Catchment Context for R,D & E



With the exception of the '*Catchment Modelling of Salt Loads and Salinity Hazard*' project, none of the projects investigated seemed to have attempted an overall and integrated catchment focus to identify and prioritise effort. Furthermore from the discussions held and information reviewed there does not seem to be an overall catchment framework used to drive and coordinate R&D Programs and initiatives to ensure that a concerted and coordinated effort is taking place across all important R&D issues.

Past and current R&D tends to focus on one or other of these system components (principally the current agriculture and land management scenario aspects) with limited consideration of interactions with other components or overall system behaviour. This in effect, assumes a presumed priority R&D and where solutions might lie, rather than a systematic analysis of need. This reflects the perspective provided in several interviews which referred to R&D being largely supply (researcher) rather than demand (user) driven or a balance between the two. Involvement of researchers is important for early problem identification and specification. Input from users is important to ensure a focus on the most promising and beneficial areas of R&D to users, and to strengthen the links between R&D and, application and implementation.

Arguably an improved strategic focus for research could be developed based on a whole of system approach and analysis, and then disassembly of the system into its separate components with research users and researchers agreeing the detailed needs and studies. This initial stage would provide a framework for mapping R&D and identifying gaps and duplication, provide a means for coordination of investment by funders, and enable analysis of investment options to target investment. The following chapter provides a preliminary attempt to map R&D need in this way based on the drivers for catchment information.

3.4 Coordination Issues

Interviews suggested that there is a significant amount of DD/salinity R&D activity in the upland/dryland parts of catchments. There do not appear to be however, any formal coordination mechanisms for these technical studies which may be funded by a number of organisations (eg. State agencies, CSIRO, LWA, GRDC, MLA, MDBC, ACCRC, CRC Catchment Hydrology, CRC for Plant Based Management of Dryland Salinity, RIRDC). However, due to the small number of researchers and the networks they have developed, there appears to be reasonable awareness of the range of studies underway, information sharing and cross membership. A more formal coordination mechanism however, could be expected to result in greater synergies between programs and projects, an improved strategic focus and coordination of the work, greater information sharing and in the longer term, greater application of the research.

Two coordinating initiatives are underway. NSW DLWC has approached QDNRM and the VDNRE with the intention of collaborating and sharing information on approaches being used to develop catchment targets and associated computer modelling including DD modelling. Also, GRDC, LWA, AWI, MLA have commenced investigations that may lead to development of the Sustainable Grain and Grazing Systems project referred to above.

In relation to irrigation R&D there is relatively little R&D activity. This is of concern given the possible risks and implications from irrigation salinity and the likelihood that it will develop in a shorter time scale than dryland salinity. Experience from the southern MDB, indicates that groundwater salinities are often high (sea water quality) in such regions and that high, irrigation induced salinisation of rivers can be more significant than dryland induced salinity.

Coordination for irrigation R&D in the NMDB is unlikely to be a major issue as there is only one industry involved.

A number of interviewees cited the need for better coordination and referred to the former 'Cotton Pesticides Program' as providing an excellent coordination model.

3.5 Conclusion

Compiling a comprehensive listing of relevant projects would be a time consuming activity as the most effective means of compilation would be by contacting individuals directly. The databases do not appear to be up to date or comprehensive. Additionally there are relevant technical studies that fall at the applied investigations end of the R&D spectrum that would not be considered to be R&D by the project managers and so are unlikely to be on the databases.

There are a number of significant DD/water balance R&D initiatives in the NMDB investigating upland dryland catchments and coordination was said to be a major issue here. A number of interviewees indicated that was a need to ensure that the various R, D&E efforts at a catchment scale were better coordinated and integrated. Although there do not appear to be good formal coordinating mechanisms, the limited number of researchers and their networks means that there is reasonable awareness of projects.

Coordination of DD/water balance R&D for the irrigated parts of catchments appears to be much less problematic and simpler as there is only the one significant irrigated industry and a very small group of researchers. R&D into DD and irrigated systems for the NMDB has been relatively small and, as for the dryland effort, an overall big picture and how the pieces will fit together is not apparent.

From the limited discussions held, there does not appear to be any mechanism for integrating R&D so that catchment scale impacts can be objectively evaluated. This is important as a current paradigm appears to be that recharge from agricultural systems should mimic recharge under natural systems. The danger of this approach is that it is unlikely to result in the best performing landscapes if the full range of environmental services or community needs are considered.

Community objectives for catchments will vary from catchment to catchment according to local conditions. For example in some catchments the objective may be to reduce DD and salinity, in others it might be to maximise the amount of good quality runoff, whilst in others it may be to increase good quality groundwater storage for stream baseflow or reuse.

Researchers from the SGS project have indicated that their results show that it is feasible to be designing landscapes in this way.

4. IDENTIFICATION OF DEEP DRAINAGE R&D NEEDS; GAPS & PRIORITIES

4.1 Identification of Technical Study Areas

This chapter identifies the key DD and water balance related studies required to address the drivers and uses of information previously identified (chapter 2) and provides a preliminary prioritisation of these technical study areas.

Figure 4.1 shows the approach used to identify these R&D study areas.

Figure 4.1: Overview of the Approach for Identifying and Prioritising R&D Needs

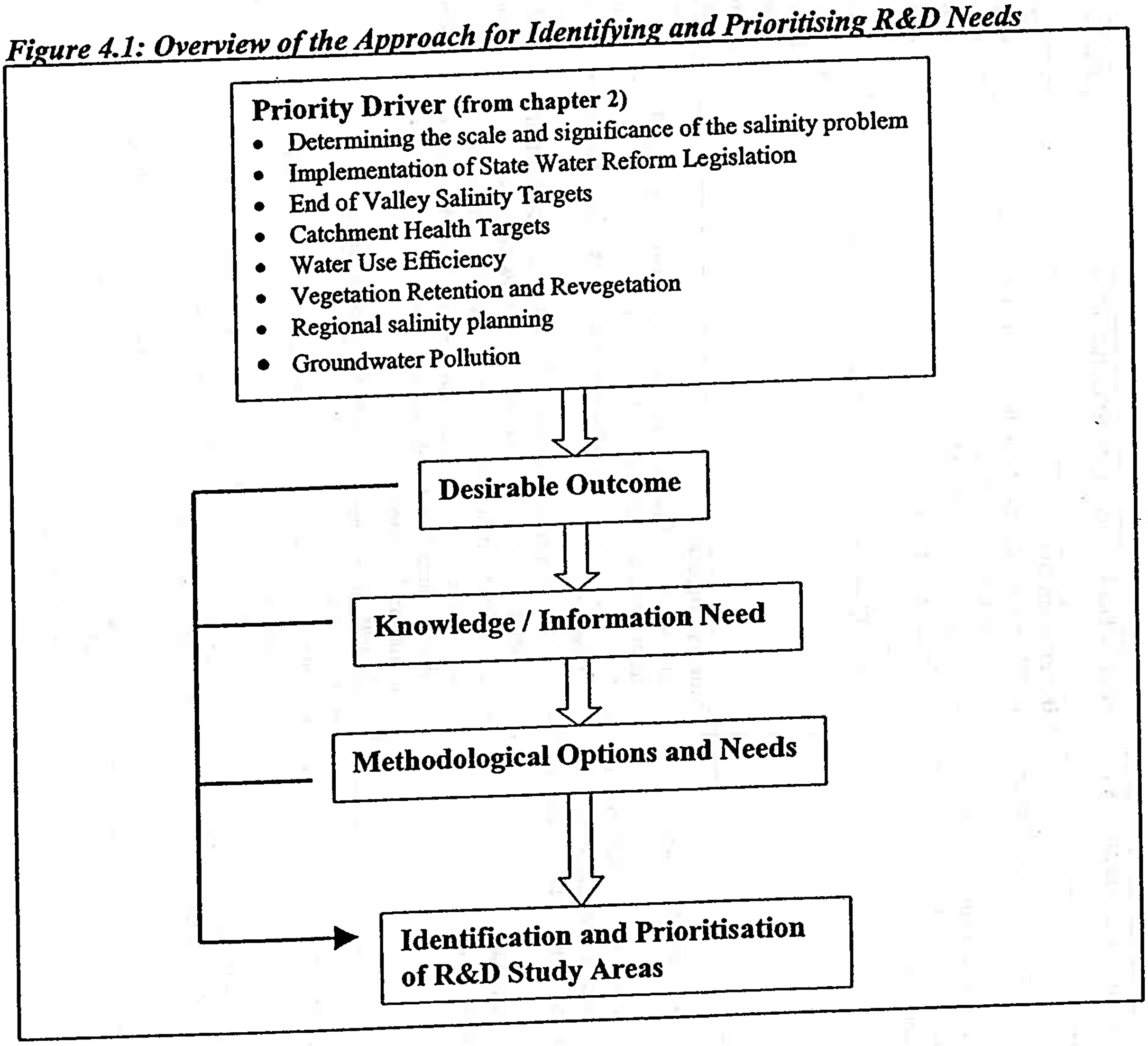


Figure 4.2 presents a detailed analysis of the desirable outcomes, mechanisms for achieving change, information requirements and study areas for each of the priority drivers previously identified.

Figure 4.2: Outcomes, Information Requirements and Related Studies for Priority Issues

PRIORITY DRIVER	DESIRABLE OUTCOME AND MECHANISM	WATER/DD INFORMATION REQUIREMENTS	DD RELATED STUDIES
1. EFFECTIVE IMPLEMENTATION OF WATER ACTS	**Outcome** Salinity and water quality impacts avoided. **Mechanism** Farm Land and Water Management Plans which avoid land and water degradation require official approval.	**Information Need** • DD risk for different soil types, land use, water qualities and climatic conditions • Groundwater levels and change • Groundwater salinity **Information Product** • Salinity hazard/risk maps for parcels of land.	1. Accurate measurement of DD for specific soil types. 2. Rapid appraisal of soil types. 3. Capacity to predict DD for different soil types, land use, water qualities and climate including sensitivity analysis/importance of input parameters. 4. Groundwater conditions (depth and salinity) 5. Groundwater model linking DD to change in watertable level and risk of shallow watertables developing.
2. END AND IN-VALLEY SALINITY TARGETS	**Outcome** Agreed salinity targets set for rivers. **Mechanism** • Salinity targets will be set using a suite of computer models ranging from 1-D. 2-D, catchment and flow routing models. • In the longer term targets will be set on the basis of asset values	**Information Need** • Surface water (quantity and quality) accessions to and from streams in uplands and plains areas. • DD rates at well characterised sites for model calibration. • Characterisation of catchment LMU's and groundwater systems so that models can represent flow processes • Groundwater inflows to and from surface water bodies. • Innovative land management practices and options which reduce DD to sustainable levels. **Information Product** • Targets agreed and monitored for selected sites.	1. Accurate estimates of DD for characterised sites 2. Calibrated soil-water models. 3. Rapid Appraisal Methodologies for catchment characterisation at an LMU level. 4. Models linking surface water and groundwater behaviour 5. Routing of surface water and salt flows through catchments.
3. CATCHMENT HEALTH TARGETS	**Outcome** Catchments managed in a sustainable way (salinity). **Mechanism** • Agreed water balance developed for catchments and monitored. • Means of achieving water balance agreed.	**Information Need** • Catchment and sub-catchment salt and water balance scenarios. • Hydrogeology and surface hydrology of catchments. • DD rates for different LMU's, crops and climate **Information Product** • Catchment health indicators (eg based on design recharge) agreed and monitored	1. Accurate DD measurements 2. Prediction of DD for different LMU's, land uses and climate.
4. REGIONAL	**Outcome** Effective Regional Salinity Management	**Information Need** • Catchment salt and water balance scenarios.	1. Accurate DD measurements. 2. Predict DD for different LMU's.

Priority Driver	Desirable Outcome and Mechanism	Water/DD Information Requirements	DD Related Studies
Salinity Planning	Plans **Mechanism** Communities develop plans which identify sustainable land use practices and include mechanisms to achieve land use change.	• Catchment hydrogeology, surface hydrology. • DD rates for LMU's, crops and climate • Innovative land use options which reduce DD to sustainable levels **Information Product** • Salinity hazard and risk maps	3. Rapid appraisal catchment characterisation 4. Estimation of soil salinities and hence economic and environmental impacts 5. Innovative management practices and options to reduce DD. 6. Hydrogeological models evaluating development of shallow watertables. 7. Water and salt routing through catchments.
5. Improving WUE	**Outcome** Water being used with high WUE to achieve economic and environmental outcomes **Mechanism** WUE Programs that clearly identify efficient practise that are adopted by water users	**Information Need** • Farm system efficiency studies identifying DD from fields, channels, storages. runoff losses. • Management approaches to reduce DD and runoff losses. **Information Product** • BMP Manual	1. Farm water balances which identify where losses are occurring 2. Irrigation practices which reduce DD losses and manage salt inputs. 3. Soil-water models for gaming of management options.
6. Native Vegetation Retention	**Outcome** Native vegetation retained for salinity mitigation as well as bio-diversity value. **Mechanism** Native vegetation plans developed which include salinity prevention objectives.	**Information Need** • Data identifying DD for different LMU's with and without native vegetation **Information Product** • Native Vegetation Plans	1. Measurement and modelling of DD under native vegetation, alternative land uses and different LMU's. 2. Catchment characterisation linking DD from different land use to salinity risk .
7. Targeting Revegetati on	**Outcome** Revegetation targeted to high impact parts of catchments **Mechanism** Programs (including GAP, Tender approaches etc) specify high impact zones for revegetation	**Information Need** • Data identifying DD for different LMU's with and without native vegetation **Information Product** • Salinity impact map identifying LMU's where deep rooted vegetation most beneficial.	1. Measurement and modelling of DD under native vegetation, alternative land uses and different LMU's. 2. Catchment characterisation linking DD from different land use to salinity risk
8. Groundwat er Pollution	**Outcome** Long term groundwater quality protected **Mechanism** Extension Programs Declaration of protection zones	**Information Need** • DD rates for different soils and practices • Pollutant mobility • Identification of groundwater resources **Information Product** • BMP's	1. DD rates from different land uses 2. Pollutants leaching hazard

4.2 APPRAISAL OF TECHNICAL STUDY AREAS

The studies that could be undertaken by DD / Water Balance program are consolidated here by grouping and linking the possible studies identified from the above analysis. Figure 4.3 shows the DD related studies identified in Figure 4.2 with a brief description of some more immediate outputs. A summary list of projects together with a preliminary prioritisation is provided (Figure 4.4).

Figure 4.3: DD / Water Balance Studies and their Relationship to Priority Drivers

DD Related Studies	Purpose/Outputs	Priority Driver
Irrigation and Dryland Catchments		Bold > priority
1. Direct and indirect measurement of DD for characterised sites	• Measurement of DD rates for a range of soil types. • Calibration of DD models. • Refinement of pedo-transfer functions including the impact of saline water on hydraulic properties.	**1, 2, 3, 4, 5, 6, 7, 8**
2. Development and application of adequate rootzone soil-water-solute models	• Predict DD for different soil types, LMU's and land use/management • Input into salinity hazard maps and LWMP. • Investigation of risk of groundwater pollution • Gaming of management options • Sensitivity testing to identify degree of accuracy required of soil measurements	**1, 2, 3, 4, 5,6, 7, 8**
3. Rapid appraisal of soil types and catchment hydro geological characteristics	• Rapid identification of soil types for model application. • Rapid characterisation of catchment hydrogeology (aquifers, salinity) for input into models and salinity hazard maps	**1, 2, 3, 4, 5, 6, 7, 8**
4. DD from storages, channels etc,	• Determine DD from farm water features other than fields (eg. storages) • Develop approach for estimating DD hazard for non field features • Identify options to reduce DD from features	**1, 2,** 3, **4, 5**
5. Watertable conditions/ monitoring (depth and salinity)	• Input into salinity hazard maps • Monitoring trends, calibration of groundwater models	**1, 2, 3, 4, 5, 6, 7, 8**
6. Field trials of attractive options	• Field test most attractive management options identified from gaming.	**1, 2, 3, 4, 5, 8**
7. Landscape model with economic impacts of salinity/land use change	• Determine the most economically attractive management options.	**3, 4, 5**
8. Routing of surface water and salt flows through catchments	• Develop end of valley and in valley targets • Manage catchment salt and water balances	**1,2,3,4,5**
Plains Areas (irrigation/dryland)		
9. 3-D groundwater model of plains area.	• impact of DD from different LMU's and land uses (including storages etc) on groundwater rise/fall and eventual salt discharge to streams/rootzone	**1, 2, 3, 4, 5, 6, 7, 8**
Uplands Dryland Catchments		
10. Construct and apply 2-D/3-D models	• Allow for lateral flows in current rootzone models.	**2, 3, 4, 6, 7**
Native vegetation & afforestation		
11. DD measurement at characterised sites	• Measurement of DD rates for a range of soil types.and LMU's • Calibration of models so that revegetation can be targeted.	**3, 4, 6, 7**

Each of the study areas was appraised subjectively against the success criteria of:

- The potential benefits of addressing the issue through R,D&E (assuming research success and full adoption). This criteria takes into account factors such as the proportion of the industry affected, the potential costs of not investing in R,D&E, whether the research has already been done, and the potential magnitude of the impact of investing in R,D&E.
- The likelihood of research success. This criteria considers the likelihood of success of conducting the research, the track record of researchers, the chance of 'break-through research', factors influencing success, and the R,D&E investment required for success.
- The likely adoption/application of successful research outputs. Factors considered include assessing the principal adoption barriers, the anticipated implementation profile (time/level), experience with similar projects, and the role of policy.

The scores are in the range 1 to 5, (1 = low (undesirable); 5 = high (desirable) rating). This is a preliminary analysis based on the consultant's best judgement of the situation following the interviews. A more thorough analysis would require more direct surveying and prioritisation procedures with scientific specialists in particular.

Figure 4.4: Preliminary Analysis of Project Priorities

Study Area	Ben.	Succ.	Adop	Comment
Plains and Uplands Catchments				
1. Direct and indirect measurement of DD for characterised sites	4	4	4	Methodologies reasonably established, although application in vertosols will be difficult
2. Development of adequate rootzone soil-water-solute models	4	4	4	Methodologies established, but some further development for vertosols required. Ready application of results.
3. Rapid appraisal of site catchments (soil types and catchment hydro geological characteristics)	5 / 2	2	4	High benefits if it can be used to determine soil type for modelling studies (5) but success considered to be low (2). Use of EM for salinity and aquifer identification seems to be a well established technology elsewhere. Main application in this project is to characterise study sites. Further identification & justification of outputs required.
4. DD from storages, channels etc,	4	3	2	Further information and measurement of this is needed.
5. Watertable conditions/ monitoring (depth and salinity)	5	4	4	There is an urgent need to reconcile differences in results from groundwater models and higher DD.
6. Field trials of attractive options	2	2	2	Project premature until problem is better understood.
7. Landscape model with economic impacts of salinity/land use change	2	4	3	Useful approach for integrating approach into a district picture for planning purposes. One input into planning process. R&D undertaken elsewhere (Liverpool Plains)
8. Routing of salt and water flows through catchments	3	4	4	Methodologies are well developed (IQQM) although salt component is being added and model adapted to NMDB catchments. NSW, Qld and MDBC sponsoring this work
Plains Areas (irrigation/dryland)				
9. 3-D/2-D intensive groundwater model of selected irrigation areas.	5	4	4	Need to reconcile differences in DD from groundwater vs models vs soil hydrology results. Also to scope locations and landuse that are most hazardous at a sub-regional scale.
Uplands Dryland Catchments				
10. Construct and apply 2-D/3-D models	2	3	5	Governments are making major investments in this area and so benefit of additional investment low
Native vegetation & afforestation				
11. DD measurement at characterised sites	4	3	2	Whilst potential benefits are high decisions are said to be still driven by politics and economics

4.3 CONCLUSION

The previous analysis identified and prioritised a range of possible technical studies that could be further developed.

Important findings are:

- There are significant public and private benefits from funding R&D into delivering better estimates of DD and then applying the results to produce products such as salinity hazard maps across catchments, salt load estimates and water quality targets, catchment and land and water management plans, native vegetation retention and clearing plans.
- A high priority should be given to appraising and further developing past groundwater modelling to:
  - reconcile differences between DD estimated from current groundwater models and emerging DD and water balance field measurements.
  - assist identification of the best investment options for R&D, works and measures. This is likely to conclude that more detailed groundwater modelling at a district scale is required to appreciate the hazard of shallow watertables (and salinity outcrops) developing, and the interactions and connectivity between watertables, aquifers and surface water bodies including deeply incised rivers.
  - develop and field test models which can adequately simulate water and salt movement in vertosols including where there are other 'peculiar' characteristics such as paleo-channels and slickensides as well as episodic recharge events.
- Although development of agreed methodologies to determine end-of-valley targets is a very high priority, investment by the MDBC, NSW and Queensland governments in this is already substantial and focussed. Other investors are probably best to consider other investment opportunities.
- There appears to be a significant number of projects dealing with DD in one form or another in Upland (dryland) situations. Before considering further R&D investment in this area there is a need to firstly identify and then appraise all of this work from a catchment, gaps and likely benefits perspective, and to consider strengthening formal coordination arrangements.
- The benefits of investment in further developing radio-metric and electro-magnetic methodologies of salinity, aquifer and soil type appraisals needs further development by technical specialists. Application of EM methodologies appears to be routine elsewhere and the benefits/success aspects of further R&D are hard to judge. Organisations such as. BRS, are active in the area and DLWC apparently uses EM approaches routinely. The main application of this project is assisting in characterising the field study sites.
- There is an urgent need for modelling studies to routinely evaluate uncertainty and sensitivity of modelled results (perhaps there should be 'national standard' of reporting) so as to focus in on the most crucial input information. There is a high uncertainty in natural systems (soil, hydrogeology, areal and temporal distribution of rainfall, aspect, slope, land cover etc) and consequently there is scepticism of modelled results which are often not calibrated to field behaviour.

5. FUTURE DIRECTIONS AND IMPLEMENTATION ISSUES

5.1 Program Structure and Proposal

A wide range of drivers for R&D at a range of scales including catchment, dryland, irrigation and natural vegetation systems were reviewed in this report. The analysis indicated that there would be value in developing an overall catchment framework so that R&D needs can be identified, prioritised, analysed and, information and problems shared. This framework would also provide guidance to improve R&D coordination and implementation.

The proposed program structure is presented in Figure 5.1. A landscape-based approach that has 3 semi-independent sub-program elements with overall project coordination at the catchment scale is recommended. Options for project coordination are discussed in a following section.

The three sub-programs are:

Sub-Program 1: Uplands Landscapes:

This sub-program has two deliverables:

(i) Measurement and prediction of DD from land use and management practices for upland landscapes and, using this information as an input into hazard and risk maps being developed as part of the third sub-program. Land uses would include both agricultural and forest (natural and reafforested). Other applications include input into vegetation and salinity management plans.

(ii) Provision of DD estimates required by catchment scale groundwater models which can predict catchment impacts of changed DD and possible development of a landscape design component for the catchment outcomes project

The first of these deliverables is largely underway in the GRDC project previously described as well as state agency projects although there may be justification in expanding the 'forests' component of it. The second part is underway in the NSW, Qld and MDBC end-of-valley and in-valley target setting work. The main immediate need is to ensure consistency of methodologies and data standards, that the approach is comprehensive and resources adequate, and that connection is made between the DD R&D and the catchment scale groundwater modelling.

It should be noted that while there is some irrigated agriculture in the Uplands Landscapes this represents only a small percentage of activity and would not warrant R&D investment at this stage.

Sub-Program 2: Plains (irrigation and dryland) Landscapes:

This sub-program is the main area in need of additional R&D for several reasons, including:

- the various audits of salinity appear to have focussed on uplands catchments without recognising the major risk and economic and environmental impacts from salinity developing in the (Plains) area due to irrigation.
- the development of shallow watertables is likely to be accelerated due to the increased impact of irrigation on the water balance compared to other land uses.

- limited measurements of DD under irrigation are indicating DD rates could be much higher than previously considered.
- there is a likelihood that groundwater salinities in these more arid zones will be high and so salinity impacts may be severe on land and water resources should shallow watertables develop.
- the cracking nature of vertosols pose special challenges for field measurement and computer modelling of DD. This will necessitate development of new and innovative approaches with a strong science underpinning

The studies required in this sub-program are:

(i) Sub-regional groundwater modelling in the valleys where irrigation occurs to evaluate:

- any differences between DD measurements and previous estimates from groundwater modelling and watertable behaviour.
- the impacts on land and water conditions if shallow watertables develop.
- DD from a range of land uses in the zone including irrigated agriculture, dryland cropping, and pasture and forests (native and reafforested).
- groundwater management options (necessary reductions in DD, groundwater pumping).
- sensitivity of results so that R&D is directed to the most likely productive information needs.

(ii) Measurement and prediction of DD to:

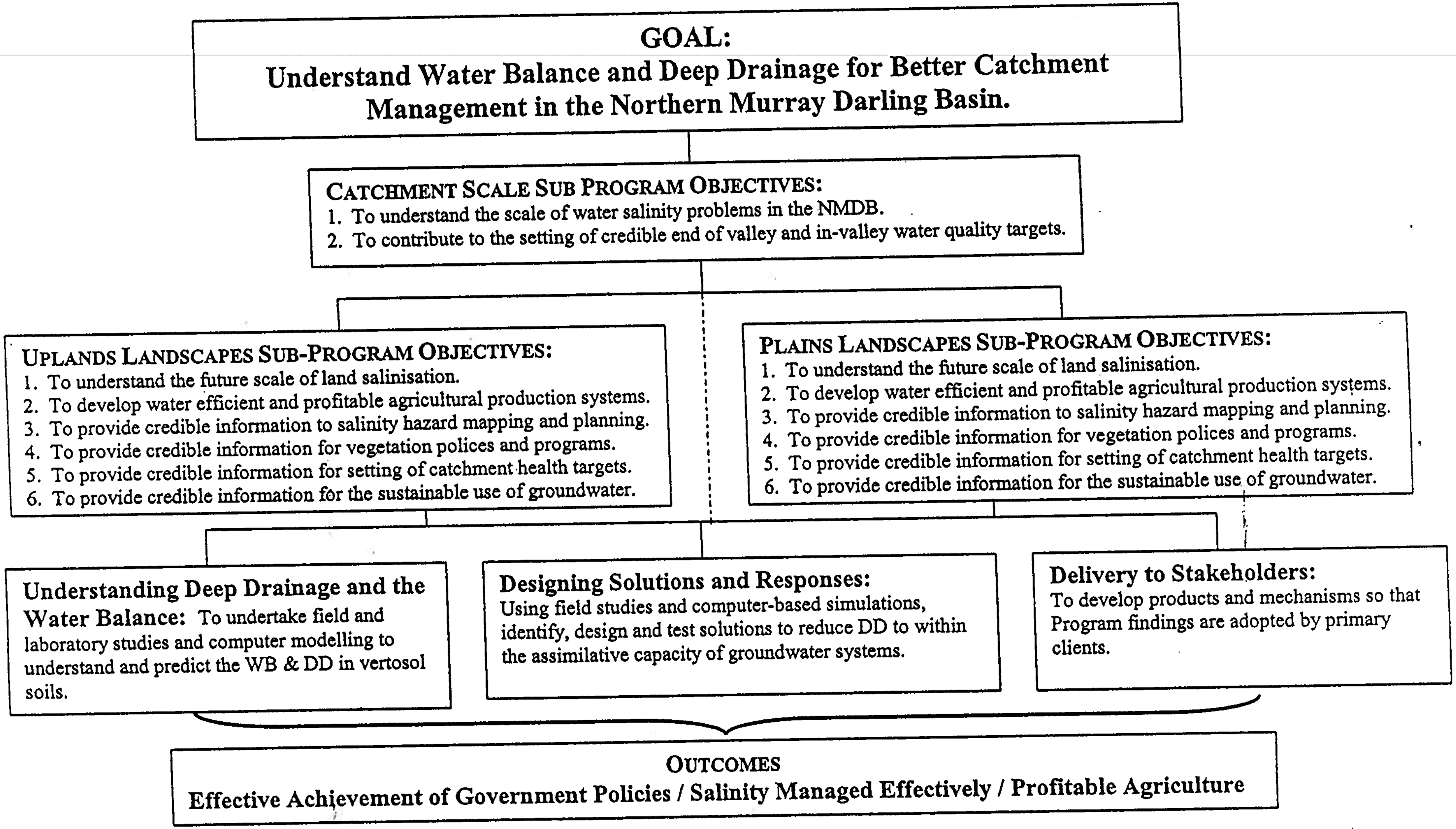
- estimate DD from a range of land uses and LMU including irrigated agriculture, dryland cropping, and pasture and forests (native and reafforested).
- provide input into hazard and risk maps of salinity (these may be prepared as part of sub-program 3 but this needs to be confirmed and a commitment obtained).
- enable gaming of alternative management options and the identification of better management practices.
- undertake sensitivity testing of results so that R&D is directed to the most crucial information needs.
- input information to primary users (government policy and the irrigation industry) and into land and water management plans and salinity hazard mapping.

Sub-Program 3: Catchment Scale:

This work aims to establish the risk of land and water salinisation by developing and applying models of surface and subsurface hydrology to set, monitor and refine end-of-valley and in-valley water quality targets. An added component of this sub-program will be to develop in partnership with other sub-programs, catchment scale maps of salinity hazard and risk.

This work is underway as part of the NSW, Qld and MDBC end-of-valley target setting initiative. There is a need to ensure that there is consistency and information interchangeability between this work and the other 2 sub-programs. In particular the other 2 sub-programs should provide credible, field tested DD information for catchment scale models.

Figure 5.1: Proposed Program Structure



5.2 Relationship Between Projects and Study Areas

The relationship between the study areas identified in Figure 4.4 the projects broadly described in Appendix 6 are as follows.

Figure 5.2: Relationship between Projects and Study Areas:

Project (Appendix 6)	Study Area (Figure 4.4 numbering)
1. Field studies of WB & DD.	1. Direct measurement of DD 3. Rapid appraisal of site characteristics 6. Field trials of attractive options 11. DD under native vegetation
2. Computer models of DD	2. Development of rootzone soil-water models
3. DD from farm water storages	4. DD from farm storages
4. Sub-catchment groundwater models	5. Watertable monitoring 9. Intensive groundwater models (plains) 10. Intensive groundwater models (uplands)
5. Evaluation of economics and policies	7. Landscape based economic models of salinity impacts and land use change
6. Development of flow and salt routing models	8. Routing of water and salt through catchments

5.3 Program Coordination

Range of Project Options Considered

Stakeholders were questioned on the range of project management models from an integrated project focussed on the catchment scale, through to the more specialised agricultural systems project focussed on irrigation and the many options in between. The strengths and weaknesses of each model were sought and alternative approaches suggested. The strengths and weaknesses of these two main options are:

Integrated Project Focussed on the Catchment Scale

Strengths

- The big picture / catchment perspective is taken and significant gaps avoided (isolated R&D would not capture the whole water balance and might miss important R&D needs).
- The approach enables an objective focus on the most beneficial areas for investment and those areas identified as the big contributors to DD.
- A consistency in standards, units, protocols and terms is more likely.
- The approach maximises the potential for cross-fertilisation of research from a multi-disciplinary team.
- There is likely to be less duplication and greater cooperation between funders and between researchers.
- Research gaps can be more easily identified and addressed.
- Linkages between land uses are more likely to be explored.
- There would be a higher profile and likelihood of success for funding, adoption and influence with stakeholders.
- The potential for community involvement and understanding would be increased.
- Maximum flexibility in moving resources between sub-programs and projects to achieve highest return outcomes.

Weaknesses

- Co-ordination and start-up costs and effort large and potentially unwieldy.
- A very clear and strong management structure would be needed with formal commitments made by funding bodies.
- The project would be long term.
- There may be less individual focus and ownership by both funders and researchers.
- Flexibility to change/adapt direction approach during the project would be more difficult.
- It may be difficult to get all funders committed to the project and so important projects may be left unfunded. Experience shows that projects dealing with communications and economic aspects often have more difficulty in being funded.
- It is more complicated negotiating a large project with large budget.
- More meetings, reviews and co-ordination required from researchers which could detract from core research effort.
- More players lead to more agendas and less individual ownership.

Agricultural Systems Project Focussed on Irrigation

Benefits

- More focussed R & D for individual funders without resistance to funding generic work.
- R & D seen to be more directly applicable.
- Management and co-ordination is simpler and more transparent for both funders and researchers.
- Higher flexibility and ownership for researchers.

Costs

- High potential for important gaps to be missed.
- R & D effort could be directed to areas of lower importance without the foundation of the big picture.
- Catchment perspective could easily be lost or never appreciated.
- Impossible to achieve complete picture with fragmented R & D (linkages lost).
- Potential for duplication would be high.
- More limited range of skills available from individual funders and researchers.
- Inconsistent protocols, standards , terms and units probable.
- Profile and community perception not as good (individual funders seen to be looking after their own agendas).
- Limited flexibility in moving funds between Sub-Programs and projects.

Alternative Models

Most stakeholders agreed that DD and water balance R&D needed some form of integrated approach. Without some co-ordinated and integrated effort, R&D in this area would not be fully successful. Most also agreed that a very strong and committed management structure with formal commitments from each funding body was essential.

It was also recognised that funding bodies would be more likely to commit funds and effort to those areas or projects within a large program which they see as important to their direct interests rather than make a contribution to an overall program.

The model most likely to succeed should therefore involve individual funding bodies concentrating on those areas most directly applicable to them but within a coordinated and integrated framework.

The Proposed Model

The main options for implementing coordination of an overall catchment scale project are:

Option 1. Implement and Manage as One Large Program

There is expected to be some benefit from implementing the project in this way however it is considered that it would be unwieldy and unlikely to be feasible as some funders will want to take a strong role in some projects but remain independent of others.

This is not recommended.

Option 2: Implement and Manage the Sub-Programs or Projects Separately

This option would be the most simple to implement however it would depend on cross membership and informal researcher networks for sharing of information. It is unlikely that a comprehensive range of R&D would be undertaken. There would be a high risk that information/data would not be interchangeable between projects or scale up into an overall catchment picture other than by accident. Independent projects would focus on the immediate 'industry' objectives and largely overlook spin-offs to others. There would also be a risk of duplication (eg. using / developing pet models).

This is not recommended.

Option 3: Overall Catchment Focussed Coordination of the Three Semi-independently Implemented Sub-Programs.

This approach would comprise all sub-programs coming together at regular intervals (eg. annual but initially more frequently) to ensure a catchment scale approach was being taken. Some of the activities that could be undertaken at an overall program level are:

- recognise the catchment drivers and preferred outcomes,
- recognise industry needs,
- map current technical studies and information,
- identify where cooperation would be valuable and offer opportunities,
- standardise methodologies and data quality standards to ensure compatibility and exchangeability of results,
- develop a common database and data directory system,
- information sharing,
- continual monitoring of R&D needs and opportunities.

As well as involving researchers, it would include catchment committees and groups developing catchment and salinity plans as well as other end users of the results.

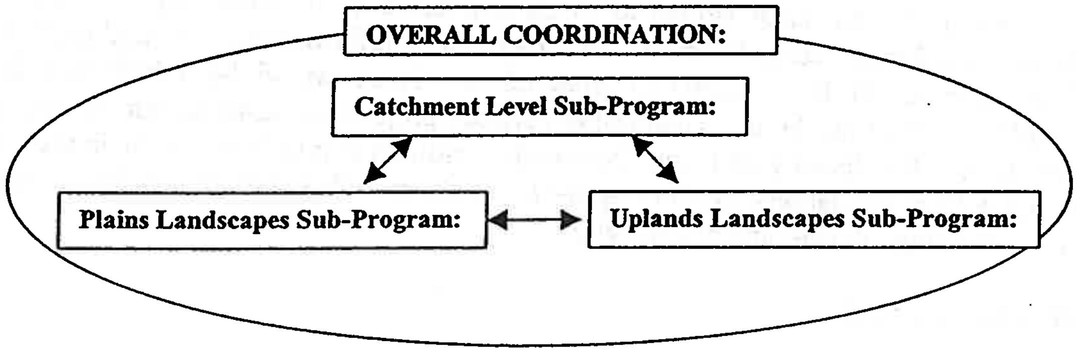
The three sub-programs would then be implemenfed and managed semi-independently. The task in each of these sub-programs would be to ensure the individual projects comprehensively addressed need and achieved outputs.

The benefits of this approach would be that it would increase the likelihood of:

- ensuring that all stakeholders are aware of the bigger catchment (and industry sustainability) issues,
- consistency and compatibility of data and methodologies between projects,
- encouraging synergies,
- focussing on catchment level and practical outcomes

This option is recommended and shown diagrammatically in Figure 5.3.

Figure 5.3: Suggested Coordination Arrangements



Developing the Program Coordination Arrangements

Investors will need to review and negotiate the preferred management arrangements including who should take on the lead roles for overall coordination and of the separate sub-programs.

We recommend initially a peak Management Committee to ensure the development, delivery and coordination of the overall Program of research. Initial membership of this body should have strong representation from user groups and include representatives of funders, key industries, R&D providers, Catchment Management Boards / Committees, and organisations legally responsible for management of the water resource. An important need at this stage is to develop a partnership with shared ownership,. clear responsibilities, and formal commitments to the Program.

The convener of this group needs to be an organisation with a Basin wide or national perspective with a strong natural resource management and government policy perspective. It is expected that the committee will take a lead role in developing the overall strategic approach and consequent business/implementation plan, approving project proposals and ensuring they focus on outcomes and user needs, setting of performance objectives and milestones, approval and oversight of budgets, and monitoring progress including adaptation of the approach as required.

Once commitment fo the program is agreed, we strongly recommend Sub-Program Committees for each of the 3 sub-Programs. These would include representatives of specific funders, R&D providers, local CMB's, and the legal manager of the water resource. These sub-Program committees would ensure the execution of the respective sub-programs on a more day to day basis.

Comment

Feedback during interviews indicated a preference for the research coordination model used during the Pesticides Program. In this model, LWRRDC facilitated identification of priority research, funded priority research with partners, organised an annual information sharing and project review workshop, managed funds on behalf of other funders such as the MDBC, ensured flexibility so that small and urgent information needs could be funded at short notice and commissioned research with appropriate partners. This would include facilitating information sharing to ensure adoption by end users particularly water resource and catchment managers and policy makers.

The current state of Deep Drainage research and related on-ground activities in the northern MDB region is probably at a more advanced state of development than was the case when the pesticides research program was initiated. Successful management and coordination of the RD&E effort however will be more complex due to the many dimensions of the DD related issues. There are also many independent or semi-independent stakeholders and investors with slightly differing needs and perspectives including:

- Different R&D funders
- Different agricultural industries.
- Organisational divisions in governments/agencies that implement policies such as vegetation clearance, water licencing, catchment targets, etc. semi-independently.
- Catchment management organisations.
- Multiple States developing/implementing policies within the same policy environment.

The impression formed from interviews is that in relation to the catchment scale and uplands zone in particular, there is an inadequate level of coordination and information sharing between the various research and policy agencies and hence the suggestion that LWA or MDBC with its national perspective has an important role to play here.

5.4 Potential Co-investors in Sub-programs for WB & DD related R&D

There are a large number of possible investors in the R&D Program envisaged. The level of investment and role in the project is expected to reflect the principle of beneficiary pays as well as the degree that the project is a part of the (management) organisations core business. For example state agencies and the MDBC are investing heavily in developing the methodologies and applications to set end-of-valley targets. Our analysis of possible investors is shown in Figure 5.4.

Figure 5.4: Possible investors and their Roles.

Organisation	Potential Funder	Potential R&D Provider	Potential Information User/Client
State agencies	✓	✓	✓
CMB	✓		✓
CSIRO	✓	✓	
LWA/Industry	✓		✓
MDBC	✓		✓
GRDC/Industry	✓		✓
CRDC/Industry	✓		✓
RIRDC/Industry	✓		✓
ACCRC/Industry	✓	✓	✓
MLA/Industry	✓		✓
AHC/Industry	✓		✓
AWBC/Industry	✓		✓
Universities	✓	✓	
CRCCH	✓	✓	
CRCPBMDS	✓	✓	

5.5 RESEARCH ADOPTION

Scope to Change DD Rates through Management

Deep drainage can occur from natural events such as direct rainfall and/or inundation from stormwater runoff, overland flow or flooding from streams as well as irrigation. Land-use and management has a direct effect on the magnitude and extent of DD for all catchment land uses, from forestry through grazing and dryland farming to intensive irrigated agriculture.

Deep drainage is not directly and immediately identifiable because it is "out of sight" and currently difficult to measure directly. A better understanding of the magnitude and processes for DD, and the affects of management practices within each land-use, is necessary to drive adoption of better practices. Without this there is little likelihood of changes in practices to improve DD management.

It will be necessary for resource managers to understand that improved DD management should maximise beneficial and minimise harmful DD. It should also be recognised that DD and water balance processes are relevant to all land-uses and industries and the linkages need to be well understood.

Application of Research Results

There are two main client groups for the adoption of R&D Program results: government policy and program managers and, the industry.

There is a high likelihood that results will be transferred to government programs and policies provided the necessary connections are made to mechanisms such as revegetation and land use planning initiatives, the setting of targets, salinity hazard maps, land and water management plans, and regional plans.

The second aspect is that of adoption by industry. The likelihood of this occurring is considered to be moderately high through the implementation of those government polices and programs but there is also good evidence of irrigators in the NMDB adopting practices to improve water use efficiencies once it can be credibly demonstrated that there are significant DD losses and possible gains.

There is good awareness and appreciation in the NMDB of the impacts of rising groundwater levels in the southern MDB and the potential for reduced production and environmental impacts is well known. Dryland salinity in the Liverpool Plains and areas of rising groundwater in the Macquarie Valley are recent reminders to NMDB communities of the need to be conscious of the medium to long term impacts of excessive DD. If it is established through credible R&D that DD is significantly higher than originally thought, and practical management options are offered as tools, adoption should be high.

A major driver for change in the irrigation industry would be increased water use efficiency and profitability. All irrigation areas in the NMDB are water limited and recent reductions in both surface and groundwater licence allocations will add to the incentive to reduce non beneficial DD.

Recent commercial evaluations of field irrigation application efficiency have indicated that irrigators are willing to take management decisions that increase application efficiencies to save water and improve production. Obviously simple methods of measuring DD in the field would be very useful in assisting awareness and adoption.

5.6 Implementation Processes

An indicative implementation process for the proposed Program is outlined in Figure 5.5:

Figure 5.5: Outline of Process for Implementing the Proposed Program.

STAGE	TASKS
Core management group (LWA, MDBC, CRDC, GRDC) agree whether to proceed	Core group agree whether to proceed and in-principle agreement to fund. Finalise the strategy and plan for developing the Program. Preliminary discussion of roles.
Investors agree interest and roles.	Discussions held with the range of possible investors and clients. Investors agree indicative levels of involvement, investment, roles, expectations /constraints to involvement.
Initial Program Planning Coordination Meeting **(Funders, researchers, end users)**	• Agreement of Program and sub-Program objectives. • Discussion of current R&D and R&D needs for sub-programs. • Consideration of end user needs, requirements and end products (using formats from Figures 4.2 and 4.3). • Agreement of scope of sub-program areas. • Identification of data sharing issues including protocols standards. • Adoption and communication planning. • Review of indicative roles
Detailed Planning through Separate Sub-Program Workshops	Detailed: • Review of current R&D initiatives. • Review of end user needs and specific product requirements.

(Funders, researchers, end users)	• Planning of R&D to meet end user needs. • Identification of data requirements, methodologies and data standards issues and resolution needs. • Identification of milestones, deliverables and products. • Further development of adoption and communication plan.
Program agreement.	Co-investors and R&D Providers review, negotiate and agree: • Overall Program ensuring any R&D gaps avoided. • Projects (including communication and adoption plans). • Funding contributions. • Administrative, reporting, project management arrangements agreed. • Providers identified by commissioning or tendering as appropriate. • Formal management agreements and MoU's.
Projects Implementation	
Progress Reviews	Annual (or more frequent) meetings at Program and sub-Program levels to review progress, share information, identify gaps and emerging needs, identify constraints and opportunities.
Program Completion	

6. CONCLUSION

This consultancy involved extensive consultation with a wide range of stakeholders as well as detailed consideration and analysis of the information collected. The results of this work indicate that:

1. There are a significant number of policy, program and industry drivers where lack of DD information will constrain effective implementation of these initiatives.

2. There is wide support and demand for better information on the water balance and deep drainage. There is also wide support for funding a significant R&D Program focussing on understanding the Water Balance and Deep Drainage for better catchment, water resource and agricultural outcomes in the NMDB.

3. Detailed analysis indicates that there is:

   A critical need for better and credible WB & DD information for:
   - determining the significance and scale of the salinity problem.
   - the effective implementation of NSW and Queensland Water Acts.
   - end of valley and in-valley water quality target setting.
   - targeting vegetation retention licencing and revegetation programs.

   An important need for better and credible WB & DD information is also required for several other high priority national, MDB and State policy and program and industry initiatives including:
   - regional salinity planning.
   - catchment health targets and monitoring.
   - development and implementation of water use efficiency programs.
   - development of sustainable land management practices.

   Other significant uses of better information are:
   - groundwater licencing.
   - reducing groundwater pollution risk.

4. There are a significant number of water balance and DD R&D initiatives in the Uplands Landscapes zone of the Northern MDB. The immediate need here is for a review of the work underway and what appears to be a need for better coordination and integration of these efforts.

5. There is relatively little R&D into water balance and DD in the Plains Landscapes zone and there is strong justification for new R&D. Coordination should be relatively straight forward as there is one major irrigated industry.

6. There is a significant NSW, Queensland and MDBC catchment hydrology initiative which is developing end-of-valley water quality targets for rivers in the NMDB. This provides the basis for taking an overall catchment perspective and linking of R&D undertaken in the Plains and Uplands zones

7. An integrated catchment R&D Program is recommended.

The Goal of the Program is to understand water balance and deep drainage for better catchment management in the northern Murray Darling Basin.

The recommended Program has 3 semi-independent sub-Program elements:

- Uplands Landscapes Sub-Program and,
- Plains Landscapes Sub-Program.
- The Catchment Scale Sub Program

It is recommended that the Uplands and Plains sub-Programs will undertake activities to:

- Understand deep drainage and the water balance
- Design solutions and responses to reduce deep drainage as necessary and,
- Deliver the findings to stakeholders

Much of the R&D appears to be underway already in the Uplands zone. Significant new R&D is required and justified in the Plains zone due to potential impact should shallow watertables develop and the absence of necessary management information.

The Catchment Scale sub-Program is a primary user of the outputs of the other two sub-Programs and will take those findings into a catchment context for determining water quality impacts and development of salinity hazard and risk maps. This work is underway as part of a major NSW, Queensland and MDBC end-of-valley target setting initiative.

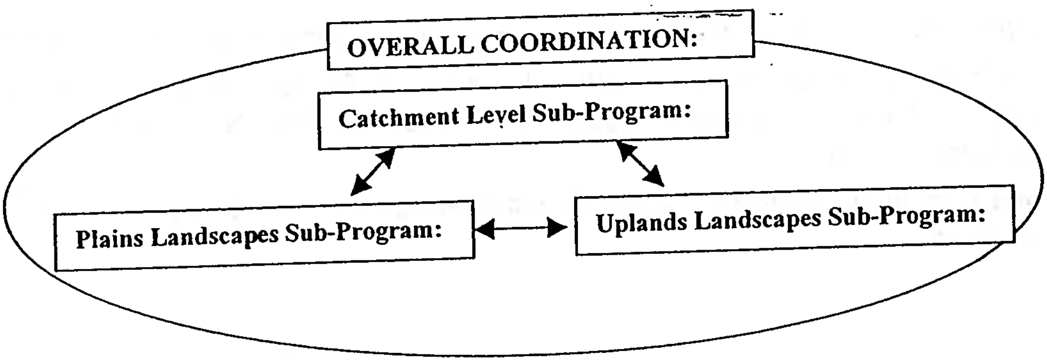
Recommended project areas to be developed and conducted as part of the Program (Attachment 6) are:

Project 1: Field Quantification of the water balance and deep drainage below the Root-Zone
Project 2: Develop Capacity to Predict and Simulate DD from Vertosol Soils
Project 3: Evaluation of the Farm Water Balance
Project 4: Develop and Interpret District-Scale Groundwater Models
Project 5: Develop, Assess and Transfer Alternative Water Management Practices and Policies
Project 6: Development and Application of Catchment Flow and Salt Routing Models

8. Overall coordination at the catchment scale is recommended for a number of reasons including to ensure consistency of methodologies, that primary user needs are being addressed and for information sharing. The 3 sub-Programs however would run with their own more intensive sub-Program management and coordination arrangements.

An initial approach to facilitate Program development is outlined which includes representatives from user groups, funders, key industries, R&D providers, Catchment Management Boards / Committees, and organisations legally responsible for management of the water resource. At this stage, investors will need to review and negotiate preferred management and coordination arrangements. Program coordination arrangements are recommended as shown in Table 6.1.

Figure 6.1: Suggested Coordination Arrangements



9. There are two prime client groups for adoption of the R&D results. The first deals with land and water resources policies and programs and includes government agencies and catchment management organisations. The second client group are agricultural industries. There is evidence indicating that there is a high likelihood of adoption following implementation of the recommended integrated Program approach.

10. Whilst this review has focussed on the northern MDB, the findings have application to other areas in Australia particularly where vertosol soils predominate.

11. There also appears to be a need to develop a similar program of user driven R&D for the southern MDB where a number of the drivers are similar. The results of this recommended R&D Program however, do not transfer directly to the southern MDB bio-region due to different industry, policy, planning and bio-physical conditions.

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Silburn, M and J. Montgomery (2001). Deep Drainage Under Cotton in Australia – A Review (in progress)

APPENDIX 1: STEERING AND MANAGEMENT COMMITTEE MEMBERS

Steering Committee
Eddie Parr, NSW Agriculture, Orange
Gary Fitt, ACCRC, Narrabri
Geoff McLeod, MDBC
Gus Hamilton DPI, Queensland,
Guy Roth, CRDC, Narrabri;
Don Yule, DNRM, Brisbane
Lamond Graham QDNRM, Toowoomba
Murray Chapman, LWA
Nick Austin NSW Agriculture, Dubbo
Nick Schofield, LWA, Canberra
Nicole Schick ACCRC, Narrabri
Peter Day, LWA
Willem Vervoort, University of Sydney

Management Committee
Gary Fitt, ACCRC, Narrabri
Gus Hamilton DPI, Queensland,
Lamond Graham QDNRM, Toowoomba
Nick Austin NSW Agriculture, Dubbo
Peter Day, LWA, Task Manager

APPENDIX 2: LIST OF THOSE CONSULTED

Abbot, Terry	NSW DLWC Sydney. Catchment Boards and planning
Austin, Nick	NSW Department of Agriculture, Dubbo
Bell, Ian	Queensland, WUE Program
Brock, Pip	Department of Land and Water Conservation, Dubbo, NSW
Browne, Dick	CRDC
Clarke, David	Landmark coordinator and RAAL coordinator
Dalton, Paul	Consultant
Day, Peter	Study Project Manager and LWA,
Dugdale, Helen	CRDC
Fitt, Gary	ACCRC, Narrabri
Gibb, Dallas	ACCRC, Narrabri
Glennon, Chris	NSW DLWC, Central West
Goss, Kevin	MDBC, Canberra. Basin Salinity Strategy
Gordon, Ian	QDNR, Brisbane. DD, salinity, end-of-valley studies
Green, Daryl	NSW DLWC, Far West
Hamilton, David	ACCRC
Hamilton, Gus	QDPI, Dalby
Harte Adrian	DLWC, Barwon Region
Hearn, Brian	Consultant, Narrabri
Hullan, Pat	NSW Macquarie, consultant. Development of hazard maps
Hulugalle, Nilantha	ACCRC, Narrabri
Kirby, Matt	CSIRO, Land and Water
Littleboy, Mark	NSW DLWC. End and in valley salinity hydrology modelling
McCormack, Lester	NSW Agric. Manilla, MLA Sustainable Grazing Systems Project
McMahon, Gavin	Sugar
Mason, Warren	MLA, Natural Resources coordinator
Merrick, Noel	UTS, lower Namoi Valley groundwater modeller
Michalk, David	NSW Agric, Tamworth, Sustainable Grazing Systems Project
Milroy, Steve	CSIRO
Parr, Eddie	NSW Agric, Orange
Price Phil	Grains RDC
Price Richard	Land and Water Australia
Power, Ed	QDNRM, Brisbane. Salinity, end-of-valley studies
Ringrose-Vose, Anthony	CSIRO, Land and Water
Schick, Nicole	ACCRC, Narrabri
Schofield, Nick	Land and Water Australia
Schulze, Ralph	CRDC
Silburn, Mark	QDNRM/ACCRC, ToowoombaDD research
Sinclair, Peter	NSW DLWC, Groundwater Section, Sydney
Triantifillis, John	University of Sydney
Vervoort, Willem	University of Sydney
Young, Rick	NSW Agriculture, Liverpool Plains
Yule, Don	QDNRM, Brisbane
Zischke, Rachael	QDNRM/ACCRC, Brisbane

APPENDIX 3: STAKEHOLDER INTERVIEW FORMAT

1. GENERIC INFORMATION

Name: Organisation: Telephone number:

2. BACKGROUND

- The organisation's objective/purpose in relation to Deep Drainage/Water Balance
- The organisation's involvement in research (eg. funder, research-provider, user of research etc)

3. DRIVERS FOR DD RESEARCH

- What are the main reasons (eg. industry, catchment) for undertaking DD and water balance research?
- What are the specific policies and/or catchment issues that demand this better information? For example,
    - MDBC cap on water diversions and Surface water licences
    - MDBC Salinity Strategy
    - End of valley targets
    - Groundwater licencing
    - National Action Plan for Salinity and Water Quality
    - State and Regional salinity, water quality, surface & sub-surface allocation strategies
    - State (Qld and NSW) Water Use efficiency Programs
    - Vegetation clearance and biodiversity targets (State & Regional)
    - River health (River biota, environmental flows, algal blooms, wetlands and groundwater interactions)
    - Profitability/water use efficiency
    - Groundwater pollution – status and trends
    - Other??
- How important are each of these drivers? (1= unimportant, 5= essential/obligatory)

4. SPECIFIC IMPACTS OF LACK OF INFORMATION

- What are the specific issue (policies, models, on-farm management, plans, extension programs, advisory services, teaching aids, delivery and communication mechanisms etc) where lack of DD information is limiting progress? (nb describe so that the specific need can be understood etc).
- How important are the impacts of lack of knowledge for each issue? (1= unimportant, 2= should be considered, 3= important, 4= very important, 5= essential/obligatory)

5. SPECIFIC INFORMATION NEEDS TO ADDRESS THE ISSUE

What is the R&D or information needed to address the issue identified above?

6. COMPARE PROJECT MANAGEMENT MODELS

Integrated Project Focussed on Catchment Scale

- What are the benefits (nrm outcomes, coordination etc) of an integrated catchment scale R&D project?
- What are the costs (nrm outcomes, coordination etc) of an integrated catchment scale R&D project?
- Is there an alternative model?

Project focussed on Agricultural systems

- What are the benefits (nrm outcomes, coordination etc) of a project focussed on DD from specific agricultural systems?
- What are the costs (nrm outcomes, coordination etc) of a project focussed on DD from specific agricultural systems (irrigation focus)?

7. ADMINISTRATIVE ISSUES

- What are the administrative issues (good and bad) associated with alternative project models?
- What are the most critical ones?
- Is there a preferred approach?

Administrative issues might be coordination of the project, coordination of funders, project management, increased or reduced paper work by researchers, inability to control project directions by funders etc. (be specific on what the issue raised is.

Conclusion: Preferred approach

APPENDIX 4: SELECTED R&D PROJECTS

Project	Project Manager	Funding
Water quality sustainability in groundwater abstraction for irrigation	Wendy Timms UNSW	NPRID, 1998-2001
- Cropping and pasture systems to manage rising water tables and salinity on the Liverpool Plains - Agricultural systems to reduce groundwater accessions in northwest New South Wales - 'Water efficient cropping and pasture systems for hydrologic stability on the Liverpool Plains and adjacent slopes of New South Wales,' - 'Hydrologic impact of grassed woodlands and lucerne based pastures on the northwest slopes of New South Wales' - 'How much deep drainage occurs in Vertosols under fallows and lucerne? - ('Tracking deep drainage and salt mobilisation from leaky landscapes in the Peel Catchment')	Rick Young NSW Ag	• GRDC Project DAN 159N (1993 – 99) • Salt Action Project NSW government, 1999-2002, $480k • GRDC Project Dan 407 1999-02, $450k • GRDC Project DAN 347 (1997 – 2001) • GRDC Project DAN 466 • (Proposed project submitted to Salt Action NHT, 2001 – 2002)
Best management practices for maximising whole farm irrigation efficiency in the Australian cotton industry	Paul Dalton, Toowoomba	CRDC, 1998-2001
Evaluation of the different measurement and modelling techniques for comparing deep drainage under current and alternative farming systems	John Williams CSIRO	LWA, 1995-99
Watertable change in western slopes cropping areas of NSW	David Dent BRS	NDSP
Delineation of potential salinity hazard in Queensland cropping lands	Ian Gordon QDNRM	NDSP
Measuring the influence of water quality on drainage through irrigated cotton soils	Rachel Zischke	CRDC
Understanding the salinity threat in cotton growing areas of Australia	John Triantifillis	CRDC
Salinity prevention in cotton rotation systems	John Friend	CRDC
Long term effects of cotton rotations on the sustainability of cotton soils	Nilantha Hulugalle	CRDC

APPENDIX 5 OUTLINE OF NSW DLWC CATCHMENT MODELLING INITIATIVE

Mark Littleboy, October 2001

Recharge Modelling Project
This project applies a water balance model to produce maps and a database of recharge potential for NSW to support regional planning and property management. This work is contributing to Actions 6.1 and 7.2 of the NSW Salinity Strategy.

Recharge of groundwater by rainwater infiltrating into the soil is one of the primary drivers of dryland salinity. The project is proposed to be in two stages. In stage 1, existing models and available data will be used to derived interim outputs. In stage 2, a model that captures the impacts of land use change on hydrology in a spatial context will be developed. A 2-Dimensional water balance modelling framework will be developed and validated. A 2D approach permits the quantification of the lateral subsurface movement of water; a major limitation of 1D water balance approaches.

There are close linkages with the initial CATSALT (1-D based model of salt movement in sub-catchments) rollout by August 2001. Recharge estimates will be linked with CATSALT modelling to ascertain the impacts of land use change on salt loads at a sub catchment scale. In addition, this project plays a key role in the development of the proposed CATSALT 2-D model in subsequent years.

This project will also provide information to the LAMPS diagnostic and management response options tools (for salinity management in dryland catchments). There are linkages with David Hoey's (dryland) recharge mapping project (classification of land into recharge classes based on soil type position in landscape) which provides the opportunity to cross validate the two different approaches to enhance confidence in project outcomes.

In subsequent years of the project, model comparisons will be made against available water balance datasets in southern Australia to validate the modelling approach.

Results from the project will be subject to critical review, firstly to ensure that the software is working correctly and, secondly, to establish the credibility of the results with community groups. This will be undertaken through presentations to CMBs and other groups. The degree of acceptance of the project products will be the main measure of success.

Recharge Validation Project
This project provides essential data to support DLWC salinity modelling activities under the Salinity Information Program. The salinity modelling activities currently underway in CNR involve the delivery of a range of products through a number of projects. Key deliverables include:

1. Estimated recharge maps of New South Wales under current land use and different land use scenarios
2. Predicted areas of landscape wetness and likely discharge areas for major Murray-Darling Basin and coastal catchments
3. Predictions of variations in streamflow, EC and salt loads from sub catchments for various land use scenarios

4. Calibration of the salinity component of IQQM (catchment run-off routing model)

These modelling activities involve the integration of a range of different simulation models. At a sub-catchment or catchment scale, the validity of model output can be quantified by comparing model predictions against currently measured streamflow, stream EC and groundwater data.

However, the modelling tools need to address intervention actions at a scale more detailed than sub-catchment - initially at a landscape scale and eventually at a property level. The datasets to support this more detailed level of modelling are currently not available. These datasets are required to increase the Departments confidence in model predictions at those finer scales.

The proposed recharge modelling approach has been extensively validated in Queensland and some overseas countries. However, there has been little quantitative validation in the NSW environment. Confidence in the recharge maps would be dramatically increased if experimental data were collected in parallel studies across various soil types and land uses in New South Wales. Direct measurement of soil moisture, plant water use and recharge data would provide DLWC with datasets to validate the recharge maps. This activity would run in parallel with the other components. The same datasets would also increase our knowledge of water movement in different landscapes - a key area for salinity modelling. For example, to determine the relative partitioning of salt export from groundwater or surface wash-off.

The project will monitor key components of the water balance across key environments in NSW. It will improve the reliability and confidence in recharge estimates by comparing modelled outcomes with measured data. Estimates of the impacts of land use change on recharge and runoff are critical inputs into the sub catchment and catchment scale streamflow and salt load modelling.

In order to improve confidence in recharge estimates, a number (4 sets of paired sites, Murray, Lachlan, Namoi, North Coast where water balance measured and closed) of continuously logged drainage lysimeters and soil moisture probes would be installed in key and environmentally important areas of NSW. Evapotranspiration is a major component of the water balance across NSW. There are few datasets that quantify evapotranspiration. The use of Bowen Ratio equipment would provide such data sets. This technology has been successfully used by Departmental staff at Wagga. Due to the complexity of the experimental approach, DLWC could either utilise skills at CSIRO to install the equipment and monitor evapotranspiration through time, or further develop its own capabilities (which option is yet to be decided and requires further consultation.

These data sets to be collected under this project would be invaluable for other DLWC activities (e.g. estimation of crop water use within IQQM).

The experimental approach to be adopted is dependent on further consultation. Presently there appears to be two likely options

1. Establishment of paired experimental sites (either contrasting soil type or land use) at 4 locations in NSW. Three of the four sites would be established within the MDB with the remaining site established in a coastal catchment. Wherever possible, this sites would be

established in collaboration with other existing experimental activities. For example, NSW Ag work in the Liverpool Plains, CSIRO projects in the Upper Billabong, DLWC monitoring sites in the Central West. At each of these 4 sites, very detailed monitoring of hydrological processes would occur.

2. Establishment of monitoring activities at each of the proposed 20 Environmental Services Investment Fund model sites. Given the larger number of sites to be monitored, the detail of monitoring would be less than for option one, but this second option would also provide important validation data for salinity modelling activities as well as support other departmental activities at the ESIF model sites. Additional funding is probably available as top up funding to support this activity.

In year 1 of the project, extensive project funds are required for equipment purchases and installation. In year 2 of the project funds are required for data collection, analysis and comparisons against CNR salinity modelling tools.

APPENDIX 6: OUTLINE OF PROPOSED PROJECTS FOR THE PLAINS LANDSCAPE ZONE:

The following outline of projects specifically targets the Plains Landscapes sub-Program. Equivalent projects for the Upland Landscapes projects need to be considered as a component of the review and coordination of current R&D. Project 6 is in essence the current State and MDBC project on catchment water quality targets although stronger linkages with projects in the Uplands Landscapes and Plains Landscapes components should be developed.

Project 1: Field Quantification of the water balance and deep drainage below the Root-Zone

Objectives:

(i) To develop reliable field techniques for estimating DD from vertosols.

(ii) To measure the quantity and quality of DD below the root zone and other components of the closed water balance from irrigated vertosol soils at soil profile and paddock scales using both direct and indirect methods.

(iii) To measure the quantity and quality of DD below the root zone from non irrigated vertosol (crops, pastures, forests) soils using both indirect and direct methods.

(iv) To develop the capacity to rapidly characterise sites at a paddock scale for DD risk.

(v) To estimate the probable impact of degrading irrigation water quality on DD and crop production.

(vi) To trial the most promising management options for managing DD identified from other field and modelling work (project 2).

(vii) To quantify the levels of uncertainty in DD estimates.

Outputs/Deliverables:

(i) Estimates of DD rates and other components of the water balance for characterised field sites with a representative range of land uses and including estimates of uncertainty.

(ii) Methodologies and improved capacity for rapidly appraising sites leading to DD risk assessments and hazard mapping.

Project 2: Develop Capacity to Predict and Simulate DD from Vertosol Soils

Objectives:

(i) To develop the capacity to model and predict DD for vertosol soils at soil profile and paddock scale.

(ii) To compare and validate model predictions with DD measurements from field measurements (project)1.

(iii) To target field measurement effort by identifying the most important input parameters by sensitivity testing model results.

(iv) To estimate the significance of episodic climatic events.

Outputs/Deliverables:

(i) A computer model for general application in estimating DD from vertosol soils and for use in other projects (project 4, project 5 and project 6).

(ii) Understanding of the levels of confidence and sensitivities of modelled results.

Project 3: Evaluation of the Farm Water Balance

Objectives:

(i) To estimate DD and other components of the water balance across whole farms including the impacts of water storages, drains and supply channels.

(ii) Develop a methodology for predicting DD from storages, channels and drains.

(iii) To appraise options for reducing DD from storages, channels and drains.

Outputs/Deliverables:

(i) Estimates of DD from across whole farms.

(ii) Options for reducing DD from water storages, channels and drains.

Project 4: Develop and Interpret District-Scale Groundwater Models

Objectives:

(i) To building on existing monitoring information, measure groundwater conditions (depth, quality, transmissivities etc) and develop groundwater monitoring networks.

(ii) To construct a detailed multi-layered groundwater model at a district scale which links DD from the root zone to groundwater response for a number of representative situations including the influence of paleochannels. The model should include unsaturated and saturated zone behaviour and have a capacity to explore management scenarios for different land use and climatic circumstances such as episodic rainfall events.

(iii) To estimate the likely rates of DD from land uses and soil types.

(iv) To predict the possible future extent and salinities of shallow water tables.

(v) To appraise the likelihood of shallow watertables developing and their impact on local land and water resources.

(vi) To estimate the critical level of district hydraulic loading (areal summation of DD from a range of land uses) beyond which shallow watertables are expected to develop.

(vii) To explore the likely impact on land and water resource condition of alternative land and water management strategies.

(ix) To appraise the impact of episodic rainfall events and possible changing climatic conditions.

Outputs/Deliverables:

(i) Estimates of DD from a range of land uses and soils types for comparison with DD estimates from projects 1, 2 and 3.

(ii) Identification of the risks and impacts of salinity developing in the Plains Landscapes.

(iii) Identification and evaluation of management options for better managing shallow watertables.

(iv) Impact analysis of local salt and water balances.

Project 5: Develop, Assess and Transfer Alternative Water Management Practices and Policies

Objectives:

(i) Using the models and results developed in other projects, identify water and soil management strategies for reducing DD to acceptable levels.

(ii) To estimate the economic impact of anticipated salinity and possible deterioration in irrigation water quality on farm profitability

(iii) To undertake an economic analysis of options for reducing DD and salinity impacts.

(iv) To develop and implement most appropriate mechanisms for transferring project findings to client groups.

(v) To link the project and its findings to existing water use efficiency programs and other industry initiatives such as Best Practice approaches.

(vi) To develop a communication strategy so that stakeholders are informed of project directions, approaches and findings to stakeholders from an early stage.

Outputs/Deliverables:

(i) Improved land and water management options and management solutions.

(ii) More productive use of available water resources.

(iii) Early identification and better management of salinity problems.

(iv) Risk assessment of different farming and land management systems.

(v) Communication of results to stakeholders from an early stage of the project.

Project 6: Development and Application of Catchment Flow and Salt Routing Models

For the Plains Landscape project:

Objectives:

(i) To link best estimates of DD from Plains Landscapes and agriculture into catchment scale models of river water quality and flows.

(ii) To estimate the impact of upper catchment conditions on river water quality and hence on: DD, district salt and water balance, development of land salinisation, and agricultural production in Plains irrigation areas.

Outputs/Deliverables:

(i) Specification of the impact of Plains landscape agriculture on stream water quality and catchment targets

(ii) Identification of the likely impact of catchment water quality targets and deteriorating river water quality on agriculture.