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Water for a Healthy Country

River Murray Corridor Systems Model

Year 2 Interim Progress Report – Task A

Rebecca Doble[1], Jeff Connor[1], Chatura Ariyaratne[1], Matthew Miles[2], Ray Evans[3], Kerryn McEwan[1], Matthew Stenson[1], Mirko Stauffacher[1] and Glen Walker[1]

[1] CSIRO Land and Water
[2] Department of Environment and Heritage
[3] Salient Solutions Australia

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The Water for a Healthy Country Flagship is a national research partnership between CSIRO, state and federal governments, private and public industry and other research providers.

The Flagship was established in 2003 as part of CSIRO’s National Research Flagships initiative. From 2004 to 2011 the initiative will receive $305 million in primary funding from the Australian Government’s Backing Australia’s Ability program.

The work contained in this report is a collaboration of the Land Technologies Alliance (LTA), a partnership of 5 State agencies and research organisations, who together are the LMLF Project's proponents:
- CSIRO Land and Water
- Primary Industries Research Victoria (Vic DPI)
- The University of Adelaide
- SA Department of Water Land and Biodiversity Conservation (DWLBC)
- South Australian Research and Development Institute (SARDI).

In addition to research provision by LTA members, other research providers include:
- SA Department of Environment and Heritage (DEH), and
- Salient Solutions.

The LMLF Project is funded with NAP funds via, both, the SA Centre for Natural Resource Management (CNRM) and the Victorian NAP/NHT Office.
The project also receives substantial in-kind co-investment through the CSIRO Water for a Healthy Country Flagship Program.

Stakeholders

- SA MDB NRM Board
- Wimmera CMA
- Mallee CMA
- Murray Darling Basin Commission
- Victorian Department for Sustainability and Environment (DSE)
- Victorian Department of Primary Industries (DPI)
- SA Department of Water Land and Biodiversity Conservation (DWLBC)

For further information contact:
Rebecca Doble
Ph: 08 8303 8705
Fax: 08 8303 8750

www.csiro.au

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EXECUTIVE SUMMARY

The milestones, as agreed by Project management and Project Steering Committee for Task A (**Development of River Corridor Systems Model-RCSM**) are as follows:

Milestone description	**Responsibility**	**Due date**
Milestone 1		**March 2005**
Acquire data to expand LMLF model into Victoria.	*Kerryn McEwan*	
Completion of the scenario analysis units	*Matt Miles/ Kerryn McEwan*	
Presentation of workplan for year 2 of project	*Glen Walker*	
Milestone 2		**June 2005**
More appropriate WUE relationships developed	*Rebecca Doble*	
Victorian SIMPACT runs	*Matt Miles*	

Milestone 1

Acquire data to expand RCSM model into Victoria

Nearly all data required for model has been collated. This includes:

- Pre-existing data in SIMRAT model
- Newly acquired hydrogeological data
- Areas of recent irrigation development
- Salinity Impact zones
- Land use
- Biodiversity values
- Depth to water table

The underlying assumptions within the SIMPACT model have been reviewed for the hydrogeology of the Victorian lower River Murray by Matthew Miles (DEH) and Ray Evans (Salient Solutions).

Completion of the scenario analysis units

The scenario analysis units were developed using spatial datasets on:

- Salinity impact zones (HIZ, LIZ 1-4)
- Irrigation districts
- River Management zones

Figure 1 shows the scenario analysis units developed for Victoria.

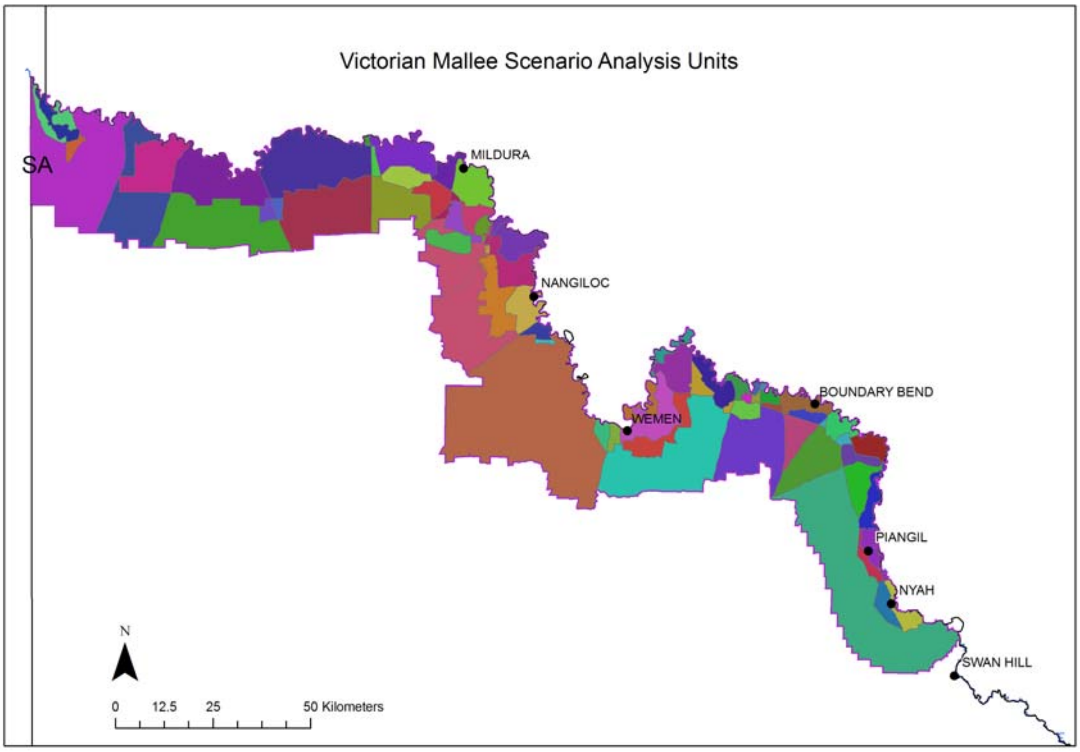


Figure 1 Scenario analysis units for Victoria

Presentation of workplan for year 2 of project

The workplan for the River Corridor Task A is shown in appendix A. This had been approved by Project Steering Committee in out-of-session meeting. Signing of contracts with research providers for this task is imminent.

Milestone 2

More appropriate WUE relationships

Identified in the December PSC meeting was the need to define water use efficiency relationships to

1. determine the effects of improving irrigation systems, technology and management on the crop yield and water use efficiency improvement, and
2. determine the impact on crop yield from root zone salt accumulation after irrigation with high salinity water at high rates of efficiency.

Irrigation technology, management and deep drainage

Effort to date has focussed on statistical evaluation of actual field practices to estimate how effectively “better” irrigation technology and management can be substituted for irrigation water resulting in reduced drainage without yield losses. Regression analysis for yield data from irrigated vines under different irrigation systems and management practices showed that significant water savings, or increases in efficiency may be made through optimal design and management of the system.

Initial results indicate that for drip irrigation:

- a water saving of around 94 mm of water may be made whilst retaining crop yield, by adequately maintaining application pressure
- a saving of over 350 mm of water may be made by designing irrigation systems to soil types rather than using uniform systems.

Further preliminary results are discussed in the main body of this report.

Salinity damage feedback relationships

The salinity damage function used within the irrigator response model is based on relationships developed in the MDBC Salinity Impact Study (GHD, 1999). These relationships are used in BIGMOD to model relative costs of salt impacts.

Gerrit Schrale and Tapas Biswas are also currently researching salt accumulation within irrigated soils, and processes used to flush the salts from the system. This project will not be completed until 2006/07. The MDBC salinity impact relationships constitute best practice until that time.

The salinity damage relationships are conceptualised by:

- Higher water use efficiencies result in salt accumulation in soils and leads to reduction of yield through salinisation.
- Yield reduction is a combination of application water EC, water use efficiency, rainfall and evaporation rates and crop type.
- As river EC increases, the water use efficiency achievable with no yield reduction decreases.
- Effective application EC also depends on the proportion of crop water requirement that rainfall provides.
- For each scenario, the water use efficiency required to achieve maximum profits is determined and used. Combined with the application rate this allows a deep drainage rate to be approximated.

These damage functions will be used within the irrigator response module to enable irrigators to choose application and efficiency rates to maximise profit.

Victorian SIMPACT runs

SIMPACT has been run using recently acquired datasets and scenario analysis units. The following runs were used to simulate effects of a range of land use and management changes.

Land use or management change	**Old Root Zone Drainage rate**	**New Root Zone Drainage Rate**	**Notes**
New development	0	80	Excludes native vegetation, existing crops, floodplain
New development	0	100	As above
New development	0	120	As above
New development	0	140	As above
New development	0	160	As above
New development	0	200	As above
Efficiency Increase	300	160	Only pre 1999 crops
Efficiency Increase	160	15	Only existing crops
Retirement	160	15	Only existing crops
Revegetation	15	0	Excludes native vegetation, existing crops, floodplain

Salt loads to river were estimated for 10, 20, 50 and 100 years after land use or management change:

The SIMPACT output for Victoria is currently being assessed against the data from the Nyah to the Border Model, but initial estimates show that results are similar.

Consultation with stakeholders

In addition to the above milestones, there have been a number of consultations with relevant stakeholders to demonstrate and discuss the prototype model, including South Australian Department of Water Land and Biodiversity Conservation (DWLBC), South Australian Research and Development Institute (SARDI), Primary Industries and Research South Australia (PIRSA), and the Victorian Mallee CMA.

More detailed comments from these meetings are shown in the body of this report and Appendix B.

Table of Contents

1 INTRODUCTION

This report forms a draft progress report for the Lower Murray Landscape Futures Project Victorian NAP June Milestone.

The individual project milestones, as agreed by Project management and Project Steering Committee for Task A (**Development of River Corridor Systems Model-RCSM**) are as follows:

Milestone description	**Responsibility**	**Due date**
Milestone 1		**March 2005**
Acquire data to expand LMLF model into Victoria.	*Kerryn McEwan*	
Completion of the scenario analysis units	*Matt Miles/ Kerryn McEwan*	
Presentation of workplan for year 2 of project	*Glen Walker*	
Milestone 2		**June 2005**
More appropriate WUE relationships developed	*Rebecca Doble*	
Victorian SIMPACT runs	*Matt Miles*	

2 MILESTONE 1

2.1.1 *Acquire data to expand RCSM model into Victoria*

Nearly all data required for model has been collated. This includes:

- Pre-existing data in SIMRAT model
- Newly acquired hydrogeological data
- Areas of recent irrigation development
- Salinity Impact zones
- Land use
- Biodiversity values
- Depth to water table

The underlying assumptions within the SIMPACT model have been reviewed for the hydrogeology of the Victorian lower River Murray by Matthew Miles (DEH) and Ray Evans (Salient Solutions).

This data has been used to develop a SIMPACT model for the Victorian river corridor, the results of which are shown in the sections below.

2.1.2 *Completion of the scenario analysis units*

The Scenario Analysis Units (SAU), the unit at which land use is distributed through the effects of policy, social and land suitability rationale, were developed by combining the following three spatial datasets to create unique discrete units.

- River Salinity Impact Zones (Figure 2)
- Irrigation District boundaries (Figure 3), and
- River Murray Management zones (Figure 4).

The five river salinity impact zones recognised for water trading rules for the Murray-Darling Basin Commission accounting were used. The zones are comprised of one high impact zone and four low impact zones.

The river management zones were derived from the RiVERS database. The RiVERS database collates a range of indices of river health and threats to river health to determine a priority ranking for management action. The River Management zones were transformed from linear riparian zones to highland areas by tracing the zone endpoints back to the study boundary along hydraulic pressure gradient directions. In other words, the highland areas were divided up into areas that discharge into the same river management zones.

The original impact zone dataset was based on a cadastral map so the zones were redigitised to remove roads and property boundaries. At the scale of redigitising some areas were amalgamated into adjacent zones, such as creeks and other small area anomalies. Impact zone borders with the river were moved to integrate with the river zone data.

The resulting units were cleaned to remove small area anomalies (slivers) from overlap of boundaries with priority given firstly to the river salinity impact zones and then to the river management zones. A unique identity number was then assigned to the final 74 units as per Table 1 and Table 2. The resulting scenario analysis units are shown below in Figure 5

Table 1. Scenario unit unique identifier code.

ID	RIVER MANAGEMENT ZONE	ID	IRRIGATION REGION	ID	IMPACT ZONE
01	M1-2	**00**	None/Null	**01**	Low impact 1
02	M1-3	**01**	Culluleraine	**02**	Low impact 2
03	M2-1	**02**	Karadoc / Iraak	**03**	Low impact 3
04	M2-2	**03**	Lake Powell / Tol Tol	**04**	Low impact 4
05	M2-3	**04**	Lindsay Point	**05**	Hi Impact
06	M2-4	**05**	Merbein		
07	M2-5	**06**	Mildura		
08	M3-1	**07**	Nangiloc/Colignan		
09	M3-2	**08**	Nurrung / Boundary Bend		
10	M3-3	**09**	Nyah / Vinifera		
11	M3-5	**10**	Piambi / Kenley		
12	M3-6	**11**	Red Cilffs		
		12	Robinvale		
		13	Thurla / Yatpool		
		14	Wemen / Happy Valley		
		15	Wood Wood / Piangil		

Table 2. Unique combination of reporting units

RIVER MANAGEMENT ZONE	IRRIGATION DISTRICT	IMPACT ZONE	UNIQUE ID
M1-2		1	010001
M1-2		2	010002
M1-2	Nyah / Vinifera	1	010901
M1-2	Nyah / Vinifera	2	010902
M1-2	Piambi / Kenley	1	011001
M1-2	Piambi / Kenley	2	011002
M1-2	Piambi / Kenley	3	011003
M1-2	Wood Wood / Piangil	1	011501
M1-2	Wood Wood / Piangil	2	011502
M1-3		1	020001
M1-3		3	020003
M1-3	Nurrung / Boundary Bend	1	020801
M1-3	Nurrung / Boundary Bend	3	020803
M1-3	Piambi / Kenley	1	021001
M1-3	Piambi / Kenley	3	021003
M2-1		1	030001
M2-1		3	030003
M2-1	Nurrung / Boundary Bend	1	030801
M2-1	Nurrung / Boundary Bend	3	030803
M2-2		1	040001
M2-2		2	040002
M2-2		3	040003
M2-2	Lake Powell / Tol Tol	1	040301
M2-2	Lake Powell / Tol Tol	2	040302
M2-2	Lake Powell / Tol Tol	3	040303
M2-2	Nurrung / Boundary Bend	1	040801
M2-2	Nurrung / Boundary Bend	2	040802
M2-2	Nurrung / Boundary Bend	3	040803
M2-3			050000
M2-3		1	050001
M2-3		2	050002
M2-3	Lake Powell / Tol Tol	1	050301
M2-3	Lake Powell / Tol Tol	2	050302
M2-3	Robinvale	2	051202
M2-3	Robinvale	3	051203
M2-3	Wemen / Happy Valley / Liparoo	1	051401
M2-3	Wemen / Happy Valley / Liparoo	2	051402
M2-3	Wemen / Happy Valley / Liparoo	3	051403
M2-4		1	060001
M2-4		4	060004
M2-4	Nangiloc / Colignan	4	060704
M2-4	Wemen / Happy Valley / Liparoo	1	061401
M2-5			070000
M2-5		1	070001
M2-5		4	070004

M2-5		5	070005
M2-5	Karadoc / Iraak	1	070201
M2-5	Karadoc / Iraak	4	070204
M2-5	Karadoc / Iraak	5	070205
M2-5	Mildura	1	070701
M2-5	Nangiloc / Colignan	4	070704
M2-5	Mildura	5	070705
M2-5	Red Cliffs	1	071101
M2-5	Red Cliffs	4	071104
M2-5	Red Cliffs	5	071105
M2-5	Thurla / Yatpool	1	071301
M3-1		1	080001
M3-1		5	080005
M3-1	Merbein	1	080501
M3-1	Merbein	5	080505
M3-1	Mildura	1	080701
M3-1	Mildura	5	080705
M3-1	Red Cliffs	1	081101
M3-2		1	090001
M3-2		5	090005
M3-2	Cullulleraine	1	090101
M3-2	Merbein	5	090505
M3-3			100000
M3-3		1	100001
M3-3		5	100005
M3-3	Cullulleraine	1	100101
M3-5		1	110001
M3-5		5	110005
M3-6			120000
M3-6		1	120001
M3-6		5	120005
M3-6	Lindsay Point	1	120401
M3-6	Lindsay Point	5	120405

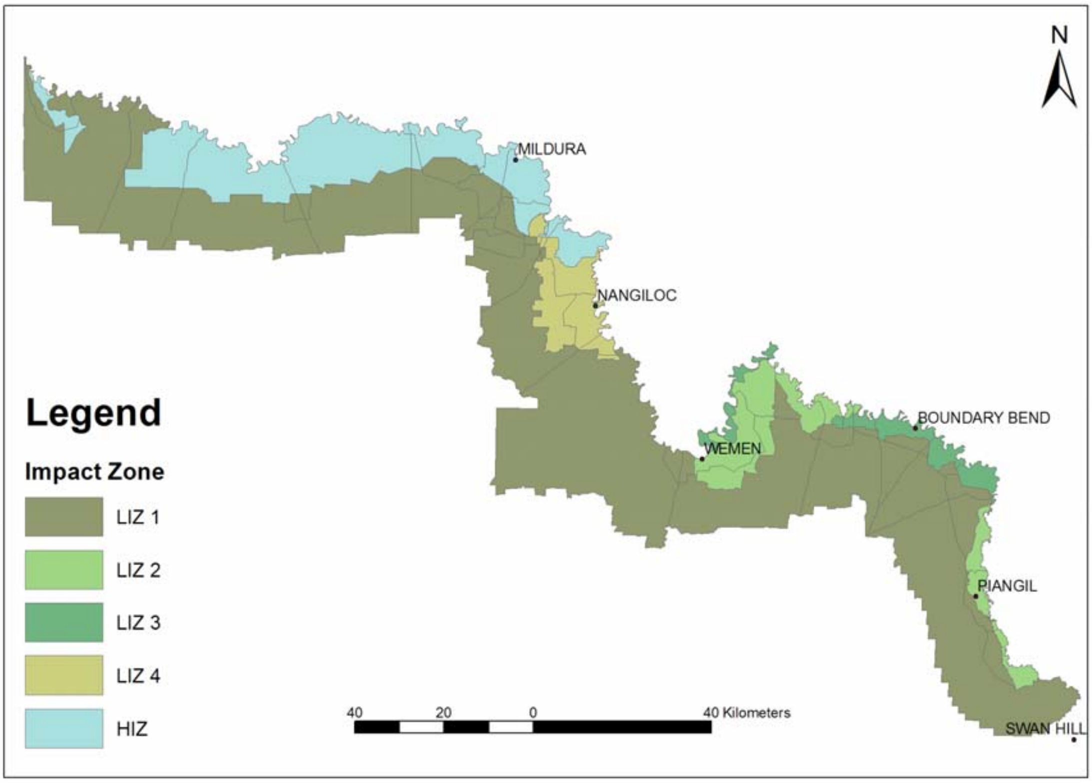


Figure 2 High and low salt impact zones

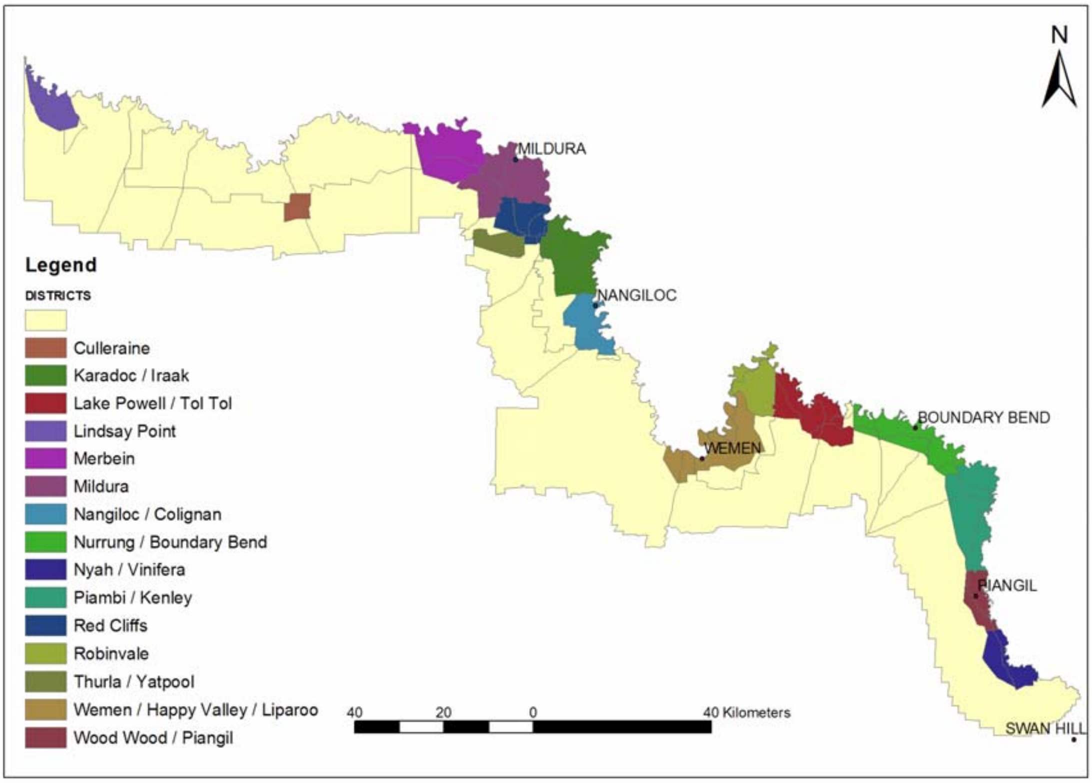


Figure 3 Irrigation districts

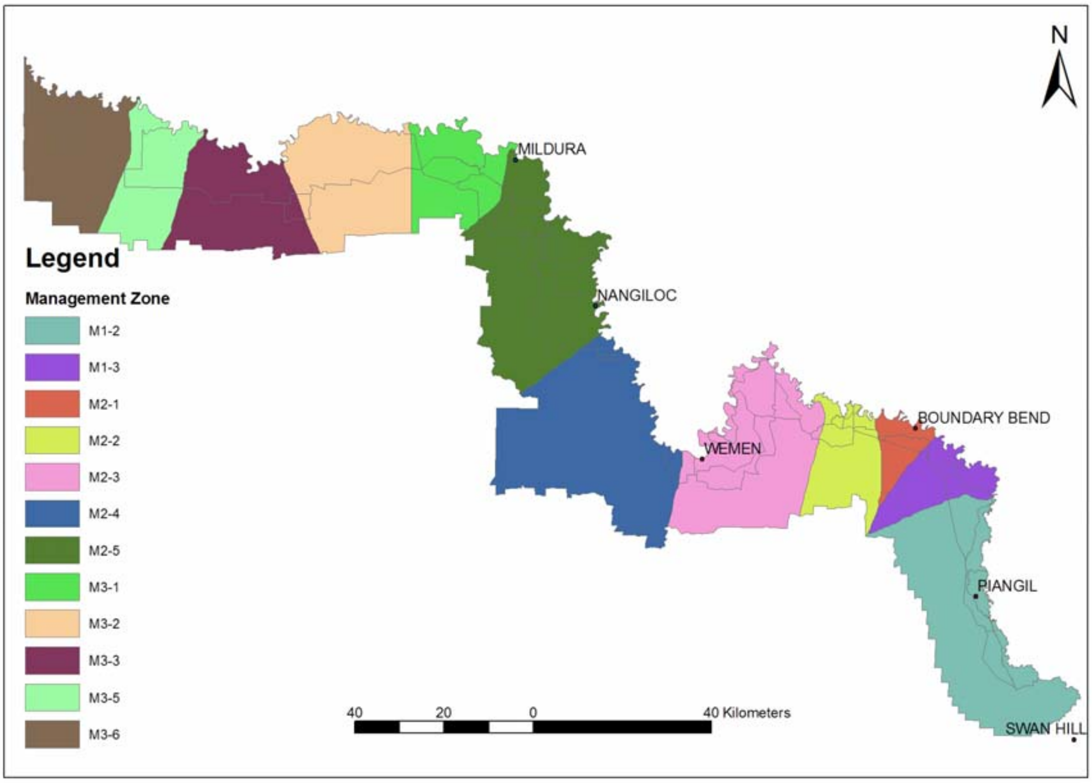


Figure 4 River Murray Management Zones

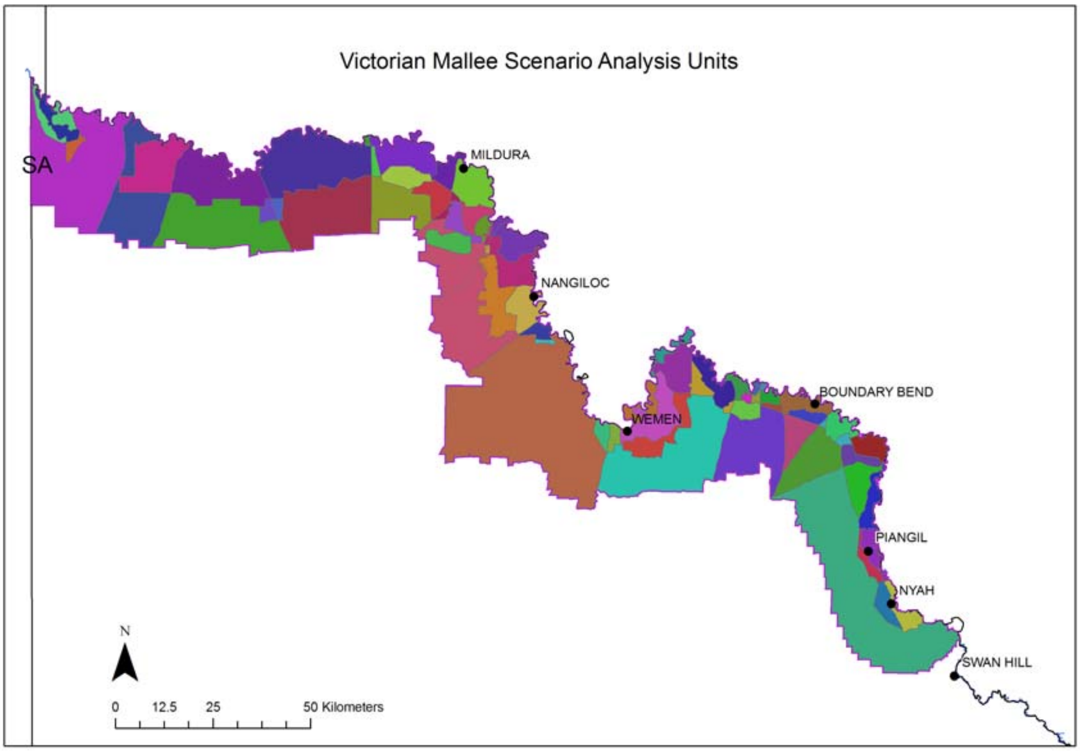


Figure 5. Victorian Mallee Scenario Analysis Units.

2.1.3 *Presentation of workplan for year 2 of project*

The workplan for the River Corridor Task A is shown in appendix A. This had been approved by Project Steering Committee in out-of-session meeting. Signing of contracts with research providers for this task should be imminent.

3 MILESTONE 2

3.1.1 *More appropriate WUE relationships developed*

Identified in the December PSC meeting was the need to define water use efficiency relationships to:

1. determine the effects of improving irrigation systems, technology and management on the crop yield and water use efficiency improvement, and
2. determine the impact on crop yield from root zone salt accumulation after irrigation with high salinity water at high rates of efficiency.

Some results of this work are discussed in the sections below.

3.1.1.1 Irrigation technology, management and deep drainage

Irrigation technology and management are key determinants of the rate of drainage below both existing and new irrigation and irrigation drainage is the single largest source of elevated groundwater levels leading to river and floodplain salinity loading. Consequently, irrigation technology (e.g. overhead versus drip irrigation) and management (e.g. frequency and timing of irrigation application, system design and maintenance) choice modelling is an emphasis of irrigator response modelling. The ultimate goal is be able to predict changes in irrigation technology and management over time in response to a range of policy, economic and biophysical systems conditions.

Effort to date has focussed on statistical evaluation of actual field practices to estimate how effectively “better” irrigation technology and management can be substituted for irrigation water resulting in reduced drainage without yield losses. Figure 6 is a representation of the kinds of results that are being obtained. It shows how many millimetres of irrigation water can be saved under various management practices with a drip irrigation system on vines. For example, comparison of bars labelled “Apres = 1” and “Apres = 0” indicates that on average drip irrigator can expect to save water around 94 mm of water without sacrificing yield by adequately maintaining application pressure. Similarly, design of the drip system to match soils will enable the irrigator to save approximately 370 mm of water. Other results are discussed in Table 3.

In addition field data collection efforts are underway to understand costs of a relevant range of technology and management practices. Ultimately, technical data on “substitutability” of technology and management for water, and economic data on costs and benefits of technology and management options will be synthesised for use in modelling changes in irrigation technology and management over time.

This work is currently being produced as a journal paper, and will form the basis of understanding the economic benefits of changing system technology, crops or management in order to improve water use efficiency. In particular data from *Irrigation Benchmarks and Best Management Practices for Winregrapes* (Skewes and Meissner

1997) and *Irrigation Benchmarks and Best Management Practices for Citrus* (Skewes and Meissner 1997) were used.

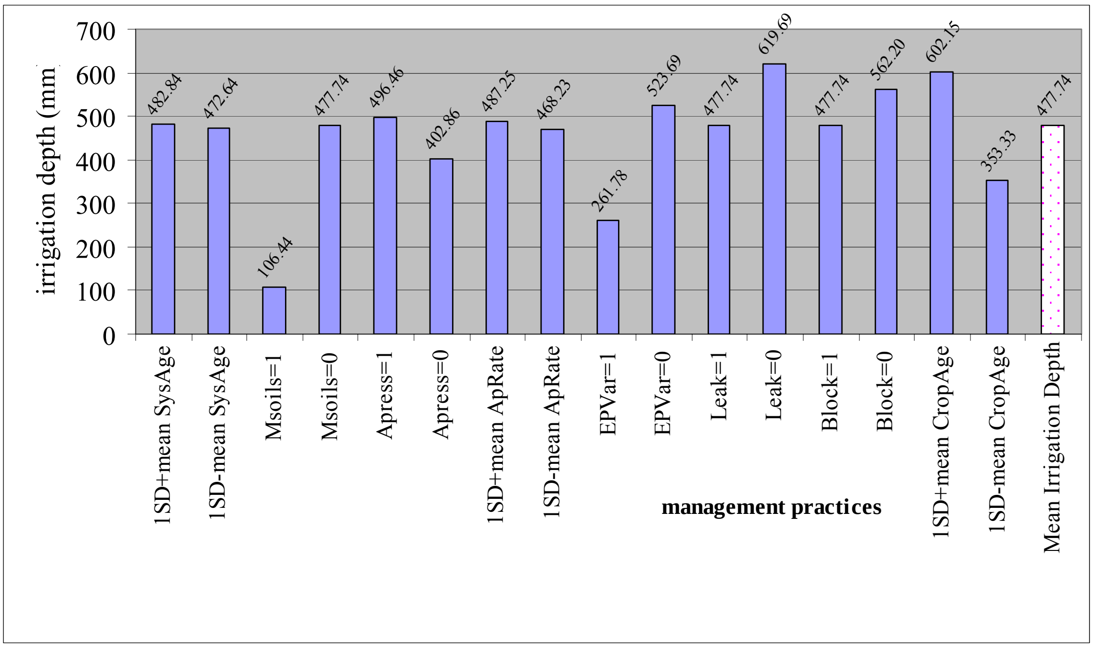


Figure 6 Irrigation water required for drip irrigation of wine grapes yield

Table 3 Description of parameters used in the regression analysis

1SD ±mean SysAge is mean age of the drip irrigation system in years plus or minus one standard deviation.	If the drip system is older (+1SD), it may consume 5mm more irrigation depth to get mean level of yield. If the drip system is new (-1SD), it may save 5mm of irrigation depth to produce mean level of yield.
Msoils is a dummy variable to reflect drip system designed to match the soils (1=yes and 0=no).	Indicates that on average drip irrigator can expect to save water around 371mm of water without sacrificing yield by using a drip irrigation system designed to match soils as opposed to the irrigation system not designed to match soils.
1SD ±mean ApRate is the mean drip irrigation system application rate in ml per hour plus or minus one standard deviation.	If the application rate is high (+1SD), it uses 9.5 mm more water to obtain mean level of grape yield. If the application rate is less (-1SD), it saves 9.5 mm of water while maintaining the mean level of grape yield.
EPVar is a dummy variable to represent presence of irrigation system emitter pressure variation (1=yes and 0=no).	Indicates that on average drip irrigator can expect to save water around 262 mm of water without sacrificing yield by using a drip irrigation system managing without any emitter pressure as opposed to the irrigation system not maintaining the emitter pressure properly.

Leak is a dummy variable to reflect leakages in the system (1=yes and 0=no).	Indicates that on average drip irrigator can expect to save water around 142mm of water without sacrificing yield by not fixing the leakages in the drip irrigation system as opposed to the repairing and managing the irrigation system properly.
Block is a dummy variable to represent emitter blockages in the system(1=yes and 0=no).	Indicates that on average drip irrigator can expect to save water around 85mm of water without sacrificing yield by not fixing the blockages in the drip irrigation system as opposed to the repairing and managing the irrigation system properly.
1SD ±mean CropAge is the mean age of the crop in years plus or minus one standard deviation.	If the vines are older (+1SD), it may consume 124mm more water to get mean level of yield. If the vines are young (-1SD), it may save 124mm of water to produce mean level of yield.

3.1.1.2 Salinity damage feedback relationships

The salinity damage function used within the irrigator response model is based on relationships developed in the MDBC Salinity Impact Study (GHD, 1999). These relationships are used in BIGMOD to model relative costs of salt impacts.

Gerrit Schrale and Tapas Biswas are also currently researching salt accumulation within irrigated soils, and processes used to flush the salts from the system. This project will not be completed until 2006/07. The MDBC salinity impact relationships constitute best practice until that time.

The salinity damage relationships are conceptualised by:

- Higher water use efficiencies result in salt accumulation in soils and leads to reduction of yield through salinisation.
- Yield reduction is a combination of application water EC, water use efficiency, rainfall and evaporation rates and crop type.
- As river EC increases, the water use efficiency achievable with no yield reduction decreases.
- Effective application EC also depends on the proportion of crop water requirement that rainfall provides.
- For each scenario, the water use efficiency required to achieve maximum profits is determined and used. Combined with the application rate this allows a deep drainage rate to be approximated.

An example of crop yield reduction with increasing water use efficiency and application water EC is shown for vines in Figure 7. Figure 8 indicates the maximum water use efficiency possible required to maintain maximum crop yield at varying EC of application water, which is the weighted average EC of irrigation water and rainfall.

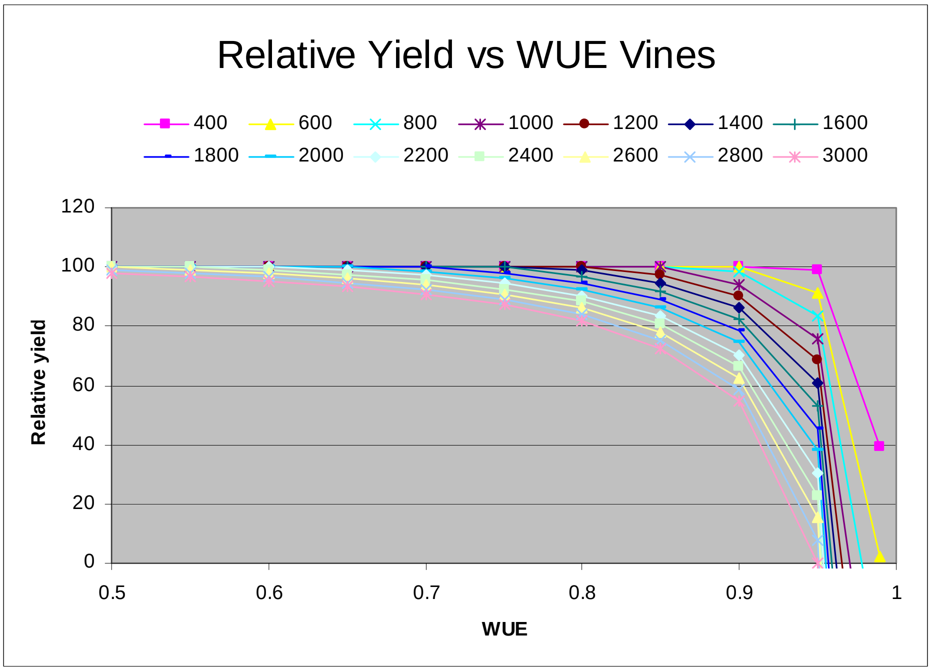


Figure 7 Change in relative crop yield for vines with water use efficiency and application water EC.

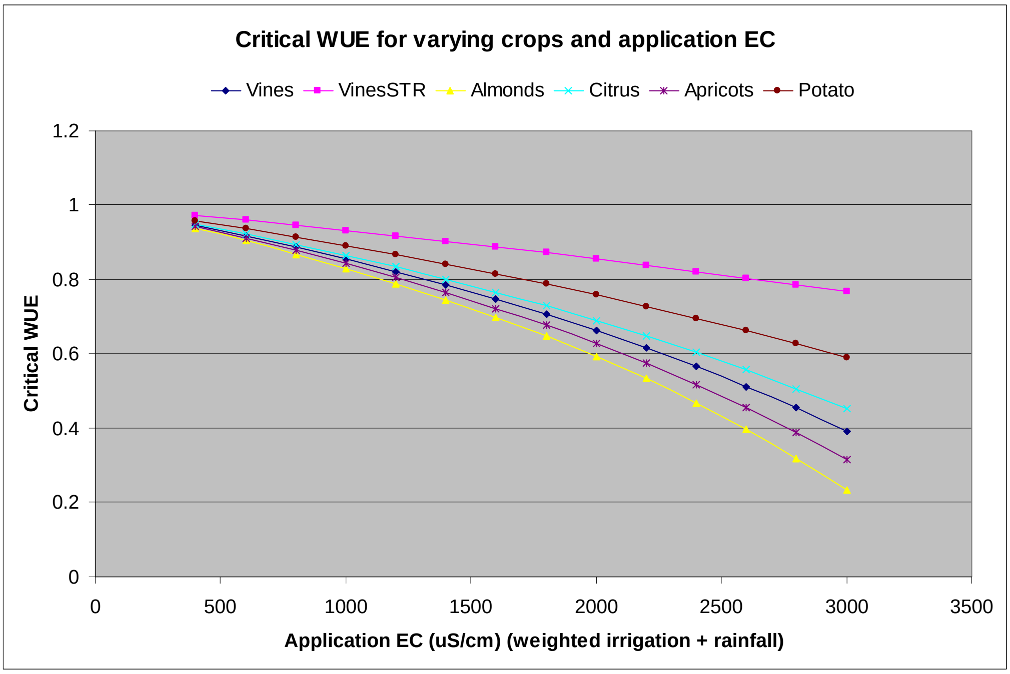


Figure 8 Maximum water use efficiency required to maintain maximum yield at varying application water EC.

These damage functions will be used within the irrigator response module to enable irrigators to choose application and efficiency rates to maximise profit.

A description of the methodology used to develop the salinity damage relationships is found in Appendix D.

3.1.2 *Irrigator response model*

In response to the better representation of water use efficiency relationships, a method of distributing irrigation development and deep drainage data spatially is being developed. This will link the model scenario policy choices (incentives for WUE improvement, zoning restrictions) to on ground distribution of development within the river corridor systems model. The theory behind this model is discussed in the following section.

3.1.2.1 Economic Decision Making and Impact Models for Lower Murray Landscape Futures River System Modelling

CSIRO economists are making two contributions to the Lower Murray Landscape Futures project: economic decision making modelling and economic impact modelling.

The economic response modelling is to simulate key irrigator responses and follow-on consequences including:

- irrigation development levels and locations,
- choices of irrigation technology and management,
- irrigation economic activity levels and profits from irrigation.
- irrigation application rates and drainage levels by location (a key input into the linked biophysical salt and water process models that will be used to predict salinity state of the river, and floodplain ecological health).
- The cost to governments (or irrigators, depending on assumed policy) of investment in salt interception and drainage disposal to meet MDBC salinity targets

The response models will be built to be capable of predicting irrigator response to changes in:

- economic conditions (e.g. commodity prices, production costs)
- policy (e.g. irrigation land use zoning, or salinity charges)
- biophysical system state (e.g. salinity of irrigation water, climate influence on crop ET and water availability).

Economic impact modelling is to estimate how changes in irrigation management can be expected to change farm profits and regional irrigated agricultural sector level economic activity levels.

3.1.2.2 Integrating irrigator response and salt and water process models

The project will require integration of economic irrigation practice change models and biophysical salinity impact models on very different time scales. This will be accomplished by modelling scenarios as consisting of two distinct time periods. The first is a period of change (typically a decade or more) in which economic, policy or biophysical system state changes result in changes in irrigation. Farm profit and regional economic consequences are assume to become manifest in this period.

The second period is the salinity impact assessment period of a century. Salinity impacts that would follow-on from irrigation practices over the period of change is assessed in this period. To model consistently with the steady state groundwater model used in salinity impact assessment, it will be assumed that changes in irrigation practices adopted during the change period persist for the entire 100 year salinity impact assessment period.

3.1.2.3 Irrigator response modelling plans and progress

In initial model development, economic rationalism (profit maximisation) will be assumed to be the primary determinant of irrigator responses. This assumption will be modified in future work using results from a Lower Murray regional irrigator practice and attitude survey currently being conducted by the CSIRO ARCWIS group when survey results become available and their usefulness in behaviour specification has been evaluated.

The proposed approach is to build a model to represent the way that, in response to policy or environmental changes, irrigators are likely to choose among a range of strategies open to them. It is assumed in the model that choice is based on which options maximise profit (given limits such as available technology, information, management capacity or capital limits).

The intent is to model a period of change (a decade or more) in which economic, policy or biophysical system state changes result in changes in long-run capital investments including: irrigation, land and horticultural/vine stock and permanent water allocation investments. It will be assumed that each year over a change period irrigators will consider whether or not existing vine or horticultural stock and irrigation equipment is fully depreciated and thus whether to and if so where to re-invest in irrigation and what type of irrigation to invest in. In addition, each year an amount of permanent water will be assumed available on the market from out of the region, and if it is expected to be profitable to use the water for irrigation, irrigators will invest in additional development.

The location of development (distance from the river and lift above the river) is a key determinant of salinity impact and a significant determinant of irrigation development cost as well. For this reason, an algorithm that simulates how irrigators would choose among potential sites for development based on water delivery infrastructure and power costs is being developed for this part of the modelling. This involves GIS based information about distance to river, depth to groundwater on land available for irrigation development, and engineering costs estimation procedure building on estimates that have already been developed by PIRSA (2004), Connor (2003). Development zoning policy will be modelled as restrictions on choice of development site to areas zoned low salinity impact.

An updated description of the irrigator response model is shown in Appendix F.

3.1.3 *Victorian SIMPACT runs*

SIMPACT has been run using recently acquired datasets and scenario analysis units. The following runs (Table 4) were used to simulate effects of a range of land use and management changes.

Table 4 SIMPACT runs performed for Victoria

Land use or management change	Old Root Zone Drainage rate	New Root Zone Drainage Rate	Notes
New development	0	80	Excludes native vegetation, existing crops, floodplain
New development	0	120	As above
New development	0	160	As above
New development	0	200	As above
Efficiency Increase	300	160	Only pre 1999 crops
Efficiency Increase	160	15	Only existing crops
Retirement	160	15	Only existing crops
Revegetation	15	0	Excludes native vegetation, existing crops, floodplain

Salt loads to river were estimated for 10, 20, 50 and 100 years after land use or management change, and the groundwater and salt impacts are shown in Figure 9 and Figure 10 respectively. The highest groundwater impacts and high salt impacts are found in different reaches of the river corridor due to the variation of regional groundwater salinity within this part of the basin.

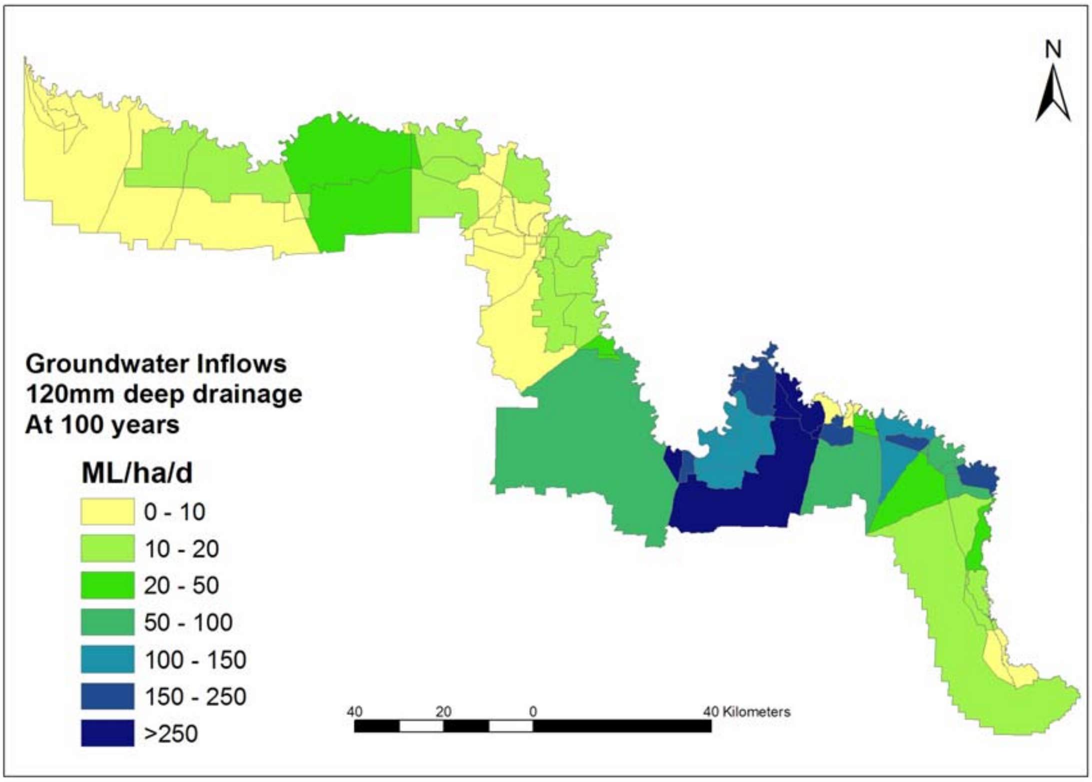


Figure 9 Groundwater inflow impacts (ML/ha/d) calculated from SIMPACT, using deep drainage rates of 120 mm after 100 years.

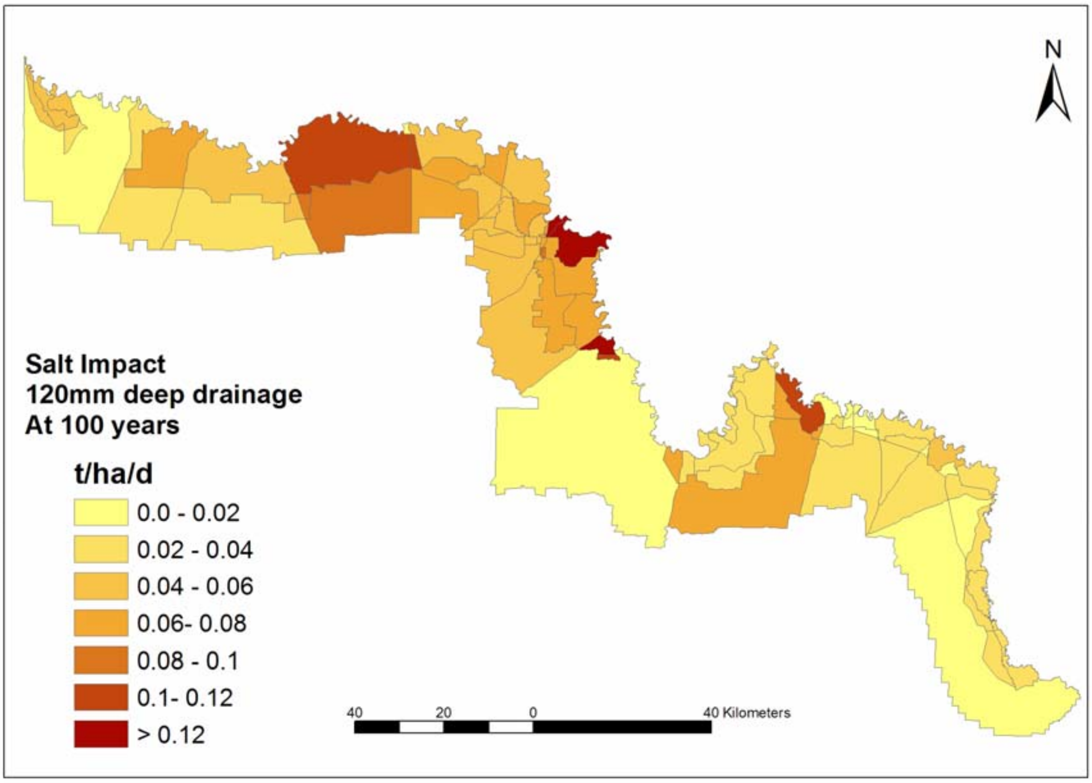


Figure 10 Salt impacts (t/ha/d) calculated from SIMPACT, using deep drainage rates of 120 mm after 100 years.

3.1.3.1 Testing of SIMPACT results

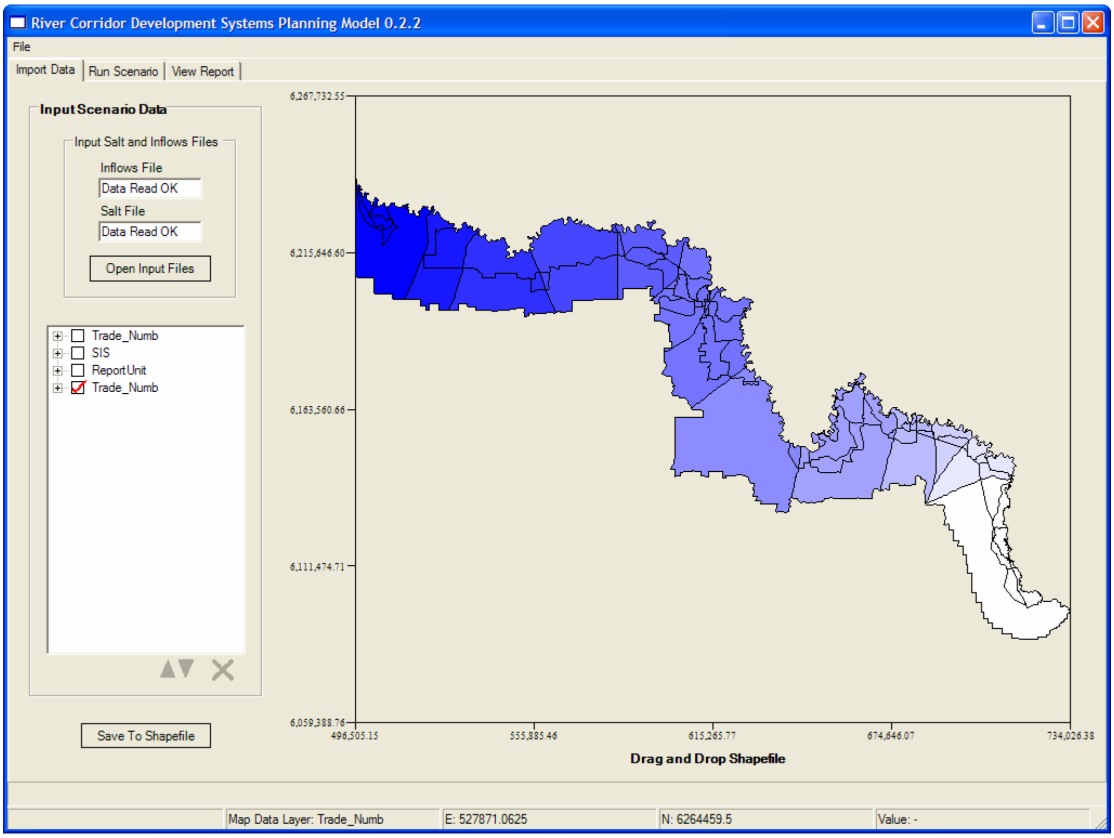
The SIMPACT output for Victoria is currently being assessed against the data from the Nyah to the Border Model. Preliminary testing is outlined in Appendix E. Initial results with coarse assumptions for timescale, irrigation rates and conversion from tonnes of salt per day to EC at Morgan show that SIMPACT is predicting salt impacts at approximately the same scale as the Nyah to the Border model. More detailed comparison of these model results is underway.

Victorian Prototype Model

The scenario analysis units and SIMPACT runs for the Victorian river corridor were developed to be used within the prototype model. Screen captures in the following figures demonstrate use of the model.

The more detailed rules governing development within the high and low impact zones in Victoria will be included in the next phase of model development, within the irrigator response function.

Baseline data on the distribution of irrigation development was only available for the period 1997 to 2003. This was weighted over a 15 year period to enable relationship with South Australian runs. This may have produced an overestimate of development rates. The irrigator response function will provide an improved method of distributing irrigation development spatially.



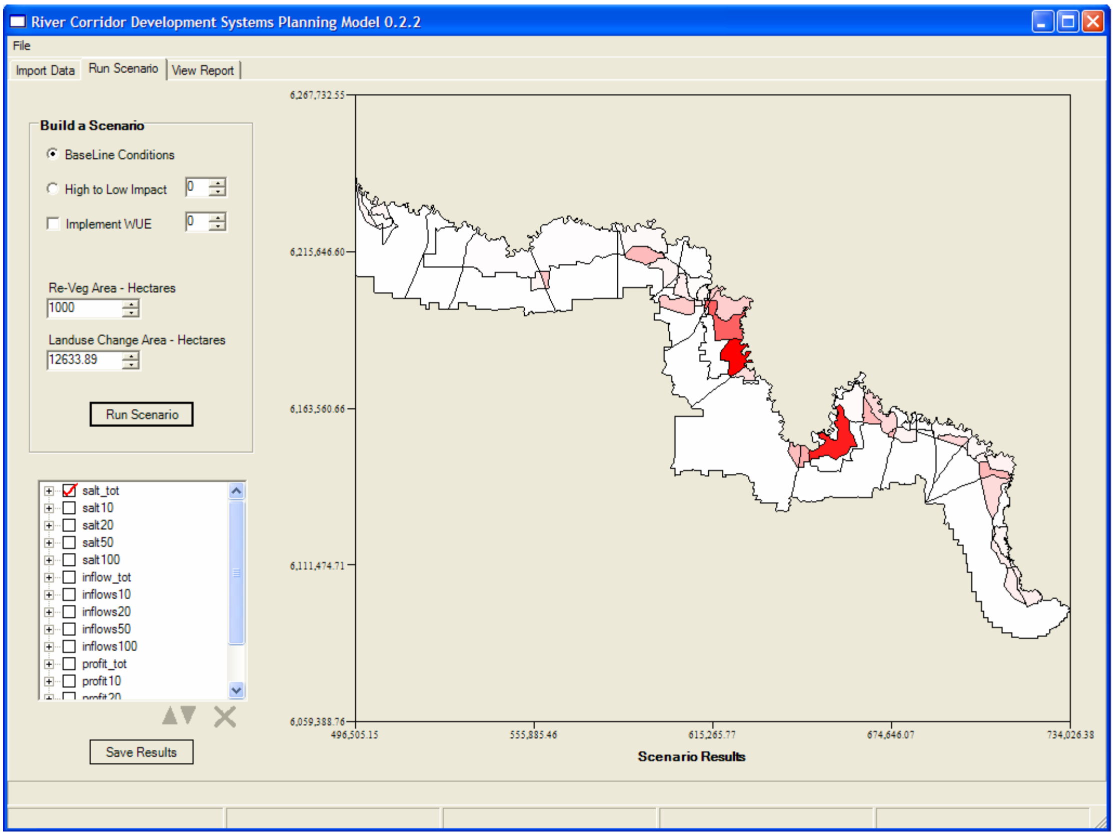
Inflows File: Data Read OK

Salt File: Data Read OK

- ☐ Trade_Numb
- ☐ SIS
- ☐ ReportUnit
- ☑ Trade_Numb

Map Data Layer: Trade_Numb | E: 527871.0625 | N: 6264459.5 | Value: -

Figure 11 Import data screen showing Victorian scenario analysis units



● BaseLine Conditions

○ High to Low Impact: 0

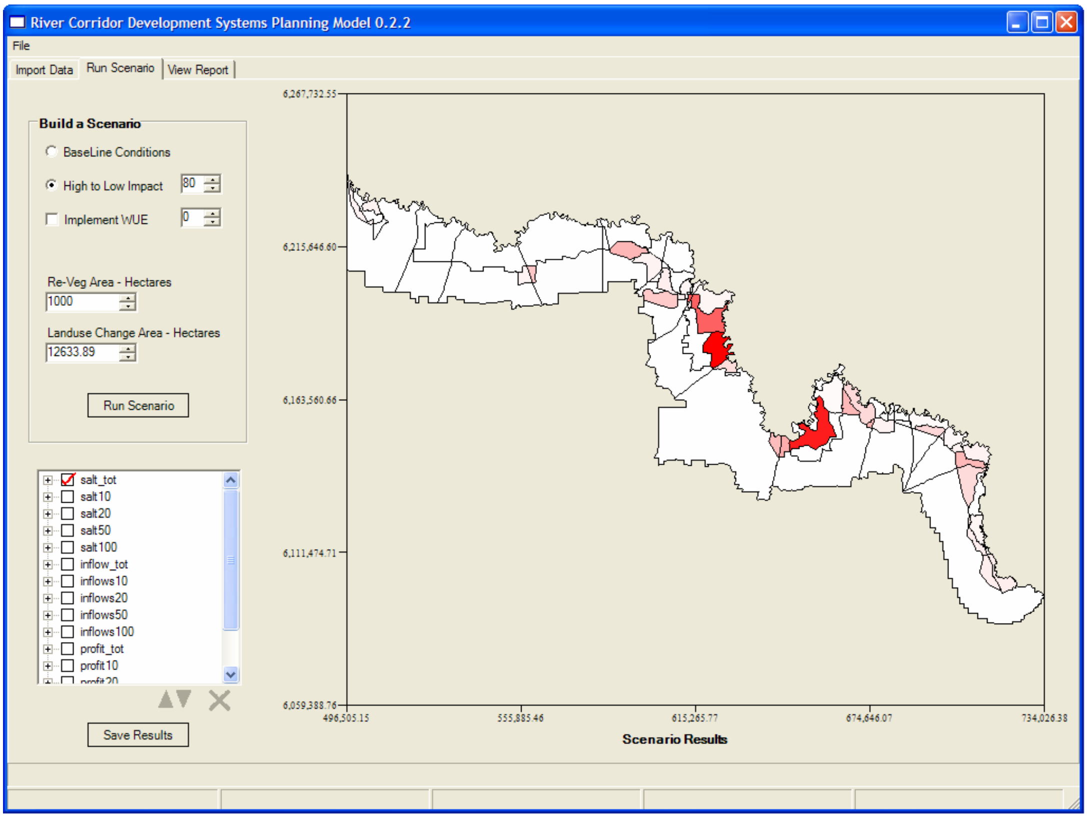
☐ Implement WUE: 0

Re-Veg Area - Hectares: 1000

Landuse Change Area - Hectares: 12633.89

- ☑ salt_tot
- ☐ salt10
- ☐ salt20
- ☐ salt50
- ☐ salt100
- ☐ inflow_tot
- ☐ inflows10
- ☐ inflows20
- ☐ inflows50
- ☐ inflows100
- ☐ profit_tot
- ☐ profit10
- ☐ profit20

Figure 12 Scenario development screen showing the salt impacts results from a baseline condition run.



Build a Scenario

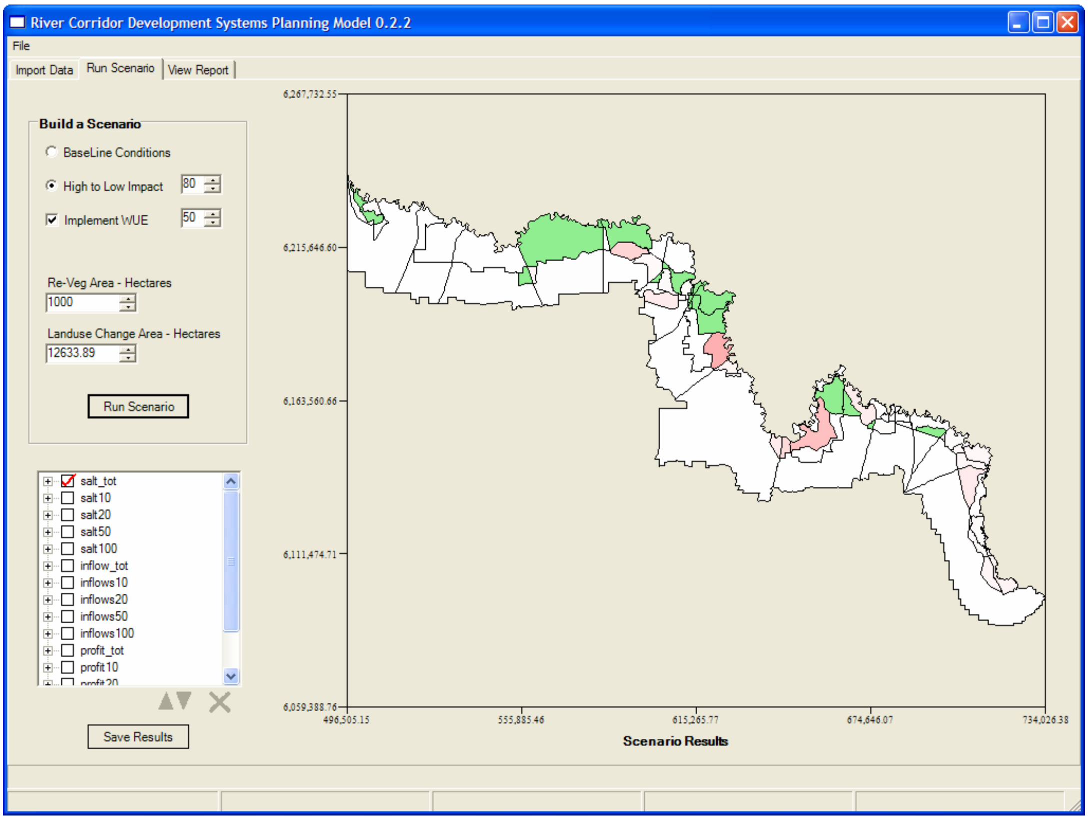
○ BaseLine Conditions
● High to Low Impact 80
☐ Implement WUE 0

Re-Veg Area - Hectares 1000

Landuse Change Area - Hectares 12633.89

☑ salt_tot
☐ salt10
☐ salt20
☐ salt50
☐ salt100
☐ inflow_tot
☐ inflows10
☐ inflows20
☐ inflows50
☐ inflows100
☐ profit_tot
☐ profit10

Figure 13 Scenario development screen showing the salt impacts results from an 80% rezoning run. Note that there is little change within the high impact zones, as there has been only little development within them during the 1997 to 2003 baseline period.



Build a Scenario

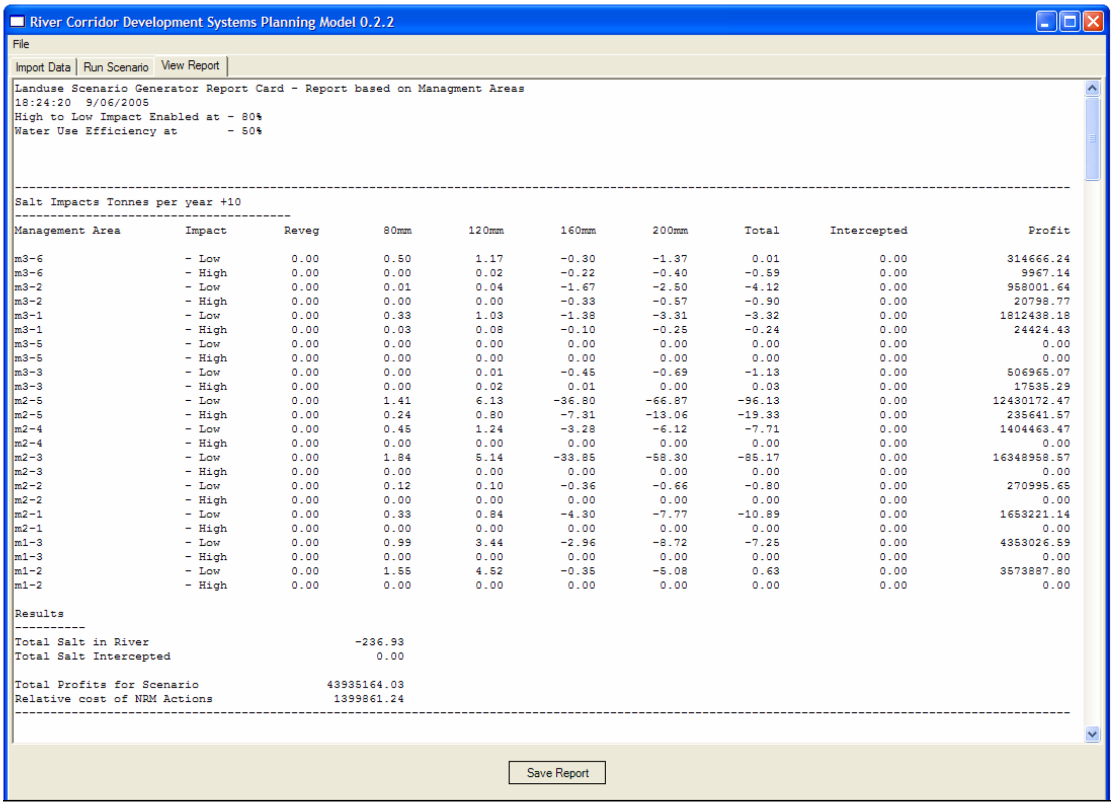
○ BaseLine Conditions
● High to Low Impact 80
☑ Implement WUE 50

Re-Veg Area - Hectares 1000

Landuse Change Area - Hectares 12633.89

☑ salt_tot
☐ salt10
☐ salt20
☐ salt50
☐ salt100
☐ inflow_tot
☐ inflows10
☐ inflows20
☐ inflows50
☐ inflows100
☐ profit_tot
☐ profit10

Figure 14 Scenario development screen showing the salt impacts results from an 80% rezoning run and 50% of WUE improvement. Green areas represent negative impact change compared with current conditions.



```
Landuse Scenario Generator Report Card - Report based on Managment Areas
18:24:20  9/06/2005
High to Low Impact Enabled at - 80%
Water Use Efficiency at       - 50%



----------------------------------------------------------------------------------------------------------------------------------------------------
Salt Impacts Tonnes per year +10
---------------------------------------
Management Area         Impact       Reveg         80mm        120mm        160mm        200mm        Total       Intercepted                Profit

m3-6                    - Low          0.00         0.50         1.17        -0.30        -1.37         0.01              0.00             314666.24
m3-6                    - High         0.00         0.00         0.02        -0.22        -0.40        -0.59              0.00               9967.14
m3-2                    - Low          0.00         0.01         0.04        -1.67        -2.50        -4.12              0.00             958001.64
m3-2                    - High         0.00         0.00         0.00        -0.33        -0.57        -0.90              0.00              20798.77
m3-1                    - Low          0.00         0.33         1.03        -1.38        -3.31        -3.32              0.00            1812438.18
m3-1                    - High         0.00         0.03         0.08        -0.10        -0.25        -0.24              0.00              24424.43
m3-5                    - Low          0.00         0.00         0.00         0.00         0.00         0.00              0.00                  0.00
m3-5                    - High         0.00         0.00         0.00         0.00         0.00         0.00              0.00                  0.00
m3-3                    - Low          0.00         0.00         0.01        -0.45        -0.69        -1.13              0.00             506965.07
m3-3                    - High         0.00         0.00         0.02         0.01         0.00         0.03              0.00              17535.29
m2-5                    - Low          0.00         1.41         6.13       -36.80       -66.87       -96.13              0.00           12430172.47
m2-5                    - High         0.00         0.24         0.80        -7.31       -13.06       -19.33              0.00             235641.57
m2-4                    - Low          0.00         0.45         1.24        -3.28        -6.12        -7.71              0.00            1404463.47
m2-4                    - High         0.00         0.00         0.00         0.00         0.00         0.00              0.00                  0.00
m2-3                    - Low          0.00         1.84         5.14       -33.85       -58.30       -85.17              0.00           16348958.57
m2-3                    - High         0.00         0.00         0.00         0.00         0.00         0.00              0.00                  0.00
m2-2                    - Low          0.00         0.12         0.10        -0.36        -0.66        -0.80              0.00             270995.65
m2-2                    - High         0.00         0.00         0.00         0.00         0.00         0.00              0.00                  0.00
m2-1                    - Low          0.00         0.33         0.84        -4.30        -7.77       -10.89              0.00            1653221.14
m2-1                    - High         0.00         0.00         0.00         0.00         0.00         0.00              0.00                  0.00
m1-3                    - Low          0.00         0.99         3.44        -2.96        -8.72        -7.25              0.00            4353026.59
m1-3                    - High         0.00         0.00         0.00         0.00         0.00         0.00              0.00                  0.00
m1-2                    - Low          0.00         1.55         4.52        -0.35        -5.08         0.63              0.00            3573887.80
m1-2                    - High         0.00         0.00         0.00         0.00         0.00         0.00              0.00                  0.00

Results
----------
Total Salt in River                             -236.93
Total Salt Intercepted                             0.00

Total Profits for Scenario                  43935164.03
Relative cost of NRM Actions                 1399861.24
----------------------------------------------------------------------------------------------------------------------------------------------------
```

Figure 15 Report card screen showing the numerical data that is used to plot the visual representations in the figures above.

4 CONSULTATION WITH STAKEHOLDERS

In addition to the above milestones, there have been a number of consultations with relevant stakeholders to demonstrate and discuss the prototype model, including South Australian Department of Water Land and Biodiversity Conservation (DWLBC), South Australian Research and Development Institute (SARDI), Primary Industries and Research South Australia (PIRSA), and the Victorian Mallee CMA. Details of these meetings are shown below and in Appendix B.

Date	Location	People Present	Topic
15/04/05	Loxton Research Centre	Dan Meldrum (RMCWMB), Tony Adams (PIRSA), Dennis Sparrow(PIRSA), Jahangir Alam, Rebecca Doble (CSIRO), Chatura Ariyaratne (CSIRO)	Water use efficiency and deep drainage distribution
23/03/05	CSIRO	Gerrit Schrale (DWLBC), Tapas Biswas (SARDI), Glen Walker, Rebecca Doble	Salinity Damage Functions
6/05/05	Licking Salinity Forum Berri Resort Hotel	Gerrit Schrale (DWLBC), Geoff McLean (PIRSA), Rob Stevens (SARDI)	Salinity Damage Functions

9/05/05	Telephone conversation	Gerrit Schrale (DWLBC), Rebecca Doble	Salinity Damage Functions
12/05/05	Telephone conversation	Andy Close (MDBC), Rebecca Doble	Salinity Damage Functions
26/05/05	Mildura	Chris Biesaga (Mallee CMA), Mirko Stauffacher (CSIRO)	Victorian model expansion
2004-2005	Mildura	Chris Biesaga (Mallee CMA),Trent Wallace, Glen Walker, Kerryn McEwan	Victorian model expansion
01/06/05	DWLBC Adelaide	Phil Cole (DWLBC), Jeff Connor, Rebecca Doble, Thea Mech	Development of future scenarios

5 ADDITIONAL WORK

5.1 River Corridor Systems Model concept development

The concept for the updated River Corridor Systems Model is being developed, including plans for coding of the relationships. A full description of the model will be provided for the December Progress Report, but this section briefly outlines the structure of the model, and the conceptualisation of the relationships between the relationships between irrigators, policy makers and the river is shown.

A conceptual model for the updated River Corridor Systems model is found in Figure 18. The structure of the model, with linkages between modules is shown in Figure 17.

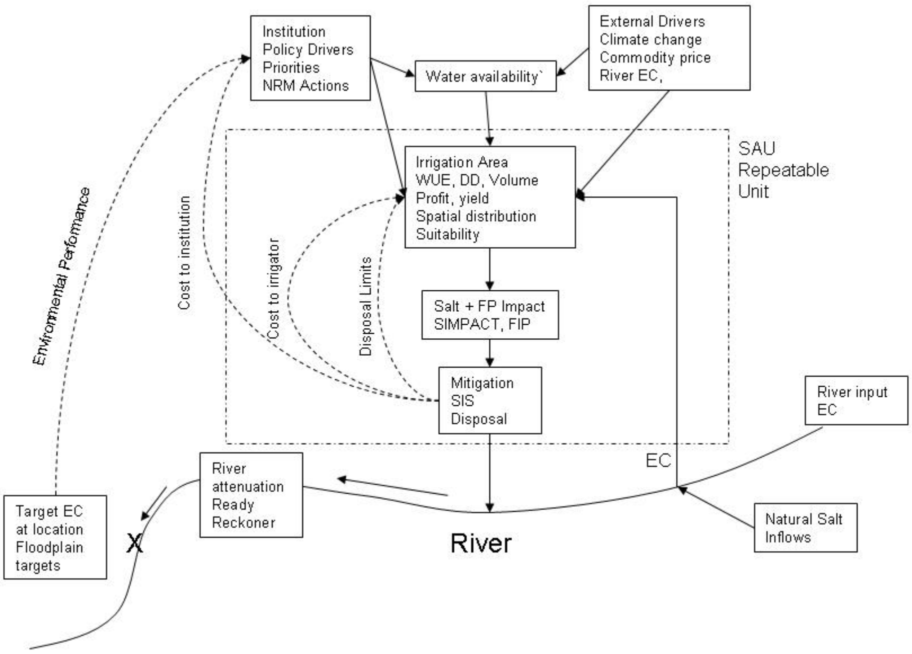


Figure 16 Conceptual model for the River Corridor Systems Model, showing the relationships between irrigators, policy makers and the river.

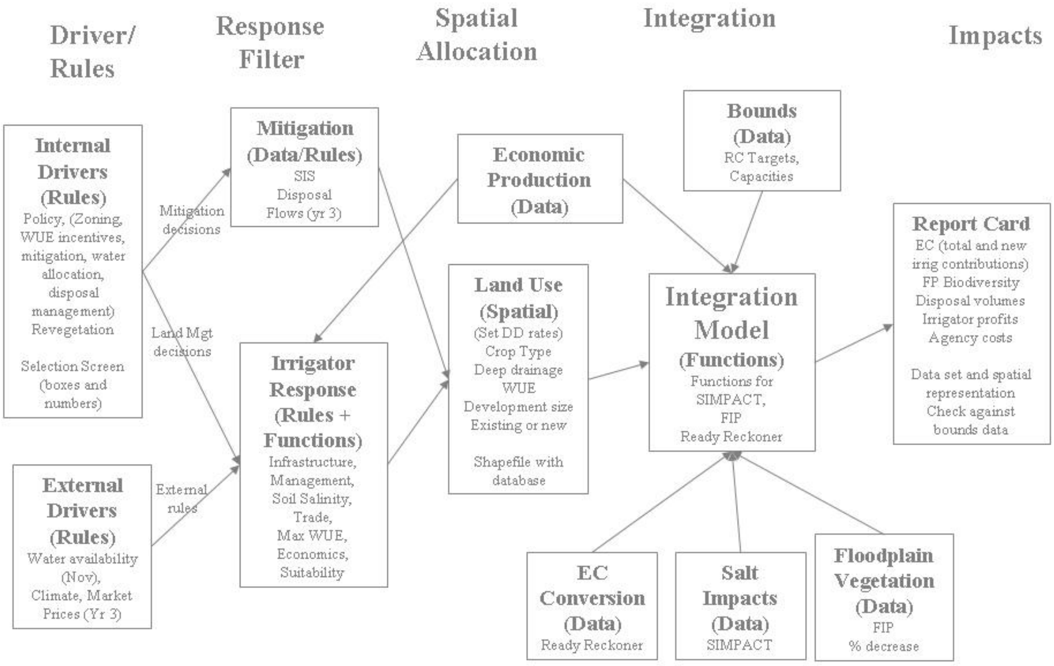


Figure 17 Model structure showing relationships between modules

The irrigator response module has been described in Section 3 above.

5.2 Floodplain Impacts

The Floodplain Vegetation Impacts module provides data for the calculation of floodplain impacts from groundwater inflows calculated by SIMPACT.

Two key resource condition targets (RCTs) relevant to floodplain and vegetation impacts include:

- Maintain and improve the extent and condition of 65% of current floodplain vegetation communities in areas of high priority by 2020.
- By 2020, a 30% reduction in priority areas of floodplain currently affected by salinity from groundwater discharge.

The first RCT is inherently related to weir manipulations and flow management, and is difficult to include within the second year stage of the river corridor model. It will be addressed when flow management is also included in the model framework.

The river corridor systems model requires a broken stick function to calculate floodplain impacts from groundwater inflows calculated by SIMPACT (Figure 18). The FIP project will provide data for the ET Commencement Point (ETCP) and the Seepage Commencement Point (SCP).

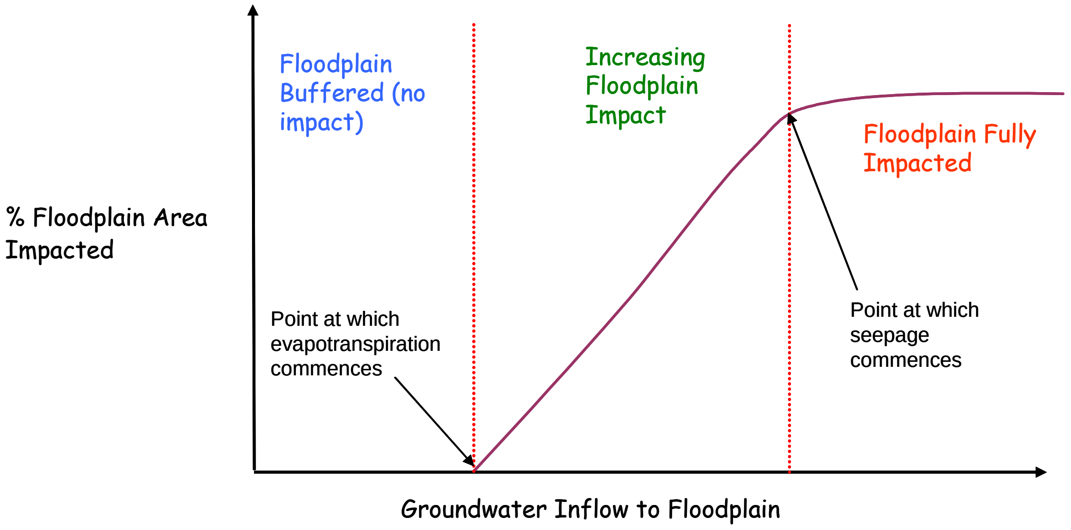


Figure 18 Diagram showing the relationship between groundwater inflow to the floodplain and the potential classifications of impact based on the points at which evapotranspiration and seepage commences.

Figure 19 shows the broken stick relationships between groundwater inflow and salinity impact for floodplains upstream and downstream of a lock and at the midpoint of a weirpool. It shows the ET commencement point and seepage commencement points. Salinity damage is higher upstream of a lock due to the shallower groundwater table, and in this case, there is no groundwater inflow buffer before floodplain damage occurs.

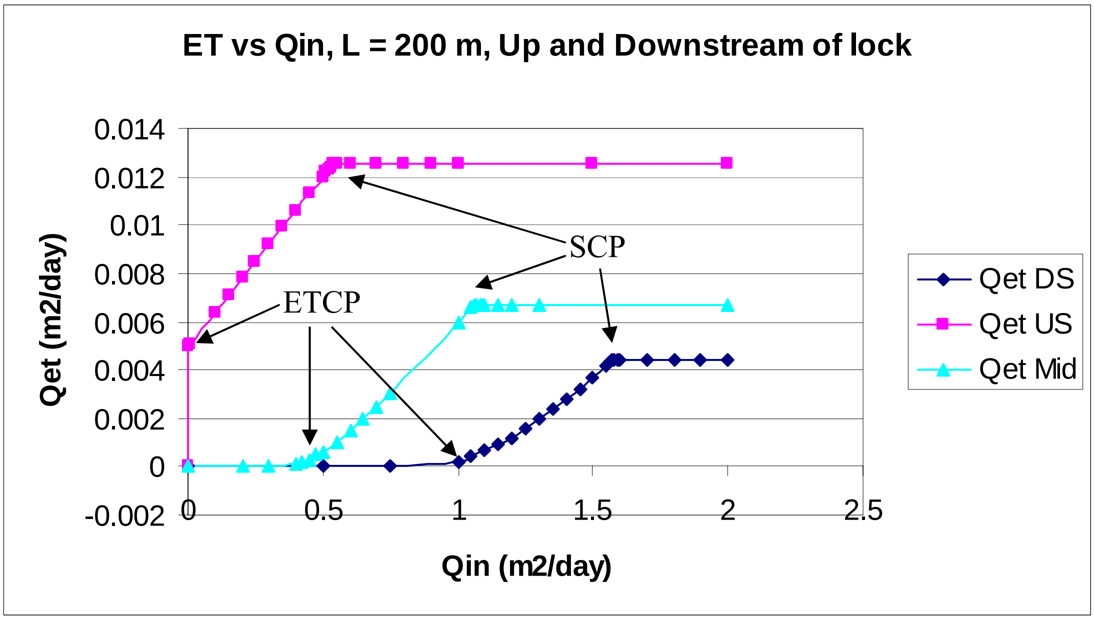


Figure 19 ET response (analogous to floodplain damage) for cases upstream (h_f = 4.5m) and downstream (h_f = 1.5m) of a weir, and in the middle of the weir pool (h_f = 3.0m).

Figure 20 shows the variation of floodplain damage for given groundwater inflow for floodplains of differing widths. Impact is higher for wider floodplains compared with narrow floodplains, in which a greater proportion of groundwater flows directly to the river.

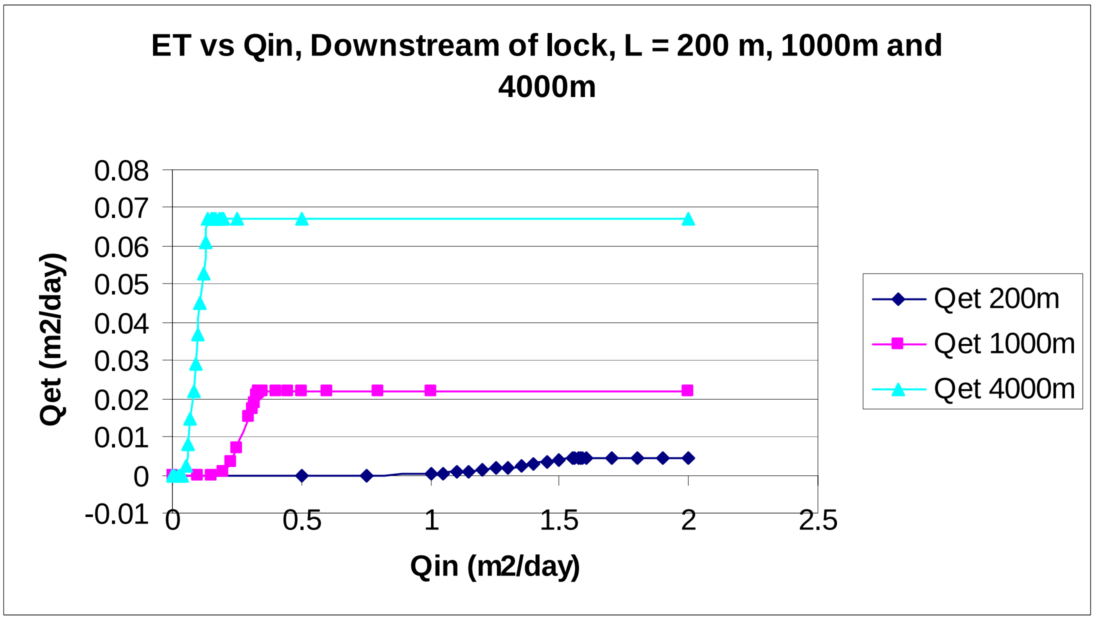


Figure 20 ET response (analogous to floodplain damage) for cases upstream (h_f = 4.5m) of a weir, for floodplain widths of 200m, 1000m and 4000m.

Floodplain impact curves will be generated for each of the floodplain units, and used to calculate salinity risk for floodplains from SIMPACT data.

APPENDIX A

Activity A: Lower Murray River Corridor Systems Model (RCSM)

Objective

The objective of the River Corridor Systems Model (RCSM) is to support catchment groups in considering the impacts of land management changes on future salt, water and biodiversity conditions with respect to LWMP targets, and to be used as a basis for the inputs of land management planning.

This section of the workplan aims to wholly or partly satisfy the following year two project milestones:

SA NAP:

- Milestone 2: Completion of riverine corridor model with respect to all 4 resource condition targets.
- Milestone 3: Model expansion:
- The prototype model developed in Year 1 and applied in the SA NAP region will be further developed and ported to the Victorian mallee region. This entails improved functionalities and tailoring to the Victorian resource condition reporting needs.
- Milestone 5: Year 2 report.

Vic NAP:

- Milestone 7: Interactive demonstration of completed Yr 2 landscape futures analyses at appropriate regional stakeholder forum.
- Milestone 6: Completion of Final Yr 2 Report, and its submission to Steering Committee at Dec 05 meeting, and to Vic NAP Office.

Background

The prototype area chosen was the Riverland area of South Australia, but in the second year of the project, the River Corridor Systems Model will be extended into the Victorian Mallee region. The main focus of the model is on river salinity and groundwater inflows to the river valley, but this is integral to water use efficiency and drainage volumes targets. The river corridor location and resource conditions have been chosen on the basis that river salinity is a major driver for the NRM strategy in both regions, and that current data, research and biophysical models are all available for this area. The result is a systems analysis model that focuses on the river corridor in both South Australia and Victoria.

Much of the data used by the systems model is already available from previous projects. The purpose of the RCSM is not to create new data, but to integrate data that is already available and use it in a format that is simple to use and more flexible for testing scenarios.

Resource condition targets were selected through a process of stakeholder consultation, and environmental impact of land use and land management is expressed as an impact on the resource condition target. Land management actions are usually not spatially explicit within the NRM plans. The Lower Murray RCSM gives the NRM actions a spatial context. Relative costs of actions and their impacts on the resource condition targets are analysed and presented spatially.

Work is being done under the LMLF project to consider natural resource and socioeconomic impacts. While the model provides some economic analysis, the main body of the socioeconomic work is being undertaken within the LMLF project, separately to the biophysical modelling.

Model Concept

The RCSM combines the outputs from existing and tested models to assess integrated effects of natural resource management actions in accordance with triple bottom line assessment. Salt loads and groundwater flow to the river are calculated using SIMPACT outputs for a series of land use and management changes to give impact per hectare of land use or management change. For each model unit, this impact rate was multiplied by the expected area of land use change predicted for land management options. The Floodplain ImPact (FIP) Model was used to convert groundwater inflows to the river valley to floodplain and biodiversity impacts, and an economic model used to denote the relative benefit or cost to irrigators for each land management action.

Targets and Actions

The resource condition targets relevant to the River Corridor Systems Model include:

1. (MDBC Salinity) For shared water resources (less than 800 EC for 95% of the time at Morgan).
2. (SA INRM) By 2015 to have salinity of water in the River Murray less than: 800EC for 95% of the time at Morgan, 412EC for 80% of the time downstream of Rufus River, 543EC for 80% of the time at Berri Irrigation Pump Station, 770EC for 80% of the time at Murray Bridge Pump Station.
3. (SA INRM Invest) Maintain and improve the extent and condition of 65% of current floodplain vegetation communities in areas of high priority by 2020.
4. (SA INRM Invest) By 2020, a 30% reduction in priority areas of floodplain currently affected by salinity from groundwater discharge.

These targets were used in the development of the RCSM output variables to enable simple analysis of the NRM plans.

The six relevant actions for the river corridor model were developed from the plans listed in the first year report, and are summarised as follows:

1. Encourage new irrigation development into low impact zones
2. Encourage best management practices on new developments
3. Improve water use efficiency of existing developments through on-farm action
4. Improve system water use efficiency through infrastructure improvements
5. Develop salt interception schemes
6. Minimise dryland recharge through vegetation, perennial vegetation and better dryland WUE

These actions are also relevant for floodplain and wetland salinity risk.

Baseline data describing the potential spatial distribution of irrigation development for the next 15 years under a ‘do nothing’ scenario was obtained from irrigation development data for the period 1988 to 2003. This baseline data was used as a first approximation to predict future irrigation development, that is development would occur at the same rate, and in the same regions as the previous 15 years.

Applying one or a series of scenarios to the model will change the magnitude and on-ground distribution of the baseline data.

Model structure

The RCSM will be coded using the TIME libraries developed for the CRC Catchment Hydrology, to facilitate future integration with other catchment management models if required, and to enable visual displays of the model outputs to be programmed quickly and simply.

The model contains interactive screens in which scenarios options can be selected for each of the model units, and sensitivities such as climate change or market price variation can be assessed. The model uses a series of input tables, made up of the most current data on water use efficiency and water use distribution to define the spatial distribution between crop types, efficiency and size of development. Salinity and groundwater inflow impact maps are imported from the SIMPACT model, and multiplied by the irrigation distribution from the scenario. Outputs of salinity impact are presented as spatial maps and in text format as a report card analysing the land management impact and comparing this to the relevant targets.

Deliverables and outcomes

Outputs

Outputs from the project include:

- River Corridor Systems Model, covering Victorian and South Australian NAP regions, and incorporating effects on salinity, riverine biodiversity,
- Results from initial scenario testing
- Chapter of second year progress report dedicated to model function and operation.

Outcomes

Outcomes of the project include:

- An improved understanding of the linkages between water use efficiency and salt impacts:
- The ability to test future land management scenarios with various sensitivity analyses using the River Corridor Systems Model to determine whether NRM targets will be met
- Increased understanding of the impacts of land management practices on NRM targets
- Defining comprehensive relationships and feedback within salinity management through interception schemes, water use efficiency and irrigation zoning,

including economic and physical feedback from disposal limitations, salinity damage functions, and soil salinisation of irrigation regions.

Timeline

The Lower Murray RCSM will have functional capability by October 2005, and be able to assess conditions such as climate change and economic sensitivities by 2006.

Workshops and consultation

Meetings with South Australian stakeholders to further demonstrate the prototype model and agree on sensitivity requirements and scenario options are organised for late March, 2005. Meetings with Victorian stakeholders will be organised following the expansion of the model to Victoria.

Workplan Components

The workplan components required for the RCSM to be achieved by October 2005 are shown in the table below.

APPENDIX B

Consultation with Stakeholders

Date	Location	People Present	Comments
15/04/05	Loxton Research Centre	Dan Meldrum (RMCWMB), Tony Adams (PIRSA), Dennis Sparrow(PIRSA), Jahangir Alam, Rebecca Doble (CSIRO), Chatura Ariyaratne (CSIRO)	Would like to learn about the efficiency of the LAP groups with respect to the reduced knowledge retention with changes in members, and the accountability of the group. Need to be able to account for flow management and trade downstream under high and low security policies Need to 'nail' the sleeper licences, and determine current % being used (current estimations may be incorrect) Some doubt over the error margins of the model, and this must be addressed (sensitivity analysis and error analysis). Also concern over the long term nature of the model, where temporal drought conditions are not accounted for (ie current conditions). Want to know where to invest money and resources. Biggest issues facing them is flows into South Australia District level data available for BL4, citrus and vines (not large data set for almonds) with are, DD, crop type by age, water meter readings, technology and system type, and value of crop, efficiency by crop and system type. Confidentiality issues with the datasets. Largest effect on WUE is from vineyard processors, to ensure a quality crop rather than through policy. WUE is a function of crop type and soils, and of management, which is limited by delivery and infrastructure, in that order.
23/03/05	CSIRO	Gerrit Schrale (DWLBC), Tapas	Trend is toward intensively managed farming, with human capital in

		Biswas (SARDI), Glen Walker, Rebecca Doble	tertiary educated managers. There are limits to WUE, until salt accumulates in soils and reduces yield. Leaching is not piston flow as previously thought, but leaches only part of the salt through preferential flow paths. Tapas developed a method of estimating DD from soil moisture capacitance probes. Paper in preparation. Using LEACHM or HYDRUS to understand transport of water and salt through the root zone, and the risk of salinisation. Some economic analyses will be done, including yield loss. Speak with Rob Walker (Plant Industries) and Rob Stevens (Sardi, Loxton), who are developing yield curves under saline conditions, duration taken to get back to 100% yield after salt imacts. Gerrit, Peter Hayman and Mike Macarthy looking at climate change issues. Temperature is one of the biggest issues (10days of 35+ degrees). Want to know where to put major infrastructure.
6/05/05	Licking Salinity Forum Berri Resort Hotel	Gerrit Schrale (DWLBC), Geoff McLean (PIRSA), Rob Stevens (SARDI)	Presentation by Gerrit and Geoff of their project work. Geoff discussed crop salinity damage functions. Although their project is investigating this further, the Maas salinity damage functions used by the MDBC (outlined in the GHD Salinity Impact Study) is currently best practice. There is some question as to resolving the temporal variations between the study functions and salinity spikes down the river.
9/05/05	Telephone conversation	Gerrit Schrale (DWLBC)	Tapas Biswas simulating salinity damage processes using summer season data for 04/05. Needs to calibrate the soil tensiometers. They are looking at recommendations for minimising and mitigating salinity damage to crops, and leaching requirements for this to occur. When the crop is dormant in winter, there is a need for sufficient leaching to 'clean the slate'. Precision irrigation may be sailing close to the wind in summer!
12/05/05	Telephone conversation	Andy Close (MDBC)	Conversation on the use of GHD functions in BIGMOD. BIGMOD daily EC outputs are weighted by offtake volumes to obtain an annual weighted average. Spikes not so much of an issue as soil salinity is buffered

			somewhat by slower accumulation of salt in the soil. Annual weighted averages are sufficient.
26/05/05	Mildura	Chris Biesaga (Mallee CMA), Mirko Stauffacher	Lower Mallee Futures project. Chris happy with the project description. Fits in well with the Victorian future work. Questioned whether the model integrates tile drainage?
Early in 2005	Mildura	Chris Biesaga (Mallee CMA),Trent Wallace, Glen Walker, Kerryn McEwan	Two additional meetings to obtain data for Victorian model expansion.
01/06/05	DWLBC Adelaide	Phil Cole (DWLBC), Jeff Connor, Rebecca Doble, Thea Mech	Agreed that a breakdown in river corridor and regional modelling was a good idea. Hugh Middlemis is undergoing modelling of whole of Victoria, NSW and SA, potential for calibration of model. Potential people for a scenario development working group include John Ginnevan, John Cooke, Phil Cole and Gerry Davies. Levees for salinity damage are unlikely in SA at present, but drainage minimisation incentives are very important (annual reporting is counter productive for this). Zoning restrictions currently in Vic and SA. Salinity damage model – higher salinity is ok if you have appropriate technology (drip irrigation, salt tolerant rootstock). Should include that in the model. Timescale for initial development may be too short, may need to be 20-30 years for irrigation infrastructure, or 70 years for pipeline. May need a 'pragmatic' option for the distribution of irrigation as well as an economic rationalism option. Compare the two. Additional specific scenarios: • closing down extreme impact developments over time and using the water in other high impact areas (offset credits option) • Investors converting old systems for new and accepting the water savings • Abandon salinity targets in the river, or change their definition • Use river as a salt drain during winter when crop damage less • All irrigation to the south of Murray Bridge.

APPENDIX C

Lower Murray Landscape Futures

Data Compilation for the Victorian Mallee SIMPACT Study

W. Ray Evans

Salient Solutions

Method Description

Salient Solutions Australia was retained by Department for Environment and Heritage, South Australia to provide 3 updated datasets for the Victorian Mallee region and within 20 km of the river channel, as part of the lower Murray Landscape Futures project requires. Specifically Salient Solutions Australia was to undertake data collation/collection/processing to enable the creation of spatial grids for use in DEH GIS modelling.

The 3 layers required were:

- Blanchetown Clay thickness (and absence);
- depth to groundwater; and
- groundwater salinity.

The following is a description of the processes adopted to compile and derive the various data input layers. Data was compiled for an area stretching from Nyah to the Border, and extending up to 25 km perpendicular to the Murray River. The additional distance from the river was used to allow the influence of *edge effect* contouring anomalies to be minimised.

Clay Thickness

Clay thickness was compiled from a total of 236 individual bore logs. The date of drilling of the bores used in this study varied considerably, as all historical data was accessed. The data used was that available via the Victorian Data Warehouse at April 2005.

The clay interval was not restricted to just Blanchetown Clay, but was widened to also include sections where the upper part of the underlying Parilla Sands has been weathered to clay as well. Clays of the Coonambidgal Formation on the floodplain were not considered.

Data was sourced primarily from drill logs from Thorne and others (1990). However, data was also sourced form the Victorian DataWarehouse to fill in gaps in the Thorne and others data coverage.

Data were supplied as an excel file and were contoured to produce a continuous grid of clay thicknesses.

The contouring was further controlled by the compilation of zero clay thickness contours which defined areas where it was known clay is absent. The zero thickness contours were derived from the point thickness compilation from bores, from contours produced by Thorne and others, and by reference to the DEM for the area. In particular, knowledge that the Blanchetown Clay is not found at elevations higher than 65 to 70 m (AHD) was employed to constrain areas where clay might be expected to be found.

Groundwater Salinity

Groundwater salinity was compiled from information from 881 individual bores across the study area. The data was sourced from the Mallee CMA, and was derived primarily from the State Groundwater Database.

All salinity measurements for the bores were compiled. Readings from the shallowest bore were preferred where there were bore nests (that is, where there were more than one completion at a monitoring site).

The number of salinity readings per bore varied considerably, with a number of bores having only one reading, and some bores having 45 readings. The time period of all salinity readings was from 1973 to 2002. In general bore salinity was read most frequently on a 6 monthly interval, but generally readings in any one year were either annual or at greater intervals.

The largest salinity value was chosen as the most representative of conditions at the bore site. This was a conservative choice that allowed for the worst conditions to be modelled.

The resultant groundwater salinity values were contoured to form a continuous grid over the study area.

Depth to watertable

A grid of depth to watertable was obtained from the Mallee CMA. This grid was developed during a separate CMA project.

The date of compilation of the depth to watertable was 2004. The grid was based on contours derived from water level measurements that were taken as close to 2000 as possible. However, some water level measurements from other years were used.

Diffusivity

Diffusivity was derived from the specific yield and transmissivity of the relevant aquifers.

The approach to deriving the diffusivity was to consider the flow path of water from recharge to the River. The flow path is comprised of 3 components – a vertically downward component under the point of recharge to the watertable, a horizontal component from the point of recharge to the river or discharge edge, and a vertically upwards component to the River at the discharge end.

The diffusivity considerations are further complicated by the nature of the saturated sediments in the aquifer. The Parilla Sands aquifer can be either unconfined or confined in the study area. Where it is confined (or more correctly, semi-confined), the watertable will be found in the overlying clays. This situation is the more typical condition over the study area. At times, there is a substantial thickness of clay that is saturated.

Given that there is a generally semi-confined condition across the study area as the natural condition, any additional water added to the groundwater system will be added within the clay sequence. However, the lateral transmission of the water will be governed by the transmissivity of the Parilla Sands aquifer.

Thus diffusivity was calculated using the specific yield of the clay sequence and the transmissivity of the Parilla Sands.

Representative values of these aquifer parameters were used in the calculation – Specific Yield of 10^{-2}; Hydraulic Conductivity of 3 m/day. The Transmissivity was calculated by assuming a constant thickness of the Parilla Sands of 75 m. The true thickness varies between 50 and 120 metres.

Thorne and others reports a wide range of Transmissivity values for the Parilla Sand as determined from aquifer tests, ranging from 60 to almost 1900 m^2/day. There are no other sources of measured Transmissivity values available for this study. Using the parameter values quoted above as being typical for the Parilla Sand, a Transmissivity of 225 is derived. This is at the low part of the range measured by Thorne and others.

There are no published measurements of the storage coefficient for the Blanchetown Clay that could be accessed w\for this work.

The adoption of constant values for the input parameters dictates that diffusivity will be a constant over the entire study area. This is a reasonable approach given the lack of spatially varying data to enable a non-constant diffusivity to be calculated.

The value of diffusivity derived by this approach is 8.2 x 10^6 m^2/yr.

Previous estimates of diffusivity used in an initial stage of the project were based on Transmissivity values of either 15 or 150 m^2/day. The lower value applied to the non-floodplain areas and the higher value to the floodplain. The basis for the lower value is unknown, but it is not representative of the Parilla Sand, as using 15 m^2/day with a thickness of 75 m for the Parilla Sand requires a hydraulic conductivity of 0.2 m/day. This is extremely low. One explanation might be that the lower value was meant to be representative of the Blanchetown Clay.

The Transmissivity value for the floodplain appears to be representative of the Channel (or Monoman) Sand.

As discussed above, the approach to calculating diffusivity in this work was to combine the storage coefficient for the clay sequence with the Transmissivity for the Parilla Sand. The diffusivity of the Channel Sand is not required using this approach.

The assumption in this work is that once the increased head induced by a recharge pulse is passed upwards through any clay layer at the discharge end of the flow path, the head is passed immediately through the Channel Sands to the River. Therefore, there is no need to consider the influence of the diffusivity of the Channel Sands.

APPENDIX D

Salinity Damage Functions

The salinity damage function used within the irrigator response model is based on relationships developed in the MDBC Salinity Impact Study (GHD, 1999). These relationships are used in BIGMOD to model relative costs of salt impacts.

Methodology

Yield reduction is given by the Maas and Hoffman (1977) crop salt tolerance relationships:

$$Y_R = \begin{cases} 100 & EC_e < a \\ 100 - b\left(EC_e - a\right) & EC_e > a \end{cases}$$

Where:

a is the threshold salinity in dS/m,

b is the slope of relative yield decline (%) per dS/m,

EC_e is the electrical conductivity of a saturated soil paste extract averaged over the depth of the rootzone (dS/m)

A modified Rhodes (1974) relationship is used to convert application water Ec to saturated paste extract EC.

$$EC_e = 0.25.EC_w\left(1 + 1/LF\right)$$

Where:

EC_w is the electrical conductivity of the applied irrigation water, and

LF is the leaching fraction.

This relationship assumes steady state conditions, or soils that have had a history of irrigation (Prendergast, 1993).

The leaching fraction is determined from the technology and management type of the irrigated development.

The relative contribution of rainfall on application water EC is calculated from the weighted average of rainfall and irrigation depth:

$$EC_w = EC_r\, Z_r \big/ \left(Z_i + Z_r\right) + EC_i\, Z_i \big/ \left(Z_i + Z_r\right)$$

Where:

Z is depth of water

i index represents irrigation

r index represents rainfall.

Yield reduction was calculated for various crop types, water use efficiency (1-LF) and application salinity.

Data

Data was taken from the MDBC Salinity Impact Study (GHD, 1999), and is shown in Tables 1 to 5 below.

Table 5 Yield reduction parameters

	Vines	Vines R2	Almonds	Citrus	Apricot	Potato	Lucerne
a	3	1.5	1.5	1.7	1.6	1.7	2
b	9.6	9.6	19	16	24	12	7.3

Seasonal crop water requirements and rainfall (Table 6) were used to calculate the relative salinity of the application water. Crop water requirement (Table 8) was calculated from pan evaporation (Table 6) and crop factors (Table 7).

Table 6 Meteorological Data and crop water requirements (Loxton)

	Pan Evap	Rainfall
J	276	22.3
F	232	19.7
M	192	14.6
A	114	19.2
M	62	24
J	45	19.2
J	53	28
A	78	25.2
S	105	29.2
O	180	33.6
N	216	21.6
D	248	17.1
Total	1801	273.7

Table 7 Crop Factors

	Almond	Apricots	Citrus	Winegrapes	Potatoes	Lucerne
J	0.9	0.9	0.5	0.5	0	0.7
F	0.9	0.9	0.5	0.5	0	0.7
M	0.8	0.8	0.5	0.4	0	0.7
A	0.7	0.7	0.5	0.3	0	0.7
M	0.6	0.6	0.5	0.3	0	0.7
J	0	0	0.5	0	0	0.7
J	0	0	0.6	0	0	0.7
A	0	0	0.6	0	0	0.7
S	0.6	0.6	0.5	0.2	0.2	0.7
O	0.7	0.7	0.5	0.3	0.4	0.7
N	0.8	0.8	0.5	0.5	0.8	0.7
D	0.9	0.9	0.5	0.5	0.6	0.7

Table 8 Crop Water Requirement

	Almond	Apricots	Citrus	Winegrapes	Potatoes	Lucerne
J	248.4	248.4	138	138	0	193.2
F	208.8	208.8	116	116	0	162.4
M	153.6	153.6	96	76.8	0	134.4
A	79.8	79.8	57	34.2	0	79.8
M	37.2	37.2	31	18.6	0	43.4
J	0	0	22.5	0	0	31.5
J	0	0	31.8	0	0	37.1
A	0	0	46.8	0	0	54.6
S	63	63	52.5	21	21	73.5
O	126	126	90	54	72	126
N	172.8	172.8	108	108	172.8	151.2
D	223.2	223.2	124	124	148.8	173.6
Total	1312.8	1312.8	913.6	690.6	414.6	1260.7

The total irrigation requirement (Table 9) is the difference between crop water requirement and rainfall.

Table 9 Irrigation Requirement

	Almond	Apricots	Citrus	Winegrapes	Potatoes	Lucerne
J	226.1	226.1	115.7	115.7	0	170.9
F	189.1	189.1	96.3	96.3	0	142.7
M	139	139	81.4	62.2	0	119.8
A	60.6	60.6	37.8	15	0	60.6
M	13.2	13.2	7	0	0	19.4
J	0	0	3.3	0	0	12.3
J	0	0	3.8	0	0	9.1
A	0	0	21.6	0	0	29.4
S	33.8	33.8	23.3	0	0	44.3
O	92.4	92.4	56.4	20.4	38.4	92.4
N	151.2	151.2	86.4	86.4	151.2	129.6
D	206.1	206.1	106.9	106.9	131.7	156.5
Total	1111.5	1111.5	639.9	502.9	321.3	987

The yield reduction parameters used were for a single year of irrigating at the given salinity. Yield reduction is higher if irrigation with saline water is applied for longer periods of time.

Results

The relative reduction in yield for vines, vines with salt tolerant rootstock, almonds, citrus, apricots and potatoes under irrigation with increasing conductivity water at various efficiency rates are shown in Figure 21 to Figure 26. Figure 27 indicates the maximum water use efficiency possible required to maintain maximum crop yield at varying EC of application water, which is the weighted average EC of irrigation water and rainfall.

These damage functions will be used within the irrigator response module to enable irrigators to choose application and efficiency rates to maximise profit.

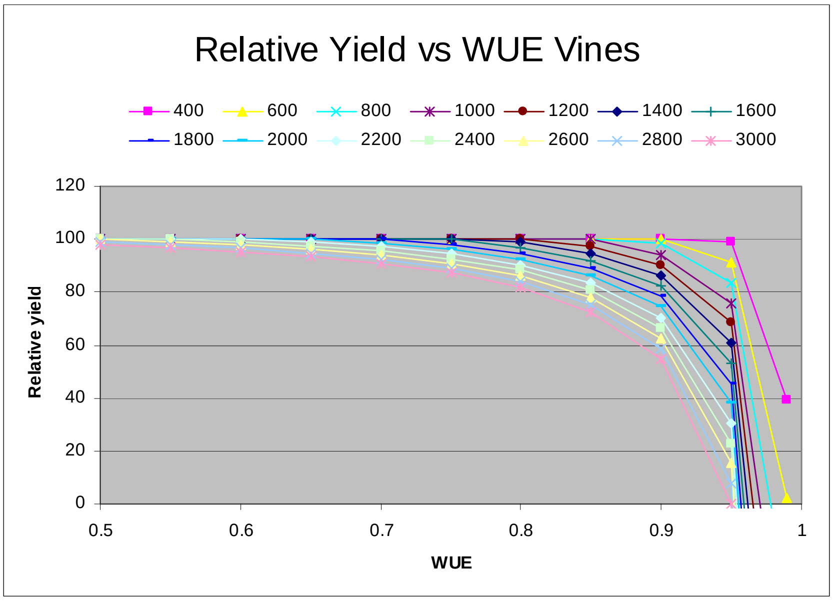


Figure 21 Change in relative crop yield for vines with water use efficiency and application water EC.

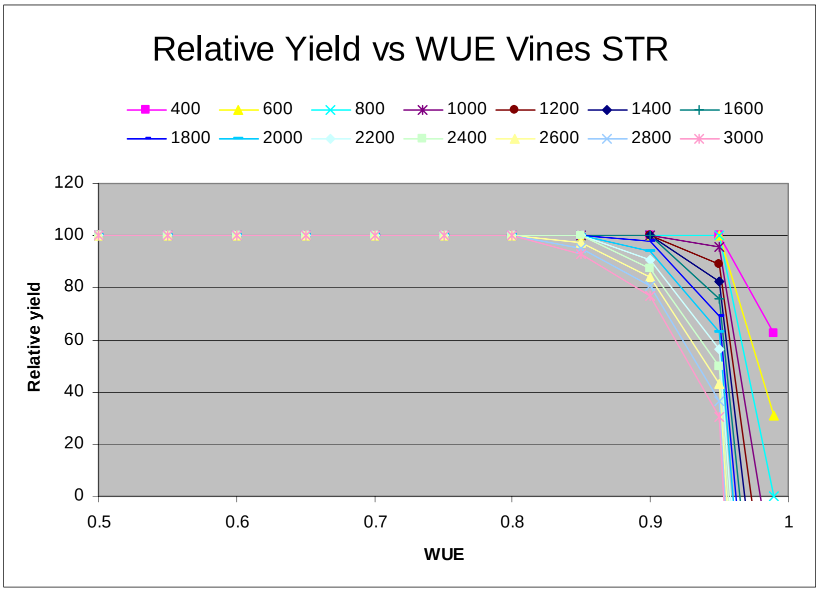


Figure 22 Change in relative crop yield for vines with salt tolerant rootstock, varying with water use efficiency and application water EC.

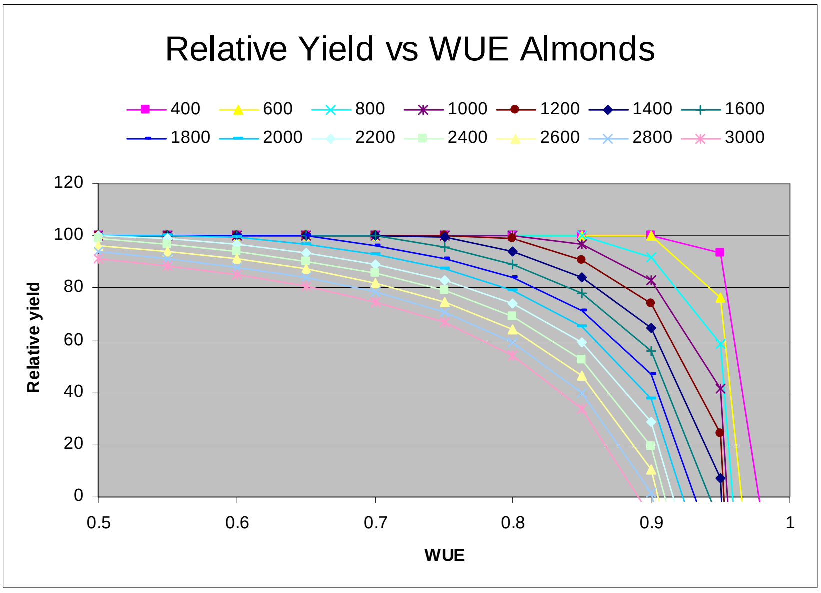


Figure 23 Change in relative crop yield for almonds with water use efficiency and application water EC.

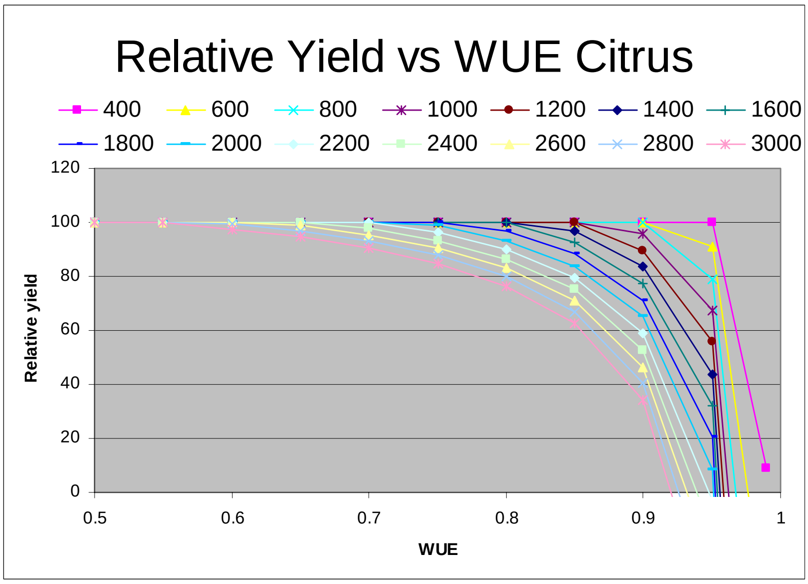


Figure 24 Change in relative crop yield for citrus with water use efficiency and application water EC.

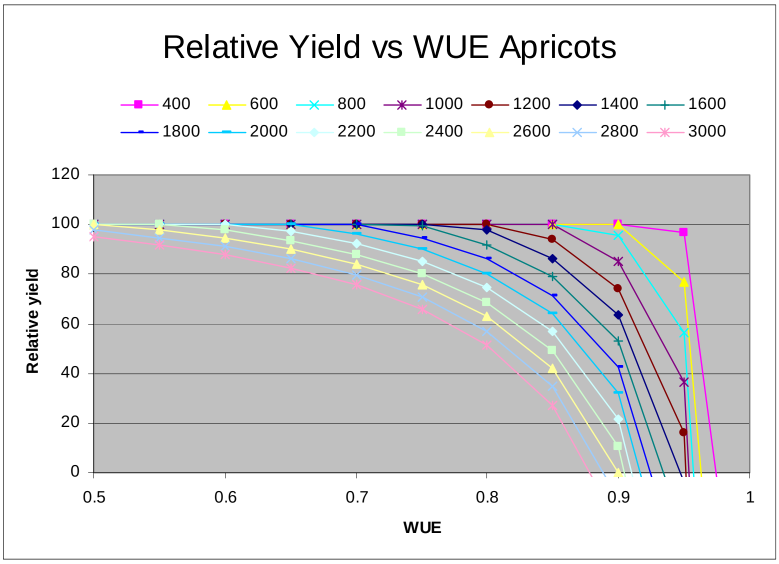


Figure 25 Change in relative crop yield for apricots with water use efficiency and application water EC.

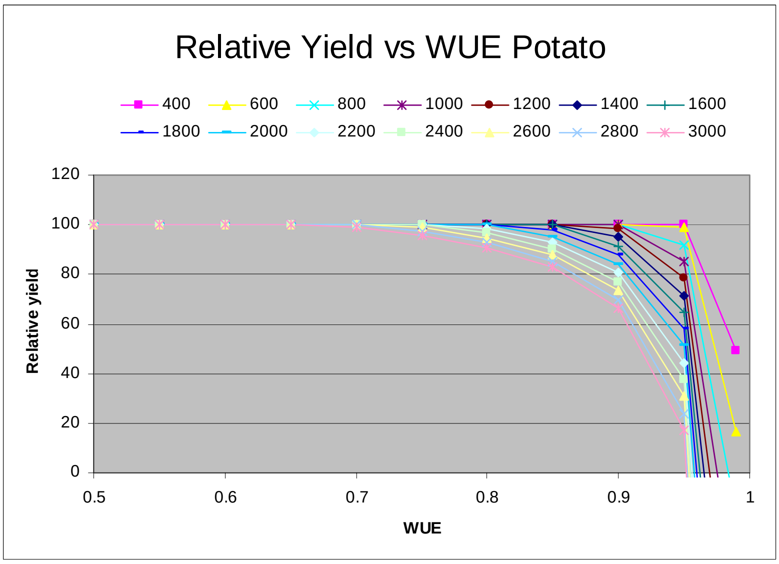


Figure 26 Change in relative crop yield for potato with water use efficiency and application water EC.

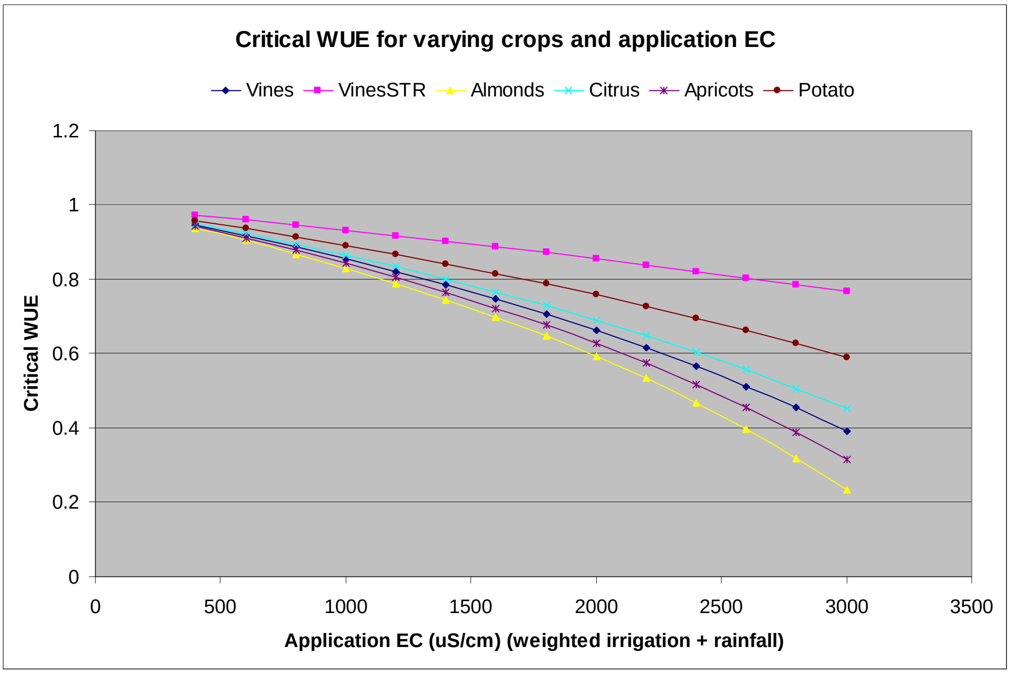


Figure 27 Maximum water use efficiency required to maintain maximum yield at varying application water EC.

APPENDIX E

Impact zones from the Victorian Mallee Salinity and Water Quality Management Plan, 2003.

Impact Zone		**River Salinity Impact (EC) per 1000 ML**
Low Impact Zone	LIZ 1	0.02
	LIZ 2	0.05
	LIZ 3	0.1
	LIZ 4	0.2
High Impact Zone	HIZ 1	0.3
	HIZ 2	0.35
	HIZ 3	0.4
	HIZ 4	0.45
	HIZ 5	0.5

Take the case of the highest impact zone, 0.5 EC per 1000 ML trade in.
1000 ML of trade is conceptually used at a rate of 10 ML/ha, which represents an irrigation development of 100 ha.

Using the ready reckoner:

	River Distance from Mouth	**Salt Load for 3 flow ranges (t/d)**	**<10 000 ML/d**	**10-20 000**	**>20 000**	**Total Impact**
Corowa	2205	100	2.22	1.33	1.31	4.86
Tocumwal	1885	100	3.65	2.71	0.58	6.94
Torrumbarry	1678	100	5.78	0.89	0.61	7.28
Swan Hill	1409	100	10.56	1.05	0.69	12.3
Kyalite	-	100	12.27	0.47	0	12.74
Mildura	**910**	**100**	**13.01**	**1.87**	**1.29**	**16.17**
Weir 32	-	100	13.1	0.58	0.31	13.99
Wentworth	825	100	13.03	3.18	1.83	18.04
Lock 6	654	100	16.69	2.35	1.21	20.25
Lock 5	620	100	18.04	1.77	1.18	20.99
Lock 4	516	100	19.89	1.56	1.13	22.58
Lock 3	495	100	20.97	1.4	1.12	23.49
Lock 2	383	100	22.42	1.32	1.1	24.84

And knowing that the high impact zone is around Mildura, the impact of 0.5 EC in terms of tonnes salt per day is approximately:

0.5 EC / (16.17 EC/100 t/d) = 3.1 t/d

Therefore we have a salt impact of approximately:

3.1 t/d per 100 ha = 0.03 t/d/ha

As the SIMPACT impacts are calculated at 100 years, while Nyah to the Border are calculated for a 30 year average, roughly convert the salt impact to a 100 year timeframe:

0.03 * 100/30 = <u>0.103 t/d/ha.</u>

This is approximately the same as the highest impacts calculated from SIMPACT.

APPENDIX F

Economic Decision Making and Impact Models for Lower Murray Landscape Futures River System Modelling

This report section outlines economic decision making and impact modelling components of the integrated biophysical-economic model focussed on irrigation in the Lower Murray region of South Australia and Victoria. The scope of economic decision making and economic impact modelling methodologies, and data are described.

The model describes is designed to estimate South Australian and Victorian River Murray irrigator development, technology, and management and irrigation drainage responses to changes in regional economic, policy and natural conditions. Economic impacts of changes in irrigation management on the regional irrigated agricultural sector are estimated.

The model simulates key irrigator responses and follow-on consequences including:

- irrigation development levels and locations,
- choices of irrigation technology and management,
- irrigation economic activity levels and profits from irrigation.
- irrigation application rates and drainage levels by location (a key input into the linked biophysical salt and water process models that will be used to predict salinity state of the river, and floodplain ecological health).
- The cost to governments (or irrigators, depending on assumed policy) of investment in salt interception and drainage disposal to meet MDBC salinity targets

The response models will be built to be capable of predicting irrigator response to changes in:

- economic conditions (e.g. commodity prices, production costs)
- policy (e.g. irrigation land use zoning, or salinity charges)
- biophysical system state (e.g. salinity of irrigation water, climate influence on crop ET and water availability).

The irrigator and policy decision making models will provide economic impact assessments and be integrated with water and salt biophysical process models to provide salinity impact assessments. As discussed in more detail below an ongoing focus of this modelling effort will be improved integration across related CMA, states, university and other CSIRO projects.

Scenario modelling

Agreed scenarios representing future conditions in the region will be the focus of analysis for exploring Lower Murray landscape futures with modelling. Conceptually, scenario modelling can take one of two forms.

1. Action scenario modelling – In this type of modelling, scenarios are assumptions about levels of actions that are the key drivers of regional economic health, river salinity

and floodplain health conditions. For example scenarios can represent assumptions about:

1. New irrigation development levels and locations
2. Level of water use efficiency (and drainage) on existing and new irrigation developments
3. Levels and locations of salt interception scheme and drainage disposal investments

2. Policy scenario modelling – In this type of modelling, irrigator response to economic, policy and biophysical system state are modelled as levers that influence decisions by irrigators including decisions to locate new irrigation development or decisions to implement more efficient irrigation management. Irrigators are modelled as though they wished to increase economic returns to irrigation and scenarios are represented as combination of policies (e.g. land use policy), biophysical system conditions (e.g. river salinity, or climate), and economic conditions (e.g. commodity prices) that restrict behavioural choices or have incentive effects that influence behaviour.

Policy scenario modelling will result in estimates of choice levels of actions that irrigators would take for a given set of policy, economic, natural system conditions. Policy scenario modelling provides a coherent approach to investigation of effectiveness of regional policy at inducing actions under alternative assumption about external drivers such as commodity prices, and climate conditions.

In policy scenario modelling, each scenario is defined as a specific set of assumptions about:

- conditions determined largely outside of the region that influence LMLF including:
    - economic conditions (e.g. commodity prices, or production costs)
    - biophysical system states (e.g. climate state)
    - conditions upstream of the region (e.g. level of water withdraws, salt loading upstream)
    - policy and investment decisions made outside of the region (e.g. MDBC policy rules governing level and location of salt interception, drainage disposal investment)
- conditions in the region that influence LMLF including:
    - regional land and water use policy (e.g. irrigation zoning, practice requirements, incentives for efficiency, salinity charges)
- conditions influenced by conditions both within and outside the region
    - water trade trends influencing regional irrigation development (e.g. supply available from outside region, demand within region under various assumptions about trends influencing each)

Through a stakeholder interaction process 5 to 6 scenarios will be chosen for testing of the River systems model working with an appropriate subset of project steering committee members.

The economic decision making model will be used some what differently in policy and action scenario analysis. In policy scenario analysis level and location of irrigation development choice of irrigation technology and management and water application will be modelled as the highest profit options among feasible responses given scenario economic, policy, or biophysical system state conditions. In action scenario analyses, changes in level and location of irrigation development, irrigation technology and management, water application and drainage will simply be assumed and the economic impact model will be used to estimate costs of actions.

Integrating irrigator response and salt and water process models

One of the important objectives of the LMLF project is understand tradeoffs between economic and salinity management goals in managing irrigation in the region. A modelling challenge arises in integrated economic response and salinity process models because changes in irrigation practice and consequent economic impacts occur in much shorter time frames than salinity impacts.

The time required for water to travel through the unsaturated zone and groundwater, mean that changes in irrigation in the Lower Murray lead to changed saline groundwater base flow to the river many years later. Delays between irrigation changes and onset of salinity impacts are estimated to vary from less than one decade to more than a century depending on depth to water table, distance to the river and aquifer transmissivity at the location of irrigation (Miles et al). The hydrogeology model that will be used to assess salinity impact of irrigation (Miles et al) assumes a constant repeated annual pattern of irrigation drainage across the corridor for several decades in predicting changes in 20, 50 and 100 years to groundwater base flow, and river salt load. In contrast significant irrigation practice changes typically take place in a few years to a decade and consequent economic impact result follow-on within a matter of months to perhaps a few years.

For modelling tractability, in integration of irrigation practice change and salinity impact that take place on very different time scales, scenarios are modelled as consisting of two distinct time periods. The first is a period of change (typically a decade or more) in which economic, policy or biophysical system state changes result in changes in irrigation. The second period is the salinity impact assessment period, where salinity impacts that would follow-on from changes in the period of change in 20, 50 and 100 years are assessed. In salinity impact assessment it is assumed that changes in irrigation assumed in change period persist for the entire 100 year salinity impact assessment period.

Integrating social survey information in irrigator response model

In initial model development, economic rationalism (profit maximisation) subject to costs and returns to choices and policy restriction on actions will be assumed to be the primary determinant of irrigator responses. In successive iterations of the model specification this assumption will be modified to better represent constraints and preference that may result in deviation from pure economic rationalism in irrigator decision making. This will be accomplished through cooperation with the CSIRO ARCWIS group who will do work to shed light on the feasibility of the irrigator management actions and potential impediments to various approaches actually being adopted and implemented. This could include key informant interviews or other appropriate methods.

5.2.1 *Irrigator response model functional specification*

The proposed approach is to build a model to represent the way that irrigators are likely to choose among a range of strategies open to them. In the first instance it will be assumed that irrigators choose options to maximise profits (given limits such as available technology, information, management capacity or capital limits). Most past modeling of similar issues has used either optimization techniques (e.g. McCarl et al, 1999; Booker et al, 2005; Rosegrant et al, 2002) or systems dynamics simulations.

The intent is to model a period of change (a decade or more) in which economic, policy or biophysical system state changes result in changes long-run irrigation, land and horticultural/vine stock and permanent water allocation capital investments. To capture the way that decision making is likely to vary depending on capital asset condition, three separate but related models will be used to distinct irrigator sub-populations:

1. **The re-development model** will represent decision making by irrigators who own capital assets such as irrigation systems and permanent planting (e.g. vines or orchards) nearing the end of their useful life.. For this model it will be assumed that each year over a change period the irrigation equipment and permanent plantings for a portion of the irrigator population becomes fully depreciated. Thus these irrigators face the decision of whether to and if so where to re-invest in irrigation and what type of irrigation to invest in.

The location of development (distance from the river and lift above the river) are key determinant of salinity impact and significant determinants of irrigation development cost as well. For this reason, an algorithm that simulates how irrigators would choose among potential sites for development based on water delivery infrastructure and power costs will be developed for this part of the modeling. This will involve GIS based information about distance to river, depth to groundwater on land available for irrigation development, and engineering costs estimation procedure building on estimates that have already been developed by PIRSA (2004), Connor (2003). Development zoning policy will be modeled as restrictions on choice of development site to areas zoned low salinity impact.

2. **The new irrigation development model** has some similarities to the redevelopment model in that capital asset decisions must be considered it deciding to develop new irrigation. The key difference is that availability of water on the market from out of region is treated as the factor limiting rate of new development. In addition, each year an amount of permanent water will be assumed available on the market from out of the region, and if profitable opportunities exist, irrigators will invest in additional development.

3. **The existing irrigator model** represents the decision making process of irrigators who have develop irrigation for a particular crop at a particular location and are not considering relocation or switching crops. In this model irrigators consider only irrigation management decisions including level of irrigation to provide and type of system to invest in.

Modeling long run decisions

The goal is to model significant irrigated agricultural sector change in response to policy, economic and biophysical system state changes. This involves decisions on investments in land, permanent water rights, vine and horticultural stock and irrigation equipment, all assets with expected economic lives of 15 years or more. Following Dantzig (1955) such investment can be thought of as involving a two stage process. The first stage is upfront investments such as planting of vines or horticultural stock. Costs of such investments are borne upfront when the investments are made regardless of uncertain outcomes of the investments.

The second stage is the annual management decisions like irrigation water application rate (this is the only relevant stage in the existing irrigator model). These decisions depend on levels of variables determining profit that vary stochastically from year to year such as weather conditions, commodity and temporary market water prices. The first stage decision must be made based on some expectation of the probability of factors such as future weather and prices that are determined stochastically in the second stage of the investment. Second stage decision must be made given that capital assets chosen in the first stage can not be varied from year to year.

To model this two stage investment decision we intend to use the Dantzig (1955) two stage investment optimization process that has been successfully applied by McCarl (1999) to a related US problem but not yet in Australia to our knowledge.

Which modeling scenarios

There are a large number of potential scenarios, each a set of assumptions about:

- conditions determined largely outside of the region that influence LMLF including:
    - economic conditions (e.g. commodity prices, or production costs)
    - biophysical system states (e.g. climate state)
    - conditions upstream of the region (e.g. level of water withdraws, salt loading upstream)
    - policy and investment determined outside of the region (e.g. MDBC policy rules governing level and location of salt interception, drainage disposal investment)
- conditions in the region that influence LMLF including:
    - regional land and water use policy (e.g. irrigation zoning, practice requirements, incentives for efficiency, salinity charges)
- conditions influenced by conditions both within and outside the region
    - water trade trends influencing regional irrigation development (e.g. supply available from outside region, demand within region under various assumptions about trends influencing each)

While the exact detail of scenarios that will be modelled will be determined in an interactive process working with a project reference group of regional experts, in broad terms base on input to date five scenarios that will be considered are:

- Status Quo
    - Current rate of expansion, no attempt at reducing river or floodplain impacts
- Pro-Development
    - Development in accordance with the State Strategic plan, river and floodplain targets not of high importance
- Sustainable Development
    - Status quo development plus compliance with the RCTs using zoning and initiatives for satellite developments further from river. Incentives for WUE improvement
- Engineering Solutions
    - Status quo development plus compliance with the RCTs using predominantly SIS and disposal.
- Environmental Protection
    - Reduced rate of development with WUE policy, zoning, and protection of significant floodplains
- Impact Offsets
    - Irrigator pays for EC impacts, SIS and disposal of salt.

- The intent is conduct sensitivity analysis for all scenario modelling to assess sensitivity of result to assumption about variations in levels of external drivers including:
    - Climatic variation
    - Water availability
    - Upstream EC
    - Crop value/demand changes

Functional representation of the model

Index values common to all process models

j agricultural activities / wine, citrus, stonefruit, nuts, vegies, pasture, ofc /
wine - wine grapes and sultana
citrus - velencia, navel, lemon, lime and other citrus
stonefrut - apricot, peach, plum and cherry
nuts - almonds
vegies - potatoes, carrots, onions and sweet corn
pasture - lucerne
ofc - other field crops such as wheat, barley, millet

z salinity impact zones / high, low /
high - high impact zone
low - low impact zone

l land and water management districts / Berri, Bookp, Blanch, Cadell, Gurra, Loxton, Merriti, Murtho, Monash, PikeR, Pyap, Qualco, Ral, RiverL, Taylor, Waikerie, Woolpun, vic sites/
Berri - Berri-Barmera
Bookp - Bookpurnong-Lock4
Blanch - Blanchetown
Cadell - Cadell
Gurra - Gurra Gurra Lakes
Loxton - Loxton
Merriti - Merriti
Murtho - Murtho
Monash - Monash
PikeR - Pike River
Pyap - Pyap-Kingston
Qualco - Qualco/Sunlands
Ral - Ral Ral
RiverL - River Land North
Taylor - Taylorville North
Waikerie - Waikerie
Woolpun - Woolpunda
Vic sites to be determined

h irrigation practice / drip, oh, oh+, uv, uv+, frr /
(drip - drip, oh - overhead, oh+ - overhead plus, uv – under vine, uv+ – under vine plus, frr – furrow)

s state of nature / 1975,…, 2000 /

e….river salinity in EC /300, 400, 500, 600, …, 2000/
6
7 Scenario parameter
<u>policy</u>

$wa_{l,z}$ – permanent water available for expansion of irrigation by management district and zone

<u>economic</u>

$p_{j,s}$ – future agricultural commodity prices

7.1 Model parameters

Parameter Prob(s) Probability of s should derive from the historical data

Ex: (Low- 0.15, Medium- 0.50 High- 0.35)

$Hs_{l,z}$ – areas suited for irrigation by management district and zone

$Hr_{l,z}$ – areas for retired from irrigation with depreciated planting and irrigation equipment

$He_{l,z,j}$– areas of existing development in hectares by management district (l), zone (z), and agricultural activity (j)

$sa_{l,z}$ – size of area suited for irrigation ($Sa_{10} = 10,\ldots$) by management district and zone

$\alpha_{l,z}^{Ha}$ – proportion of suited undeveloped land that is available for irrigation on market by management district and zone

$\gamma_{l,z}^{Ha}$ – proportion of developed irrigation capital (permanent plantings, and irrigation capital) that becomes fully depreciated by management district and zone

$awr_{j,h,s}$ – annual water requirement in ML per hectare by agricultural activity (j), irrigation practice (h), and state of nature (s)

$wr_{j,h,s}$ – average water requirement in ML per hectare by agricultural activity (j), irrigation practice (h) and state of nature

$y_{j,i}$ – yield per hectare for agricultural activity (j) and irrigation practice (h)

$fpc_{l,z}$ – fixed pumping cost by management district (l) and zone (z)

$vpc_{l,z}$ –variable pumping cost by management district (l) and zone (z)

pwc – cost of 1 ML permanent water rights

twc_s – cost of 1 ML temporary water rights depends on state of nature (s) – a frequency distribution of temporary water market prices over historical record

fc_j – fixed cost not related to irrigation by agricultural activity (j)

vc_j – variable cost not related to irrigation by agricultural activity (j)

$vic_{j,h,s}$ – variable irrigation cost by agricultural activity (j), irrigation practice (h), state of nature (s)

$fic_{j,h}$ – fixed irrigation cost per hectare by agricultural activity (j) and irrigation practice (h)

$dist_{l,z}$ – distance from river for pumping

$lift_{l,z}$ – lift from river for pumping

$et_{j,s}$ – evapotranspiration for maximum yield by crop (j) and state of nature (s) – a frequency distribution of evapotranspiration levels over historical record

$rain_{j,s}$ – level of rainfall that can be effectively substituted for irrigation by crop (j) and state of nature (s) – a frequency distribution of effective rainfall levels over historical record

$ie_{j,h}$ – irrigation efficiency by crop (j) and irrigation practice (h)

$owa_{l,z}$ – permanent water allocation owned by irrigators in area (l), zone (z) who are considering redevelopment

$lr_{j,e}$ the leaching fraction required to avoid salinity yield loss by crop and irrigation water salinity

7.2 Model variables

$HN_{l,z,h,j}$ – areas chosen for new development in hectares by management district (l), zone (z), distance to river (d), agricultural activity (j) and irrigation level (i)

$HR_{l,z,h,j}$ – areas chosen for new development in hectares by management district (l), zone (z), distance to river (d), agricultural activity (j) and irrigation level (i)

$IL_{l,z,h,j}$– irrigation practice (h) chosen for hectares of existing development by management district (l), zone (z), distance to river (d), agricultural activity (j)
PR_l^{ED} – expected profit from existing development by management district (l).
PR_l^{ND} – expected profit from new development by management district (l).
PR^{RD} – expected profit from redevelopment with owned water from areas where irrigation equipment and plantings become depreciated

New Development model

New Development governing equation and constraints

Maximise $PR_l^{ND} = \Sigma_z \Sigma_h \Sigma_j [y.*p_j - fc. - fpc. - fic. - pwc*(1 + (ie_{j,h,z} - LF_{j,h,z,e}))*wr.$
$- \Sigma_s Prob(s)*\{ y.*p_{j,s} + vc. + (vpc. + vic.)*awr. + twc*(awr. - wr.)\}] * HN.$

Subject to
$\Sigma. wr. * HN. \leq WA_{l,z}$ new permanent water allocation purchases less than or equal new permanent water allocations available on market
$\Sigma. HN. \leq \alpha_l^{Ha} * \Sigma_{d,}Hs_{l,z,d,}$ new irrigation land developed less than or equal to available land for new development
$awr_{j,h,s} = (et_{j,s} - rain_{j,s})/ ie_{j,h}$ annual water requirement by crop equal to et requirement less effective rainfall divided by irrigation efficiency by crop, irrigation practice, and state of nature
$LF_{j,h,z,e} = 0$, if $ie_{j,h,z} >= lr_{j,e}$, else $LF_{j,h,z,e} = lr_{j,e} - ie_{j,h,z}$ if the irrigation efficiency is greater than or equal to the required leaching % to avoid yield loss, leaching fraction is zero, otherwise leaching fraction is the difference between irrigation efficiency

New Development Output

$HN.$ Areas developed by LWMP, zone, agric activity and irrigation practice
PR_l Profits from development LWMP
$\Sigma. Y.* P_j* HN.$ Revenues from development
$D_{l,z} = \{ \Sigma_{j,h} * [\Sigma_s * Prob(s) (et_{.} - awr.)] * HN.\}/ \Sigma_{j,h} * HN.$ Drainage per hectare by area
$WU_{l,z} = \{ \Sigma_{j,h} * [\Sigma_s * Prob(s) awr. * HN.\}/ \Sigma_{j,h} * HN.$ Water use per hectare by area

Redevelopment model

Redevelopment governing equation and constraints

Maximise $PR^{RD} = \Sigma_l \Sigma_z \Sigma_h \Sigma_j [- fc. - fic. - pwc*(1+(ie_{j,h,z} - LF_{j,h,z,e}))*wr.-owa_{l,z})$
$- \Sigma_s Prob(s)*\{ y.*p_{j,s} vc. + (vpc. + vic.)*awr. + twc*(awr. - wr.)\}] * HR.$
$- fpc. * NA_{l,z}$

Subject to
$\Sigma. wr. * HR. \leq \Sigma_z owa_{l,z}$ permanent water allocation used in redevelopment less than or equal to owned permanent water from redevelopment areas
$\Sigma. HR. \leq \alpha_l^{Ha} *Hs_{l,z} + Hr_{l,z}$ irrigation land redeveloped less than or equal to available land for new development and redevelopment
$awr_{j,h,s} = (et_{j,s} - rain_{j,s})/ ie_{j,h}$ annual water requirement by crop equal to et requirement less effective rainfall divided b y irrigation efficiency by crop, irrigation practice, and state of nature

$NA_{l,z} = 0$, if $HR_{l,z} <= Hr_{l,z}$, else $NA_{l,z} = HR_{l,z} - Hr_{l,z}$, if the areas chosen for redevelopment is less than or equal to the area retired by LWMP area and zone, new area by LWMP area and zone is zero, otherwise new area by LWMP area and zone is the area developed in excess of area retired by LWMP area and zone
$LF_{j,h,z,e} = 0$, if $ie_{j,h,z} >= lr_{j,e}$, else $LF_{j,h,z,e} = lr_{j,e} - ie_{j,h,z}$ if the irrigation efficiency is greater than or equal to the required leaching % to avoid yield loss, leaching fraction is zero, otherwise leaching fraction is the difference between irrigation efficiency and leaching requirement for crop and irrigation water salinity level.

Redevelopment Output

$HR.$ Areas developed by LWMP, zone, agric activity and irrigation practice
PR_{l}^{ND} Profits from development LWMP
$\Sigma. Y.* P_{j}* HR.$ Revenues from redevelopment
$D_{l,z} = \{ \Sigma_{j,h} * [\Sigma_{s} * Prob(s) (et_{.} - awr.)] * HR.\}/ \Sigma_{j,h} * HR.$ Drainage per hectare by area
$WU_{l,z} = \{ \Sigma_{j,h} * [\Sigma_{s} * Prob(s) awr. * HR.\}/ \Sigma_{j,h} * HR.$ Water use per hectare by area

Existing development model

Redevelopment governing equation and constraints

Maximise $PR_{l,z}^{ED} = \Sigma_{h} \Sigma_{j} \{ y.*p_{j,s} - vc. - (vpc. + vic.)* (1+(ie_{j,h,z} - LF_{j,h,z,e}))awr. + twc*(owa_{l,z} – (1+(ie_{j,h,z} - LF_{j,h,z,e}))*awr.)\}] * HE_{l,z,h}.$
$- fpc. * NA_{l,z}$ for all states of nature s

Subject to
$\Sigma_{h} HE_{l,z,j} \leq He_{l,z,j,h}$ area irrigated in each LWMP area and zone by crop type must equal existing irrigation levels
$awr_{j,h,s} = (et_{j,s} – rain_{j,s})/ ie_{j,h}$ annual water requirement by crop equal to et requirement less effective rainfall divided b y irrigation efficiency by crop, irrigation practice, and state of nature
$LF_{j,h,z,e} = 0$, if $ie_{j,h,z} >= lr_{j,e}$, else $LF_{j,h,z,e} = lr_{j,e} - ie_{j,h,z}$ if the irrigation efficiency is greater than or equal to the required leaching % to avoid yield loss, leaching fraction is zero, otherwise leaching fraction is the difference between irrigation efficiency and leaching requirement for crop and irrigation water salinity level.

Existing development output

$HE.$ Areas developed by LWMP, zone, agric activity and irrigation practice
PR_{l}^{ED} Profits from development LWMP
$\Sigma. Y.* P_{j}* HE.$ Revenues from redevelopment
$D_{l,z} = \{ \Sigma_{j,h} * [\Sigma_{s} * Prob(s) (et_{.} - awr.)] * HE.\}/ \Sigma_{j,h} * HE.$ Drainage per hectare by area
$WU_{l,z} = \{ \Sigma_{j,h} * [\Sigma_{s} * Prob(s) awr. * HE.\}/ \Sigma_{j,h} * HE.$ Water use per hectare by area

References

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