Contents

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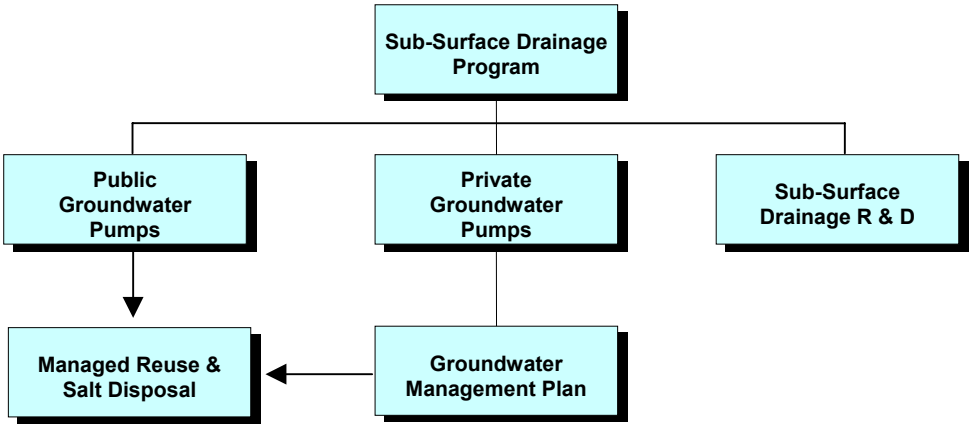
Summary

Sub-Surface Drainage Program Review 1999/2000

The Sub-Surface Drainage Program is an essential element of the Shepparton Irrigation Region Land and Water Salinity Management Plan which, in turn, is a key component of the Goulburn Broken Regional Catchment Strategy.

Program Outline



The Program is in it's 10th year of implementation. A Strategic Plan for 1995/1996 to 1999/2000 was adopted in July 1995 and outcomes of the review for the second 5 years are summarised below.

Program Objectives

The overall objective of the Sub-Surface Drainage Program is to, where possible and justified, protect and reclaim the Shepparton Irrigation Region's land and water resources from salinisation. The preferred package of works adopted by the Draft Plan (1989) aimed to serve some 213,000 ha by the year 2020 by means of:

- Implementing management arrangements for 395 existing (ie entirely landholder funded) and 365 new private pumps to serve 85,000 ha of current and future high groundwater level areas.

- Approximately 425 public pumps and some 50 disposal basins to serve a further 85,000 ha in areas where private pumping and farm reuse was not feasible.

- Tile drainage and small capacity pumps beneath 14,000 ha to protect the productive capacity of 43,000 ha where prospects for large scale pumping were limited.

A review of areas subject to high groundwater levels since 1982 and the results of 562 FEDS investigations indicate that the preferred package (1989) is still appropriate for strategic planning purposes.

Program Achievements

The main achievements in the second 5 years have been:

- Development and adoption of a Groundwater Management Plan for the Region under the Groundwater Supply Protection Area provisions of the Water Act. The primary purpose of the Groundwater Management Plan is to facilitate the implementation of the private pumping component of the program which aims to serve 85,000 ha of agricultural land. Implementation of the Groundwater Management Plan commenced in July 1999.

- Favourable audits on the efficiency and effectiveness of the private and public pasture groundwater pumping programs.

- Redirection of Plan resources to the private pasture pumping program resulting in a reduction in the FEDS waiting list from 18 months to less than 6 months and achievements for new private pumps ahead of targets. A cumulative total of 194 private pumps have been installed to the end of June 2000 serving an estimated 21,700 ha.

- Public pump achievements met annual targets which were reduced due to the higher priority for private works. A cumulative total of 21 pumps serving an estimated 4200 ha were installed to the end of June 2000. A random survey of public pump beneficiaries in 2000 indicated that only 8% did not perceive any benefits from the public pump program. In addition, the program also provided a stimulus for farm improvements such as WFPs, laser grading, reuse systems and tree planting.

- The adoption and full implementation of the Plan's beneficiary pays tariff structure for sub-surface drainage services in the Murray Valley, Central Goulburn and Rochester Areas.

- A performance review and economic evaluation of the Girgarre Salinity Control Project which has been very successful and returned a benefit cost ratio of 2.45 using the MDBC's Drainage Evaluation Spreadsheet Model. In addition, tree planting has enhanced the basin's appearance and a diverse range of bird life is making use of the artificial wetland created by the basin.

- Establishment of a "Serial Biological Concentration" trial and a saline reuse trial at Mt Scobie incorporating pasture and eucalypts to evaluate the viability of alternative groundwater disposal methods.

- Operational procedures based on real time flow conditions were developed and adopted for groundwater disposal to the River Murray and Broken Creek. In addition, salt disposal guidelines were developed and adopted for the Goulburn River and the Region's surface drains.

Works progress against the targets specified in the Strategic Plan (July 1995) are given in **Table 1-1 Works Progress 1998/1999**. Works targets for the next 5 years to 2005 are given in **Table 1-5 Targets for Next 5 Years**.

■ **Table 1-1 Works Progress 1998/1999**

Required Outcome	1998/1999 Target	1998/1999 Actual
1. Consistent pumping and reuse by existing pumps	339 pumps reusing 37910 ML/year to protect 37910 ha	382 pumps (including 55 upgrades) reusing 44670 ML/year to protect 44670 ha
2. Installation of new private pumps	113 pumps reusing 12640 ML/year to protect 12640 ha	171 pumps reusing 17610 ML/year to protect 17610 ha
3. Installation of tile drains to protect non-horticultural areas	None	None
4. Installation of tile drains to protect existing horticulture areas (mainly at Shepparton East)	85 ha	15.9 ha
5. Installation of low capacity groundwater pumps to protect existing horticulture areas (mainly at Shepparton East)	33 pumps to protect 825 ha	19 pumps to protect 475 ha
6. Provide salinity and waterlogging control for new high value crops in the region	None	None
7. Continue operation of Phase A pumps where technically appropriate	Ongoing	Ongoing
8. Install new public pumps discharging to regional channels or drains	35 pumps to protect 7000 ha	17 pumps to protect 3400 ha
9. Install new public pumps discharging to evaporation basins	None	None
10. Regulated discharge of pumped groundwater to regional channels, drains and streams within agreed guidelines (refer **Section 5.3**)	As needed	Some guidelines and management procedures implemented
11. Regulated discharge of pumped groundwater to River Murray to avoid or minimise salt accumulation within the Region's soils and aquifers	2.56 EC	2.06 EC committed to sub-surface works

Note: New high value crops and developments relates to changes in landuse for areas currently irrigated. It does not relate to new irrigation developments.

Table 1-1 Works Progress 1998/1999 lists progress to end June 2000 in order to allow direct comparison with the specified targets in the Strategic Plan (July 1995). Additional works during 1999/2000 were:

- 23 new private pumps were installed bringing the total to 194 new private pumps serving approximately 21700 ha. This is ahead of the 1999/2000 cumulative target of 125 pumps serving approximately 14000 ha which was set for the second 5 years of the Plan.

- 4 new public pumps were commissioned bringing the total to 21 new public pumps serving approximately 4200 ha. This is behind the cumulative target of 47 pumps serving approximately 9400 ha.

The combined area served by new private and public pumps to end 1999/2000 was approximately 26100 ha against a combined target of 23400 ha. No additional tile drains or low capacity pumps were installed during 1999/2000.

The works program had no specific targets for works primarily serving environmental features. However, the 21 public pumps installed to date have provided significant

environmental benefits to small stands (0.5 ha on average) to remnant vegetation on private land and road reserves. The area of remnant vegetation benefiting from new private pumps (194 to end June 2000) and existing private pumps (approximately 400) that pump on a regular basis is not known. However, assuming 0.5 ha on average as for the public pumps, the combined area of remnant vegetation served could be in the order of 300 ha.

Future Works Program

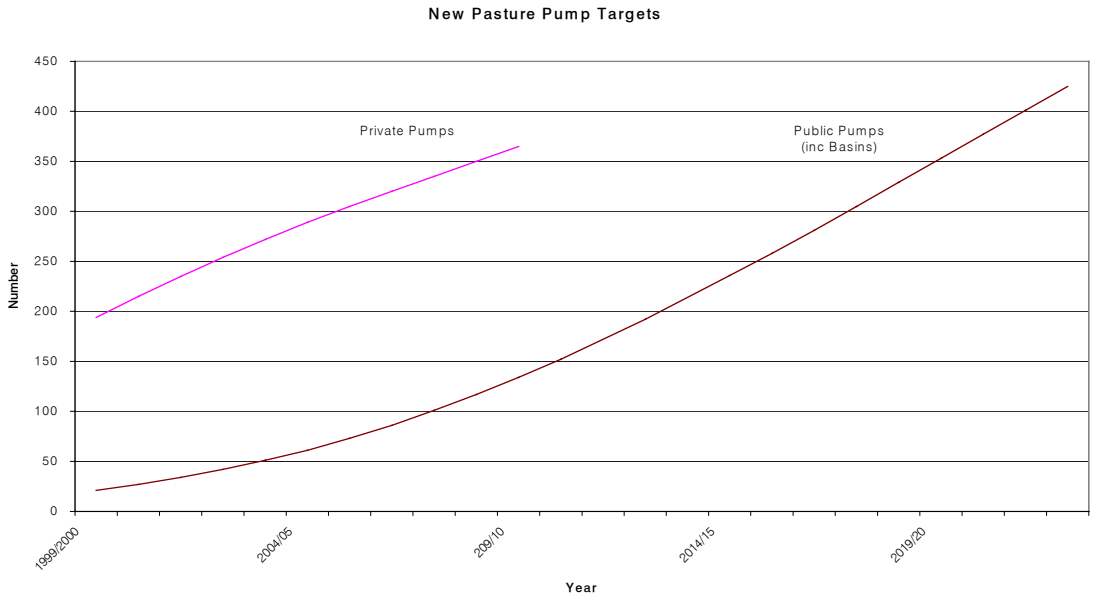
The areas served by the works program forecast to 2023 are tabulated below. The program assumes the priority for the private program will be retained and largely completed by 2010. This is 10 years ahead of the original works program target.

The timeline for public works has been extended to 2023 to partly offset the relatively low rate of implementation to date. However, an accelerating public program would be required to achieve this target. Low volume pumps and tile drains have been restricted to horticulture pending development of a cost effective strategy for pasture

■ Table 1-2 Cumulative Areas (ha) Served by Future Works Program

Year	Private Pasture Pumps	Public Pasture Pumps	Private Horticultural Works
2000	39830	4200	540
2005	76670	12200	860
2010	85000	26800	1180
2015	85000	47200	1300
2023	85000	85000	1300

The number of new private and public pasture pumps installed per year in the revised works program has been plotted below. The plot highlights the acceleration required in the public pumping program in order to meet Plan objectives. The target for public pumps may be optimistic and depending on demand and levels of funding.



Salt Disposal

Groundwater management and salt disposal is fundamental to the implementation of the Region's Sub-Surface Drainage Program. The Plan (1989) in it's original form, estimated that a Murray River salt disposal entitlement (SDE) of 16.7 EC would be required to fully implement the Sub-Surface Drainage Program.

Shepparton currently has an SDE of 3.4 EC of which 2.22 EC has been committed to established sub-surface drainage works as at 30 June 2000. The Government response in June 1990 and December 1993 indicated that the Region may receive 10.2 EC in the long term, plus part of 0.3 EC pending Campaspe West's requirements.

The estimated salt disposal requirements to 2023 including low volume pumps and tile drains in pasture areas (private C Type) are tabulated below. The revised estimated requirement to 2023 is 15.7 EC compared to the 1989 estimate of 16.7 EC.

■ **Table 1-3 SDE Estimates**

Activity	Cumulative SDE Estimates by Year End					Original Estimate (22/23)
	99/00	04/05	09/10	14/15	22/23	
Private Pasture Pumps	1.26	2.43	2.7	2.7	2.7	3.7
Private Horticultural Works	0.16	0.26	0.36	0.39	0.4	0
Private C Type	Nil	0.07	0.37	1.85	3.7	4.1
Public Pasture Pumps	0.80	2.32	3.69	5.57	8.9	8.9
Total	2.22	5.09	7.12	10.51	15.7	16.7

The Goulburn-Broken CMA requested an additional 3 EC for works implementation in the third 5 years. DNRE has made a preliminary offer of 1.5 EC and the CMA has accepted this in principle It should be noted the existing SDE of 3.4 and the preliminary offer of 1.5 amounts to 4.9 EC which is less than the estimated requirement of 5.09 EC to 2004/2005 for sub-surface drainage works alone.

Program Economics

The MDBC's Drainage Evaluation Spreadsheet Model (DESM) was used to evaluate the economics of each component of the works program. The analysis period was 50 years using a discount rate of 5%. The results are tabulated below.

■ **Table 1-4 DESM Discounted Cash Flow Results ($ x 1000)**

	Private Pasture Pumps		Public Pasture Pumps		Total Pasture Program	Horticultural Program
	Existing	New	Reuse	Basin		
Benefits						
Salinity	38,961	65,228	56,232	6,979	167,313	8,077
Reuse	23,831	22,730	4,018	0	50,580	0
Total Benefits	62,793	87,959	60,250	6,979	217,893	8,077
Costs						
Establishment	955	16,632	18,196	4,666	40,449	1,991
Annual	13,473	12,890	8,862	952	36,176	732
Downstream	2,587	2,434	8,911	0	13,932	324
Total Costs	17,015	31,955	35,969	5,618	90,557	3,048
NPV	45,778	56,003	24,282	1,361	127,336	5,029
Benefit/Cost	3.69	2.75	1.68	1.24	2.41	2.65

The DESM returned a favourable benefit cost ratio for all of the programs. The input assumptions are based on the Plan's experience to date and are considered to be reasonable.

Program Issues & Recommendations

The most critical long term issue for the Plan may be securing SDEs for future implementation. Actions by the Plan to generate SDEs and establish groundwater reuse options that minimise SDE requirements may become more pressing in the longer term.

Some other areas identified by the Sub-Surface Drainage Review Steering Committee on 23 August 2000 that may need further policy and/or technical development in the next 5 years are listed below. Recommendations in relation to the issues are also summarised.

- **Securing SDEs**
  - Continue with (and enhance when knowledge becomes available) current drainage management strategies (surface and sub-surface) and pursue opportunities for gaining additional SDEs when identified.

- **New and existing horticultural (or other high value) development**
  - Develop guidelines for new high value enterprises (Note: work initiated September 2000 in response to a developer's query on drainage options and guidelines).
  - Capture and map areas planted to horticulture on ISIA's GIS system.
  - Initiate review of distribution of horticultural plantings and Phase A rate base
  - Evaluate horticultural drainage requirements under improved farm irrigation and drainage management practices.
  - Review Phase A program performance after a return to average seasonal conditions.
  - A review be undertaken on urban encroachment and planned urban development in the Shepparton East area to identify and evaluate any implications for the private horticultural program.

- **Public and private disposal basin management and cost sharing guidelines**
  - Initiate development of implementation guidelines. Current broad technical guidelines are adequate.
  - Promote and initiate a scheme with a basin if an opportunity is identified with Groups or individuals.

- **Protection of environmental features**
  - Enhance the Program's stated principles to include the installation of sub-surface drainage works to protect environmental features where necessary, feasible and consistent with Plan criteria.
  - Develop criteria and guidelines for the protection of environmental features such as wetlands, streams and remnant vegetation (Note: work on guidelines for remnant vegetation initiated in September 2000).
  - Undertake risk assessments for high value environmental features.
  - Salt disposal guidelines be developed and adopted for wetlands within the Region.

- **Impacts of increasing irrigation supply salinities**
  - Initiate review to quantify potential sodicity problems and remedial measures, impact on conjunctive use of groundwater and salt disposal requirements

- **Alternative disposal methods for moderate to high salinity groundwater**
  - Monitor outcomes of "serial biological concentration" and Mt Scobie trials and develop an appropriate implementation package if viable options are identified.
  - Monitor the interest of the Wyuna Group in a broader land based disposal scheme for private or public works, and initiate a project if an opportunity is identified.

- **The amount of pumping required for groundwater and/or salinity control**
  - Initiate review for the Girgarre public pumps given restricted operation in recent years due to disposal constraints.
  - Review the performance of the Tongala private groundwater pumping/reuse project.

- **Operational guidelines and schedules for disposal to channels and drains**
  - G-MW to look for opportunities to refine operational guidelines and optimise schedules for disposal as part of on-going system planning and monitoring enhancements.

- **Effectiveness of works**
  - Identify requirements and appropriate analytical techniques.
  - Undertake analyses of groundwater behaviour and driving variables for selected sub-sets of bores to develop simple and robust evaluation techniques.
  - Trial analyses of late winter to late summer groundwater level contours to identify the effects of private pumping.
  - The Regional observation bore network be reviewed and rationalised, both spatially and temporally, once appropriate analytical techniques to monitor program effectiveness have been developed.
  - The current 1:25000 "Sub-Regional Groundwater Data" mapsheets be converted to a GIS format.

- **Farm management of pumped groundwater**
  - Address via the Groundwater Management Plan through review of all licence conditions in accordance with salinity guidelines.
  - Map reviewed licence allocations to assist in effectiveness/progress monitoring.
  - Retain current level of extension.

- **Prioritisation of works at the drainage catchment scale**
  - Continue current development of a sub-regional sub-surface drainage plan with the Wyuna Landcare Group.
  - Develop sub-surface drainage plans with other Landcare Groups.
  - Evaluate the likely achievable level of works within the channel and drain network disposal capacities.

- **Plan Resource Requirements**
  - Develop a strategy to address potential staff shortages and de-skilling within the implementation Agencies.

- **Reliability of Plan projections**
  - Initiate review of potential River Murray salt disposal impacts in light of current real time operational guidelines for salt disposal (Note: initiated December 2000).
  - Retain current groundwater level projections and area types requiring drainage.
  - The SDA for constructed and commissioned individual public pumps be based on the actual point of discharge in the channel or drain network rather than on the Regional reuse assumptions used for planning purposes.

- G-MW review their sub-surface drainage information storage, retrieval and reporting systems.

- **Capital Grants and level of assistance**
- Retain current guidelines for Capital Grants and level of assistance.

- **Tile drains and low capacity groundwater pumps in pasture**
- Finalise Katandra tile drainage trial economics and develop an appropriate implementation package if the works are viable.
- Evaluate options to reduce the cost of tile drainage systems and the volume of drainage that needs to be managed.
- Monitor outcomes of "serial biological concentration", and "bio-polymer" drainage trials and develop implementation strategies if the schemes are viable.
- Identify potential for a low capacity pumpsite within the Wyuna Landcare Group.
- The current success criteria for FEDS comprising a minimum capacity of 1 ML/d and a groundwater salinity not to exceed 3500 EC be reviewed. The current definitions do not recognise the overlap with low capacity and saline reuse sites where viable quantities of groundwater could be used productively.

- **Options for generation of salt credits**
- No specific actions recommended in the short term. However, evaluate any significant opportunities if identified.

- **Safe groundwater reuse intensity**
- Initiate review of Capital Grant bore data.

- **Role of the Deep Lead**
- No specific action recommended. However, monitor outcomes from Deep Lead management and monitoring activities in Groundwater Management Areas.

The issues identified for evaluation in the next 5 years are many, potentially complex and are inter-related in some cases. The program is subject to ongoing review and refinement in light of changing knowledge, technology and priorities. It is recommended that Implementation Committee develop and adopt a workplan for the next 5 years. This would assist in providing a focussed, efficient and manageable process to address areas requiring further development and set strategic directions.

A broad draft workplan is provided in **Table 1-6 SSDWG Draft Workplan for Next 5 Years** to initiate the process. No attempt has been made to allocate resources to activities at this stage as this can not be confidently done until requirements and methodologies have been better identified. The workplan would be an evolving one that is amended in line with priorities and the availability of resources. Physical targets for the next 5 years are given in **Table 1-5 Targets for Next 5 Years**.

■ Table 1-5 Targets for Next 5 Years

	Activity	Five Year Target to 2005	2005 Cumulative Target	2023 Cumulative Target
1	Consistent pumping and reuse by existing pumps	Complete metering/licence review for 395 pumps	395 pumps reusing 45000 ML/year to serve 45000 ha	395 pumps reusing 45000 ML/year to protect 45000 ha
2	Installation of new private pumps	95 pumps reusing 10820 ML/year to serve 10820 ha	289 pumps reusing 31670 ML/year to serve 31670 ha	365 pumps reusing 40000 ML/year to protect 40000 ha
3	Installation of tile drains/low capacity pumps to protect non-horticultural areas	Develop and adopt a cost effective strategy	Develop and adopt a cost effective strategy	14000 ha to protect the productive capacity of 43000 ha
4	Installation of tile drains to protect existing horticulture areas (mainly at Shepparton East)	69.1 ha	85 ha	300 ha
5	Installation of groundwater pumps to protect existing horticulture areas (mainly at Shepparton East)	12 pumps to serve 300 ha	31 pumps to serve 775 ha	40 pumps to protect 1000 ha
6	Provide salinity and waterlogging control for new high value crops in the region	Develop and adopt a cost effective strategy	Develop and adopt a cost effective strategy	Yet to be determined
7	Continue operation of Phase A pumps where technically appropriate	Ongoing operation – review performance of scheme	Ongoing	Ongoing
8	Install new public pumps discharging to regional channels or drains	40 pumps to serve 8000 ha	61 pumps to serve 12200 ha	375 pumps to protect 75000 ha
9	Install new public pumps discharging to evaporation basins	Develop criteria and guidelines and install 1 basin	1 pump and basin to serve 200 ha	50 to serve 10000 ha
10	Regulated discharge of pumped groundwater to regional channels, drains and streams within agreed guidelines	As needed	As needed	As needed
11	Regulated discharge of pumped groundwater to River Murray to avoid or minimise salt accumulation within the Region's soils and aquifers	2.87 EC	5.09 EC	15.7 EC (including an allowance of 3.7 EC for tiles/low capacity pumps in non-horticultural areas)
12	Protection of environmental features (such as remnant vegetation, wetlands and streams)	Develop criteria and guidelines and install 1 pump	1 pump primarily serving an environmental Feature	Yet to be determined

■ Table 1-6 SSDWG Draft Workplan for Next 5 Years

Activity	Year				
	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005
Securing Salt Disposal Entitlements	ongoing				
New/Existing Horticulture/High Value					
-guidelines for new development	initiated				
-map horticultural areas on GIS					
-review Phase A rate base					
-review Phase A performance					
-review urban encroachment in Shepparton E					
Disposal Basins					
-initiate development of guidelines					
-promote & initiate a scheme	ongoing				
Works for Environmental Features					
-works guidelines for remnant vegetation	initiated				
-works guidelines for streams					
-works guidelines for wetlands					
-risk assessments for environmental features					
-salt disposal guidelines for wetlands					
Impacts of Increase Channel EC					
Alternative Disposal Methods	ongoing				
Amount of Pumping Required					
-review Girgarre pumps					
-review Tongala pumping project					
-review Capital Grant bores					
Enhance Salt Disposal Guidelines	ongoing				
Effectiveness of Works					
-identify requirements					
-analyses of selected obs bores					
-review observation bore network					
-analysis of winter to summer levels					
-map GMP licence review allocations	ongoing				
-convert Sub-Regional Maps to GIS					
Farm Management of Pumped Groundwater	ongoing				
Wyuna LAP Sub-Surface Plan	initiated				
- sub-surface plans for other areas					
- evaluate level of works within disposal capacity					
Plan Resource Requirements	ongoing				
Reliability of Plan Projections					
-review Murray salt disposal impacts	initiated				
-review sub-surface drainage info systems					
Review Level of Capital Grants					
Tile Drains/Low Capacity Pumps					
-finalise Katandra economics					
-develop implementation package					
-identify opportunity in Wyuna LAP					
-review tile drain design & operation criteria					
-review FEDS criteria					
-drainage under improved farm practices					
-monitor outcomes of SBC & biopolymer drain	ongoing				
Options for Generation of EC Credits	ongoing				

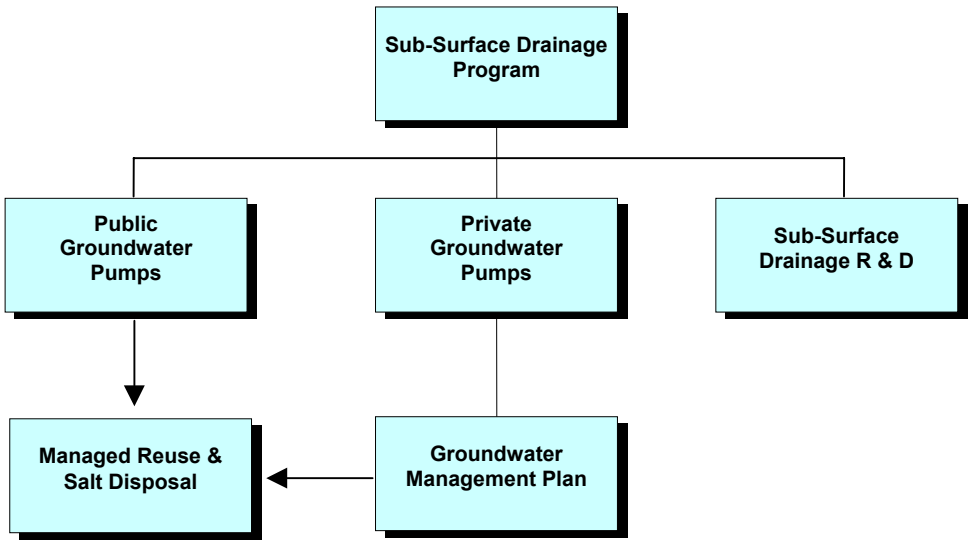
1. Introduction

The Shepparton Irrigation Region Land and Water Salinity Management Plan was established in 1989/90. The Sub-Surface Drainage Program is one of six programs within the Plan. The six programs are:

- The Farm Program
- The Surface Drainage Program
- The Sub-Surface Drainage Program
- The Environmental Program
- The Monitoring Program; and
- The Plan Support Program

The Environmental Program and it's objectives are integral to all of the Programs. An outline of the Sub-Surface Drainage Program is given in **Figure 1-1**

Figure 1-1 Outline of the Sub-Surface Drainage Program



Elements of the Program are subject to on-going refinement and review by the Implementation Committee and supporting working groups. The program, as a whole, underwent a detailed review in 1993/1994 and a Strategic Plan for 1995/1996 to 1999/2000 was adopted in July 1995.

Key outcomes of the 1993/1994 review are summarised below.

- A revised works program (in light of the Government response) requiring a Salt disposal entitlement of approximately 2.56 by the year 2000.

- A benefit cost ratio of 1.7 for the revised pasture program and 1.3 for the horticultural component.

- Continued encouragement for private utilisation of SDAs where technically appropriate however, uptake to be voluntary except for recipients of capital grants.

- The allocation of SDAs continue to be based on the nominal surface salt balance for the "area contributing" to each pump. While surplus Plan SDE is available, landholders can apply for supplementary allocations on an interim basis.

- An additional allocation restriction of 3 ML/ha/yr on the area irrigated for private grant pumps.

- Grants for private pasture pumps to continue at $200/ML with the maximum level of grant to be progressively reduced from 80 to 65% over 3 years. The total maximum amount of $30,000 per pump, per individual was retained.

- The level of grant for pumps not contracted for summer reuse (eg horticultural works or private pumps disposing to basins) was retained at up to 80% of the total cost as there would be no farm reuse benefit.

- The higher level of grant (up to 80% of total cost) could also be paid to works required (eg pipelines) to enhance the reuse of groundwater where this would result in clear benefits to the Plan.

- Groundwater Pumping Incentive Scheme payments ($4/ML on summer reuse) to be discontinued after the 1994/1995 season.

- For landholders who have a commitment to summer pumping and reuse and take up a SDA; the cost of the SDA would be a Plan cost, the cost of associated management and monitoring would become part of annual groundwater charges and the cost of pump operation and maintenance would be a landholder cost.

- For landholders requiring relatively free access to disposal (eg horticulturalists) annual charges would be set to reflect the potentially higher cost of providing this service.

- A commitment by the Plan to develop and implement a Groundwater Management Plan for the Region under the Groundwater Supply Protection Area provisions of the Water Act.

This report provides some brief background information and reviews the Program to 1999/2000 with the exception of the Groundwater Management Plan which is currently in it's second year of implementation (commenced in July 1999).

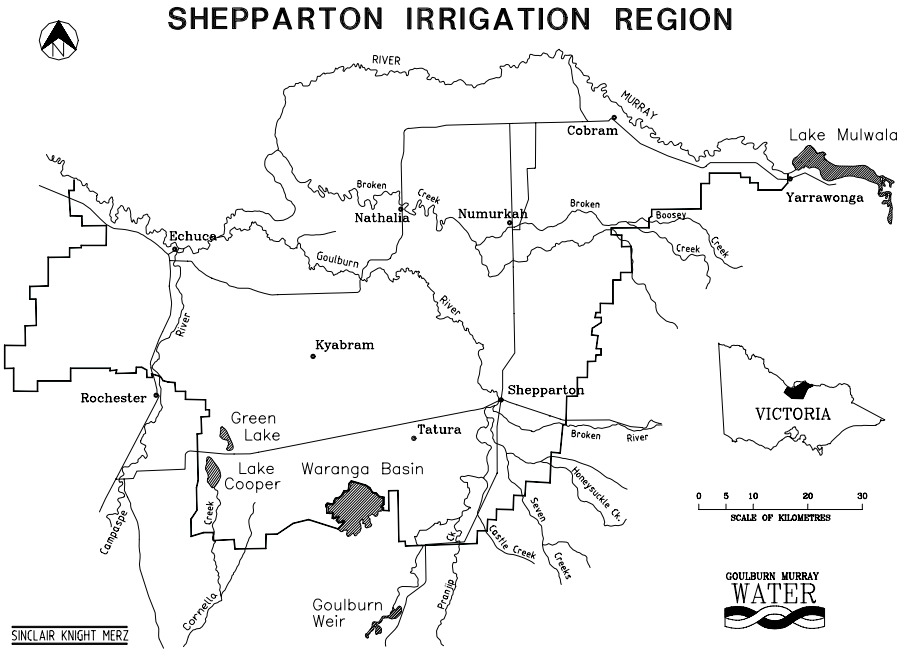
2. Background

This chapter provides some brief background information on the Plan and the Sub-Surface Drainage Program.

2.1 Location

The Shepparton Irrigation Region (SIR) is located within the Murray Darling Basin on the southern edge of Riverine Plain in Northern Victoria. The area covers some 674,400 ha (as defined by the SIR Groundwater Supply Protection Area plan boundary) including about 446,400 ha of irrigated farm holdings (1996/97 Irrigated Farm Census, G-MW) within the Rochester, Central Goulburn, Shepparton and Murray Valley Irrigation Areas.

Note: The Campaspe Irrigation District adjoins the Rochester Area. The western part of the District (approximately 5000 ha) has it's own salinity management plan and is not part of the SIR in terms of the Plan. There are differences between the Campaspe West and Shepparton Plans. These are not described in this report.



2.2 Climate, Soils and Land Use

The climate is semi arid with an average rainfall of between 380 and 500 mm/year. As evaporation in the region averages 1,350 mm/year, irrigation is necessary to support summer, autumn and spring growing crops.

The soils in the Region fall into two main groups, the "red – brown earths" and the "grey – brown soils of heavy texture". The first includes the coarser surface sediments deposited close to ancestral stream courses. The second group were deposited further out on the flood plain.

Irrigation development in the Region commenced with the establishment of the Rodney Irrigation Trust under the Irrigation Act of 1886. Currently, approximately 316,850 ha of land within the SIR is developed for irrigation (1996/97 Irrigated Farm Census, G-MW).

Irrigation application traditionally was by flood irrigation of pastures and a mixture of flood and furrow irrigation for horticulture. Over the past twenty years, pasture irrigation has improved water use efficiency through laser controlled grading of irrigation bays. Very few pasture developments have moved to overhead sprays or travelling irrigators. Horticulture is now mostly irrigated with under tree mini sprinkler systems. Irrigation intensities are typically in the range of 4 to 10 ML/ha /yr with perennial pasture typically requiring 10 ML/ha/yr and horticulture 7 ML/ha/yr.

The salinity of surface water for irrigation within the system generally varies from about 50 to 150 EC (without groundwater pump inputs) depending on the source of supply, time of year and location within the system.

2.3 Regional Hydrogeology

The Riverine Plains of the Shepparton Irrigation Region comprise unconsolidated alluvial deposits having a comparatively flat surface and gentle north westerly slope of around 1 in 2500. The depth of the unconsolidated deposits above bedrock varies, typically ranging from 20 to 150 m thick with a maximum recorded thickness of approximately 200 m.

The sedimentary sequence is complex and changes with depth, with the deeper deposits generally being coarser grained. The deepest formation, called the Renmark Group, mostly occurs to the north and west of the area. The overlying Calivil Formation is more extensive in the Shepparton Irrigation Region and generally follows the present day courses of the Murray, Goulburn and Campaspe rivers. The hydraulically undifferentiated Calivil Formation and Renmark Group aquifers are commonly referred to as the "Deep Lead".

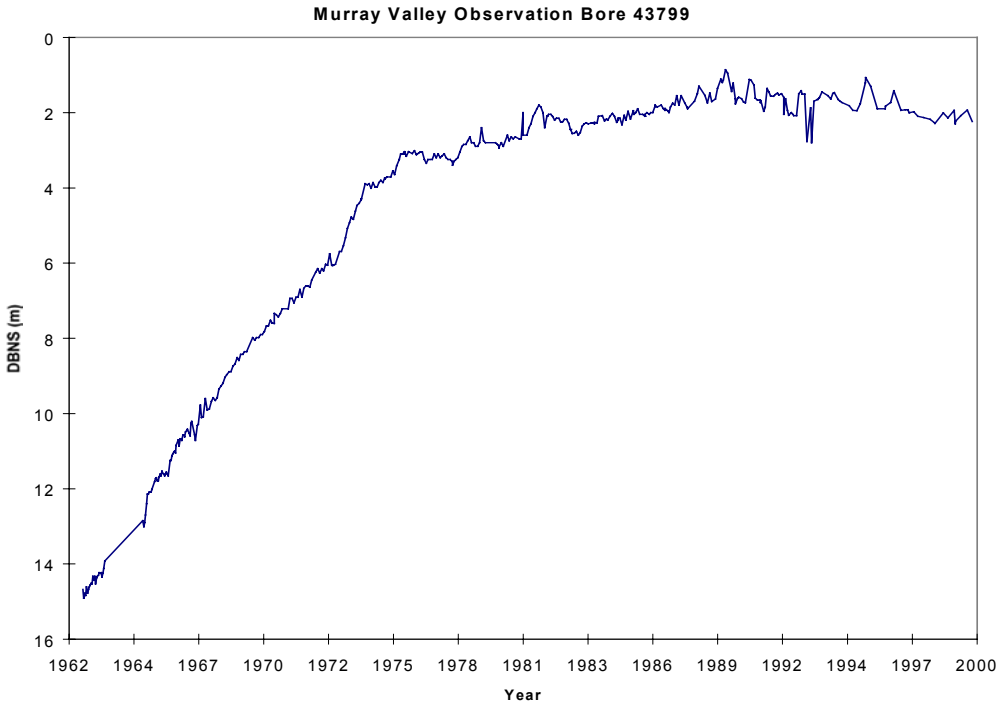
Alluvial sediments of the Shepparton Formation overly the Calivil/Renmark aquifer and extend from surface to typically 80 m deep. Although the Shepparton Formation is often thought of as one hydrogeological unit, the mixture of predominantly clays and silts interspersed with lesser quantities of sand and gravel form a complex system of aquifers and aquitards. The unit is often divided hydrogeologically into the Upper (< 25 m) and Lower Shepparton Formations.

2.4 Nature of the Problem

Prior to European settlement, groundwater levels were more than 30 m below surface. Clearing of native vegetation and irrigation development have disrupted

the natural hydrologic cycle and the Upper Shepparton Formation aquifers and enclosing clay aquitards have become saturated.

The hydrograph for Murray Valley observation bore 43799 below shows typical rises in groundwater levels observed across the Region.



Groundwater levels are now at less than 2 m below surface over much of the Shepparton Irrigation Region. Studies undertaken during the development of the Plan (1989) estimated that approximately 274,000 ha would be subject to groundwater levels within 2 m of surface by the year 2020. The area subject to high groundwater levels in August 1996 (a wet winter) was approximately 268,000 ha. The area declined to approximately 157,000 ha in August 1999 due to a combination of pumping and prevailing dry conditions since 1997.

Groundwater pressures in the deep regional aquifer system (Deep Lead) have also shown rising trends in the past. These trends have been reversed in recent years in parts of the Campaspe and Murray systems due to Deep Lead pumping. However, local scale recharge and discharge processes in the Upper Shepparton Formation are the dominant contributors to salinity problems in the Region. In addition, the hydraulic connection between the deep regional aquifer system and the shallow systems is generally poor beneath the Irrigation Region.

2.5 Origins of the Plan

Some waterlogging problems and, to a lesser extent, salinity problems were evident in the Region in the 1930's. Early attempts to solve the problems focussed on the provision of surface drainage. In a few locations, particularly

horticultural areas, tile drains were successfully used to primarily prevent waterlogging.

In the early 1960's, the broader scale occurrence of shallow groundwater levels and associated waterlogging and salinity problems became evident in the Murray Valley Irrigation Area. This resulted in the gradual implementation of groundwater observation bore networks across the Region and the commencement of groundwater pumping trials in the Murray Valley.

The trials demonstrated that pumping from the Upper Shepparton Formation aquifers was an effective means of providing groundwater control (maintaining levels > 2 m below surface) and salinity control (providing conditions for adequate leaching to occur) over a reasonable area (up to several hundred ha per pump) where suitable aquifers exist. Consequently, work commenced on the development of potential groundwater pumping strategies to address the emerging groundwater and salinity problems within the Region.

The very wet years of 1973 and 1974 saw the emergence of both serious and incipient waterlogging and salinity problems and an estimated 30% of the Region's horticultural area was destroyed. In response, the "Phase A" Groundwater Control Program was implemented as an urgent measure to protect major horticultural areas.

The Phase A Program was terminated in 1985 by which time some 170 target areas had been investigated, 79 pumps had been installed (excluding Shepparton East), 20 sites were deferred and 68 were abandoned. The estimated area protected at that time was 3400 ha of horticulture and 14600 ha of adjoining pasture. The Shepparton East Area was excluded from the Phase A program for the construction of public pumps as the hydrogeology generally restricts works to small scale pumps or tiles serving small areas.

In 1975, it was also proposed that a much larger "Phase B" Groundwater Control Program would be required in the future to protect pasture areas. In the early 1980's, the economics and downstream impacts of the Phase B program (in its original form of essentially public dewatering works with groundwater disposal to channels and drains) were questioned. In addition, private pumping of moderately saline groundwater and farm reuse was being adopted on a significant scale. With regular and consistent pumping, this could potentially provide farm groundwater and salinity control as well as provide an additional resource.

In the early 1980's, public and private groundwater pumping trials were initiated in pasture areas to build on the Phase A experience and to provide input to the development of a hybrid Phase B strategy comprising public and private works. The main trials were in the Campaspe Irrigation District, in the Tongala area and the Girgarre Salinity Control Project.

2.6 The Draft Plan

The Draft Shepparton Irrigation Region Land and Water Salinity Management Plan (1989) predicted that some 274,000 ha of the 434,000 ha monitored as at 1988 would be subject to groundwater levels within 2 m of surface by the year

2020. The areas and mix of remedial works described below are still considered valid for current planning purposes (refer **8.13 Reliability of Plan Projections**).

A number of sub-surface drainage packages ranging from do nothing to full groundwater control were evaluated against social, economic and environmental objectives. The preferred option was to serve some 213,000 ha of the estimated 274,000 ha by means of:

- Implementing management arrangements for 395 existing and 365 new private pumps to serve 85,000 ha;
- Approximately 425 public pumps and some 50 disposal basins to serve a further 85,000 ha in areas where private pumping and farm reuse was not feasible; and
- Tile drainage and small capacity pumps beneath 14,000 ha to protect the productive capacity of 43,000 ha where prospects for large scale pumping were limited.

The above mix of new works for salinity and partial groundwater control with managed salt disposal would ultimately require an estimated 16.7 EC in Salt Disposal Entitlements (SDEs). Although not specifically mentioned in the original Plan, continued operation of the existing Phase A Groundwater Control Pumps where technically appropriate was an assumed ongoing action.

The Sub-Surface Drainage Program was seen as the essential element in the SIRLWSMP because it had the ability to fully overcome the salinity problem in a large part of the Region, whereas the other programs in the Plan could only hope to reduce the impact of salinity and the need for sub-surface drainage.

The Government response in June 1990 strongly endorsed the proposal for private and public pumping with managed reuse and disposal. However, the response requested that public scale evaporation basins be justified and endorsed by Government on a case by case basis and that tile drainage for pasture and private scale basins be limited to pilot trials in the short term. It also limited the long-term allocation of SDEs to the Plan (as a whole) to 10 EC, on the basis of expectations at that time for Northern Victoria. An additional long-term allocation of 0.5 EC was undecided pending Campaspe West's EC requirements and uptake.

In April 1993, the Campaspe West Implementation Group re-submitted their sub-surface drainage program for endorsement. The revised program proposed to dispose of salt to the Rochester Irrigation Area via the Bamawm drainage system and the Waranga Western Main Channel. If this salt were exported to the River Murray, an additional 0.2 EC would be required. The Government's response in December 1993 endorsed Campaspe's revised program and increased Shepparton's indicative long term allocation to 10.2 EC to allow for salt disposal required from the Rochester Area due to Campaspe's actions. The remaining 0.3 EC of the original indicative Campaspe West requirement is yet to be allocated.

2.7 Sub-Surface Drainage Program Objectives

The overall objective of the Program is to, where possible and justified, protect and reclaim the Shepparton Irrigation Region's land and water resources from salinisation. The program aims to do this by:

- Providing conditions where adequate leaching of irrigated and other land can occur, and by preventing intrusion of saline groundwater into environmentally valuable areas;
- Providing groundwater control for high value crops which are sensitive to waterlogging; and
- Implementing its works in a sustainable and environmentally responsible manner.

The supporting principles, guidelines and corresponding sub-goals listed in the Strategic Plan (July 1995) are to:

- Encourage additional groundwater pumping and summer reuse by existing pumps, where feasible, technically appropriate and consistent with Plan economic criteria;
- Encourage installation of new private groundwater pumps for summer reuse, where feasible, technically appropriate and consistent with Plan economic criteria;
- Support the installation of tile drains in areas where pumping is not appropriate, but works satisfy the Plan economic and environmental criteria;
- Maintain the existing public groundwater pumps where appropriate;
- Install new public pumps in areas where private pumps with farm reuse in summer are not feasible, but the works satisfy the Plan's economic and environmental criteria and the beneficiaries agree to pay their share of the annual costs;
- Support high value crops susceptible to waterlogging (eg horticulture) as well as salinity by allowing off-site disposal as needed, subject to local management constraints and Plan guidelines;
- Manage salt discharge to channels, drains and streams within the Region to meet the Plan's water salinity guidelines after considering any impacts on downstream users;
- Manage salt disposal from the Region within the salt disposal guidelines and limits set by the Victorian Government and the Murray Darling Basin Commission (MDBC); and
- Install evaporation basins for local disposal of very saline water, which would have unacceptable impacts on downstream water quality if discharged to surface waters, where feasible, technically appropriate and consistent with Plan economic criteria.

The principles are still considered sound and should be retained however, they focus on agricultural land and do not specifically mention works installed to primarily protect significant environmental features. It is recommended that the principles be enhanced to include the installation of sub-surface drainage works to protect environmental features where necessary, feasible and consistent with Plan criteria.

2.8 Shepparton Irrigation Region Groundwater Management Plan

A key outcome of the 1993/1994 review was the development of the Shepparton Irrigation Region Groundwater Management Plan.

The primary purpose of the Groundwater Management Plan is to facilitate the implementation of the private groundwater pumping component of the Program while protecting both the groundwater resource and the rights of groundwater users. The main implementation elements of this plan are:

- Bore metering and monitoring to obtain more reliable data on groundwater usage and pumped groundwater salinities; and
- Review and use of license conditions to encourage regular and responsible use of groundwater.

Implementation of the Groundwater Management Plan commenced in July 1999 and should largely be completed by the year 2005. The main activities and progress to 30 June 2000 are summarised below.

2.8.1 Meter Fitting Program

A three year program was initiated to fit volumetric flow meters to all existing (pre June 1999) shallow (<25 m) irrigation bores with a licenced volume > 20 ML/year and all private dewatering bores by June 2002.

Approximately 1300 existing bores were listed on G-MW's information systems and the State Groundwater Database at that time. Approximately 300 of these were listed as being equipped with a meter. It was initially estimated that up to 750 of the remaining 1000 bores may require a meter.

501 site metering assessments were completed and 205 meters were fitted in the first year of the program. The results from the metering assessments indicated that the number of bores that may require metering was initially over estimated. The total number of shallow bores equipped with a meter at June 2000 was approximately 550 (including new capital grant bores).

2.8.2 Private Pump Monitoring

End of irrigation season meter readings were undertaken for approximately 550 bores. A salinity sample bottle mailout was conducted for approximately 1000 sites listed G-MW's licencing and billing system. 360 samples were returned. Routine monitoring of the Region's observation bore networks continued.

The mailout and the results of site metering assessments indicated a considerable number of inaccuracies in the current information systems. The bore metering program is also being used as a mechanism to validate and amend private bore information.

2.8.3 New Licence Conditions

A suite of new licence conditions applicable to the range of new or renewed shallow groundwater licences within the Region was prepared. A mailout was conducted inviting private pumpers to register for "Salinity Plan Bore" status ie reuse and dispose of groundwater in accordance with Salinity Plan guidelines. There were approximately 255 registered Salinity Plan Bores to the end of June 2000.

2.8.4 Licence Renewal Program

The proposed 5 year program to review and renew all licences by June 2004 was abandoned following legal advice that the Groundwater Management Plan could not involuntarily amend licences prior to their expiry date. Consequently, new licence conditions will be implemented during the normal licence expiry and renewal process. Metering requirements can be imposed at any time. A large proportion of existing licences will be due for renewal by 2004. However, there will be some due beyond this date and up to approximately 2010.

2.8.5 Resource Assessments

Groundwater level monitoring and analysis indicated that groundwater levels in parts of Murray Valley with a high density of shallow private groundwater pumps had fallen by more than 1 m between August 1993 and August 1998. Other areas generally showed falls of less than 0.5 m.

The fall in groundwater levels may be due in part to prevailing dry conditions since 1996 and the level of groundwater pumping. The amount of groundwater pumping over the period from 1993 to 1998 is not known with any degree of confidence. However, the evidence indicates that in parts of Murray Valley with a high concentration of groundwater pumps, the development of shallow groundwater resources is approaching a safe limit.

Allocation of new groundwater extraction licences in parts of Murray Valley with a high concentration of groundwater pumps may significantly diminish the rights of existing users. Consequently, a temporary moratorium was placed on the issues of new licences (other than D&S) effective from 28 June 1999 in areas where:

- groundwater levels (August 1998) were more than 3 m below surface; and
- levels had fallen by more than 1 m between August 1993 and 1998.

The moratorium is not applicable to the whole of Murray Valley and each licence application is assessed on the basis of all relevant local information. A reliable review can not be undertaken until existing licences are reviewed and amended to Groundwater Management Plan guidelines and better information is available on pumped volumes.

2.8.6 Communication

Groundwater Management Plan information and status reports in the first year of implementation were communicated to groundwater pumpers via a brochure, the groundwater sample bottle mailout and the invitation to register as a "Salinity Plan Bore".

Implementation of the Groundwater Management Plan will provide more reliable private groundwater pumping information and estimates of the number of existing private pumps required to operate on a regular basis to achieve Salinity Plan objectives. The results of implementation to the end of June 2000 indicates that the original Plan assumption of approximately 400 existing private pumps ultimately serving approximately 45000 ha would still seem reasonable for planning purposes at this stage.

3. Works Program Review

The Strategic Plan (July 1995) for 1995/1996 to 1999/2000 nominated revised works targets to end June 1999 in light of activities to date, the Government response of 1990 and potentially limited SDEs. The overall original Plan targets for the larger capacity private and public pumps were retained. However, targets for tile drains and low capacity pumps were restricted to horticultural areas pending development of a cost effective strategy for pasture.

3.1 Works Progress 1998/1999

Works progress against the targets specified to end June 1999 in the Strategic Plan (July 1995) are summarised in **Table 3-1.** Comments on some individual components are provided in sub-sections following the summary table.

■ Table 3-1 Works Progress 1998/1999

Required Outcome	1998/1999 Target	1998/1999 Actual
1 Consistent pumping and reuse by existing pumps	339 pumps reusing 37910 ML/year to protect 37910 ha	382 pumps (including 55 upgrades) reusing 44670 ML/year to protect 44670 ha (refer 3.1.1)
2 Installation of new private pumps	113 pumps reusing 12640 ML/year to protect 12640 ha	171 pumps reusing 17610 ML/year to protect 17610 ha
3 Installation of tile drains to protect non-horticultural areas	None	None
4 Installation of tile drains to protect existing horticulture areas (mainly at Shepparton East)	85 ha	15.9 ha
5 Installation of low capacity groundwater pumps to protect existing horticulture areas (mainly at Shepparton East)	33 pumps to protect 825 ha	19 pumps to protect 475 ha
6 Provide salinity and waterlogging control for new high value crops in the region	None	None
7 Continue operation of Phase A pumps where technically appropriate	Ongoing	Ongoing
8 Install new public pumps discharging to regional channels or drains	35 pumps to protect 7000 ha	17 pumps to protect 3400 ha
9 Install new public pumps discharging to evaporation basins	None	None
10 Regulated discharge of pumped groundwater to regional channels, drains and streams within agreed guidelines (refer **Section 5.3**)	As needed	Some guidelines and management procedures implemented
11 Regulated discharge of pumped groundwater to River Murray to avoid or minimise salt accumulation within the Region's soils and aquifers	2.56 EC	2.06 EC committed to sub-surface works

Table 3-1 lists progress to end June 1999 in order to allow direct comparison with the specified targets in the Strategic Plan (July 1995). During 1999/2000:

- 23 new private pumps were installed bringing the total to 194 new private pumps serving approximately 21700 ha. This is ahead of the 1999/2000 cumulative target of 125 pumps serving approximately 14000 ha which was set for the second 5 years of the Plan.

- 4 new public pumps were commissioned bringing the total to 21 new public pumps serving approximately 4200 ha. This is behind the cumulative target of 47 pumps serving approximately 9400 ha.

The combined area served by new private and public pumps to end 1999/2000 was approximately 26100 ha against a combined target of 23400 ha. No additional tile drains or low capacity pumps were installed during 1999/2000.

3.1.1 Existing Private Pasture Pumps

Some 382 existing private pumps were listed as having participated in the Program to varying degrees since the early 1990's ie involved in the Groundwater Pumping Incentive Scheme and/or allocated interim SDAs. However, formal agreements were not in place and there is limited confidence in the reliability of the figures and pumped volume and salinity data. More reliable estimates will become available as implementation of the Groundwater Management Plan proceeds.

The Groundwater Pumping Incentive Scheme was initiated in 1991 to provide a stimulus to the private component of the Sub-Surface Drainage Program. The Government funded incentive comprised a subsidy of $4/ML on summer pumping and reuse. The scheme was discontinued after 1994/1995 due to Government policy not to fund ongoing annual costs.

3.1.2 New Private Pasture Pumps

Achievements to 1998/1999 for new private pumps are ahead of target. This is largely due to the Plan favouring private works and may also be partly due to prevailing dry conditions and limited surface water availability since 1997 which has further encouraged landholders to install pumps.

3.1.3 Tile Drains in Pasture Areas

The Strategic Plan (1989) did not nominate any physical targets for tiles in pasture areas pending the development of appropriate criteria. This is further discussed (including recommendations) in **Section 8.15**.

3.1.4 Tile Drains in Horticultural Areas

Achievements for private horticulture tile drainage works are behind target. This may be due, in part, to prevailing dry conditions since 1997 and the use of more efficient farm irrigation and drainage management practices promoted by the Plan. The effectiveness of improved management practices under average or above average rainfall conditions is not known.

3.1.5 Low Capacity Pumps in Horticultural Areas

Achievements to 1998/1999 are behind target with 19 pumps installed (mainly in Shepparton East) to serve approximately 475 ha. As for tiles, this may be due to prevailing dry conditions and more efficient farm irrigation and drainage management practices promoted by the Plan.

3.1.6 New High Value Crops

The Strategic Plan (1989) did not nominate any physical targets for groundwater and salinity control works in new high value crop areas pending the development of appropriate criteria. This is further discussed (including recommendations) in **Section 8.2**.

3.1.7 Continued Operation of Phase A

Identification of direct beneficiaries of the Phase A pumps was completed in 1994/1995. At that time, the total area subject to local rates in Murray Valley and Central Goulburn was approximately 15,570 ha of which, 3520 ha was existing orchard (1992 orchard census) provided with groundwater control.

Phase A works have continued to operate to maintain groundwater levels at more than 2 m below surface within target orchard areas. Pumping is undertaken when necessary to maintain groundwater pressures in nominated observation bores within specified limits. A review of the overall performance of the Phase A program has not been undertaken since the early 1990's. A review should be undertaken in the next 5 years. This is further discussed (including recommendations) in **Section** 8.2.

3.1.8 New Public Pumps Disposing to Channels & Drains

Public pump achievements are behind the Strategic Plan (July 1995) target, which was based on an accelerated program. However, this target was later revised to 4 sites/year on average in light of budget constraints and a higher priority for private works. The latter targets have been achieved.

DNRE conducted a random survey of 70 direct beneficiaries with a rateable area in excess of 2.5 ha in July – August 2000. The public pumps ranged from recently installed to operational for a number of years. Approximately 65 % responded representing approximately 854.7 ha of rated area.

Outcomes of the survey are summarised below. There were a number of no responses to some questions, which accounts for discrepancies in total percentages.

- 40% had a Whole Farm Plan (WFP) prior to installation of the public pump
- 24% that did not have a WFP have registered with the WFP Incentive Scheme or have had one completed

- 422.5 ha had been laser graded since installation of the pump
- 42% had installed reuse systems
- 42% had planted approximately 12,066 trees
- 33% had observed increase in pasture production
- 28% indicated they had visible signs of salinity or had periods of waterlogging while 49% of those who replied said they did not perceive they had any problems
- only 8% did not see any benefits associated with the pump while the majority saw benefits in lowering groundwater levels and achieving salinity control

The survey results provide a largely qualitative assessment of the effectiveness of public pumps in providing salinity reclamation and control. However, the results are very positive and also indicate that the public pumping program may provide a stimulus for landholders to participate in other Plan program activities resulting in an acceleration over what is happening in the Region as a whole..

3.1.9 New Public Pumps Disposing to Basins

The Girgarre Salinity Control Project has been very successful. An economic evaluation of the scheme in 1999 using the MDBC's Drainage Evaluation Spreadsheet Model Version 3 returned a benefit cost ratio of 2.45 in 1997/98 values. In addition, tree planting has enhanced the basin's appearance and a diverse range of bird life is making use of the artificial wetland created by the basin.

The Strategic Plan (July 1995) did not nominate any targets for pumps disposing to basins pending the development of policy and implementation guidelines. The development of guidelines needs to be undertaken in the next 5 years. This is further discussed (including recommendations) in **Section** 8.3.

3.1.10 Disposal Guidelines and Procedures

Disposal guidelines for Regional streams and drains were developed and implemented during the second 5 years of the Plan. In addition, operational procedures were implemented for groundwater disposal to the Murray and Broken Creek. These will be covered in more detail in **Chapter 5**.

3.1.11 Regulated Groundwater Discharge

An estimated 2.06 EC had been allocated to private and public works as at June 1999. The private works component is largely based on interim individual allocations in the early 1990's. The private component will be reviewed as an activity within the implementation of the Groundwater Management Plan. Winter disposal did not occur in 1997, 1998 and 1999 due to un-favourable disposal conditions.

Winter and summer salt disposal estimates are summarised below. The salt loads are at the point of discharge and exclude any diversion. An estimated 75% on average of the summer salt load from new public pumps is reused via the channel and drainage system.

■ **Table 3-2 Winter Salt Loads from Private & Public Pumps**

Year	Private Pumps		Public Pumps		Total Salt Load (t)
	No of Pumps	Salt Load (t)	No of Pumps	Salt Load (t)	
1990			1	282	282
1991			1	241	241
1992	111	3448	1	201	3649
1993	117	6450	1	449	6899
1994	no disposal opportunity available				
1995	58	2326	7	1784	4110
1996	86	3947	8	1899	5846
1997	no disposal opportunity available				
1998	no disposal opportunity available				
1999	no disposal opportunity available				

Notes: Operational guidelines for winter disposal from private and public pumps initiated in 1992.
Extended disposal period available in 1993 due to prolonged wet conditions and high River Murray flows.

■ **Table 3-3 Summer Salt Loads from Public Pumps**

Year	No of Pumps	Salt Load (t)
1990/91	0	0
1991/92	1	229
1992/93	1	172
1993/94	2	261
1994/95	5	914
1995/96	8	1609
1996/97	10	2014
1997/98	13	2386
1998/99	17	3267

3.2 Prioritisation of Works

The Plan favours private works where feasible rather than public works and also favours working with recognised landholder groups to maximise regional benefits. In recent years, added priority has been given to private works to meet demand brought about by prevailing dry conditions and limited surface water allocations.

3.2.1 Private Works

Private works are further prioritised by confirming that the property is subject to high groundwater levels (August 1996) and, if needed, giving priority to:

- properties with known salinity problems;
- properties which have potential to provide salinity control to adjoining properties with known salinity problems; and
- properties where some lowering of the generally high watertable level can be achieved.

The reference watertable map for prioritisation is reviewed and adjusted accordingly every 5 years (base year August 1993). The August 1998 map was not considered to be representative due to prevailing dry conditions

since 1997. Consequently, the 1996 map was adopted as representative under normal conditions.

3.2.2 Public Works

Where private works are not feasible due to high groundwater salinities and limited reuse potential, site investigations for public pumps are scheduled on the basis of order in which the application is received and accepted. Further prioritisation has not been required to date, as extension activities have been managed to achieve the target of four public pumpsites per year on average.

An informal prioritisation process for extension activities was undertaken in the past on completion of FEDS investigations. A more structured and focussed prioritisation process based on a number of parameters was adopted in August 1998 on a preliminary assessment of:

- salinity problems;
- disposal options;
- key landholder support;
- hydrogeological conditions;
- land use;
- surrounding landholder support; and
- environmental benefits.

The information is collected during the FEDS investigation and ranked in order to focus resources.

3.3 Program Audit Outcomes

External audits were undertaken for the Farm Exploratory Drilling Service (FEDS) in 1996 and the public pump program in 1998. The audits included both the Lake Wellington and Shepparton Plans.

Key outcomes from the FEDS audit in relation to Shepparton were that:

- Quantitative targets were being met.
- Project eligibility and prioritisation criteria were appropriate.
- The administrative process is efficient and professionally run.
- Customer satisfaction is high although there was some concern about the length of the waiting period. However, the audit concluded that the waiting period, together with the prioritisation criteria, is effective in getting the service to those landholders who most need it.
- The project is an integral part of the Plan's sub-surface drainage program.

The audit recommended (in relation to Shepparton) that:

- estimates made of the annual yield of pumpsites on the basis of the investigations should be checked; and
- the level of capital grant provided for successful sites be reviewed.

The first recommendation resulted from landholder interviews (7 in number) to obtain their views of FEDS. One investigation was classed as unsuccessful in

terms of the agreement (ie a minimum volume of 1 ML/d and pumped groundwater salinity not to exceed 3500 EC) due to the low estimated yield of the site. The landholder's concern was that the low volume pumping potential was not recognised as part of the criteria for success and that the yield estimates were too conservative. The interviews also noted that 2 of the other 7 investigations were also classed as unsuccessful however, the 2 landholder's proceeded to install pumpsites. It would seem worthwhile reviewing and enhancing the current criteria for success to include an assessment of what volume could be productively used (refer further discussion and recommendation **Section 8.15)**.

The estimated daily yield of a potential pumpsite is based on a 3-day pumptest of 2 trial wellpoints and field measurements. There is a high level of confidence in the estimated daily yield however, the annual yield estimate is less reliable. The Groundwater Management Plan will provide more comprehensive records of private pumping and a mechanism for checking initial estimates of annual yields. However, a performance review for a sample set of capital grant bores should be considered (refer **Section 8.17**).

The maximum level of capital grant was reduced from 80% to 65% over three years commencing in 1994/95 as a result of the 1993/94 review of the sub-surface drainage program. In addition, the summer reuse volume, and level of grant is currently limited by one of 5 parameters (**Section 6.1**). An analysis of costs for capital grant bores installed since January 1999 indicated the average Plan contribution to the capital cost was approximately 43%.

The reduction in the grant ceiling to 65% was undertaken on the proviso that targets for new private pumps could be met. New private pump installations to the end of June 2000 have exceeded targets and uptake in capital grants did not seem to be influenced by the reduced ceiling. Capital grants are further discussed in **Section 8.14**.

The FEDS audit raised some concern over the length of the waiting period. This concern was shared by the Plan and resources (from within the Plan) were redirected to the FEDS program from 1997/98. Consequently, the waiting period has been reduced from 18 months at that time to currently less than 6 months.

Key outcomes from the public pump audit in relation to Shepparton were that:

- The program is economic, provides positive environmental returns, and the government gets good value for its investment.
- The program is supported by institutional arrangements for management and ownership of the pumps, and these arrangements provide for a community driven public pump program.
- Customers (through the Implementation Committee) are satisfied with the services provided, the program is benefiting from competitive tendering, and the Implementation Committee supports the competitive tendering process.
- The program is accountable and includes processes to ensure that groundwater disposal is environmentally and socially acceptable. The program complies with the Murray-Darling Salinity and Drainage Strategy.

The audit made a number of recommendations in relation to Shepparton. The recommendations and responses by Implementation Committee are reproduced below.

Extract from IC response dated 28 October 1998.

"Key Recommendations

1. The public groundwater pump program continue to be strongly supported.

Irrigation Committee strongly supports this program. Progress is currently behind Plan targets because of:

- the time required to develop rating and disposal guidelines,
- priority given to the private pump program which has a higher cost-benefit ratio, and
- Plan policy that requires private pumping options be fully explored before resources are committed to public pump investigations.

Irrigation Committee has progressively increased the priority for public pumps in the last two years, and Goulburn-Murray Water has identified funding requirements to achieve original Plan targets by the end of the next 5-year review period. Work done through the private pumping program in recent years, with both individual landholders and groups, has provided a pool of potential sites for future development. However, achievement of the target is clearly dependent on total Plan funding, continuing community demand and access to the required SDEs. Both the federal and state components of government funding have reduced this year. This severely hampers our ability to continue to **"strongly support'** this program. The issue of priorities will be closely reviewed as part of the next 5 year Plan review process.

2. SICs develop a 5 year strategy and works program to accelerate implementation to maximise the economic, environmental and social benefits.

As mentioned above Goulburn-Murray Water has identified funding requirements to meet the original plan targets by the end of the next 5-year period, and a pool of potential sites has been developed. Irrigation Committee has identified the need to target landholder groups as the most effective means of generating support for public pumps. This can be done as part of, or separately from Local Area Plans, which are now being developed. Irrigation Committee will encourage G-MW and DNRE to focus their extension resources on those areas which are known to have significant salt problems and good potential for location of public pumps. However Irrigation Committee is also concerned that extension resources should not be used to generate demands which cannot be met with current funding.

3. SICs consider opportunities to improve the environmental returns of their public pump program.

Irrigation Committee requires that environmental assessments be a basic component of all public pump investigations. DNRE's Environmental Management Group:

- identify all existing high value environmental features, and any current salinity impacts on them, at the commencement of each feasibility investigation, and
- report on the environmental benefits and disbenefits of each works proposal.

Irrigation Committee's policy is that the environmental benefits of any site be explicitly accounted for if it is clear that the site cannot be justified solely on socio-economic grounds. In principle the Irrigation Committee would endorse the site if the environmental values were considered to offset the shortfall in the socio-economic benefit/cost ratio. However it would be expected that this environmental value could be confirmed by identification of an environmental beneficiary who would accept the appropriate cost-share for operation of the pump. Irrigation Committee will request the Environmental Management Group to address this issue.

Irrigation Committee has already identified the opportunity to promote environmental enhancement in areas protected by groundwater pumps as currently occurs with new surface drains. The Environmental Management Group has been requested to advise the Committee on the opportunities that exist, and propose a project for consideration.

The completion of the biodiversity strategy, and the development of a number of management plans for specific environmental features, will both identify potential improved environmental returns. The integrated nature of our catchment strategy means that we try to maximise multiple benefits. Our environmental monitoring program should also specify opportunities for improved environmental returns.

4. SICs liaise to compare costs, implementation policies, and public pump systems.

G-MW has historically provided advice to Southern Rural Water based on experiences gained in the Shepparton Plan, particularly in relation to technical procedures. The Irrigation Committee would be happy to initiate a more formal and broadly based liaison arrangement with the Lake Wellington Implementation Committee. I will contact the Lake Wellington Committee and arrange a meeting to develop appropriate arrangements to ensure that relevant issues are identified and effective liaison occurs at reasonable cost. I would welcome input from your unit to the proposed liaison process to ensure that all relevant issues are addressed.

Specific Audit Report Recommendations

1. That the Irrigation Committee develop a 5 year strategy to accelerate the implementation of public groundwater pumps.

Addressed under Key Recommendation 2.

2. That the Irrigation Committee considers the merits of broader cost sharing arrangements based on regional beneficiary and polluter pays principles.

Irrigation Committee believes that its current cost-sharing and rating arrangements meet this requirement. The need for a Local Beneficiary rating scheme was identified as high priority when the Plan was being developed. This followed from community concerns about the inequities resulting from the previous RWC Phase A Pump rating, in which all irrigators contributed to operating costs regardless of any benefits.

The current rating scheme was developed as part of an intensive study carried out by independent consultants RJ Rendell and SA Brown in 1992. The objective was to develop a rating formula and a testing program which:

- was seen to be objective so far as is possible,
- would give reproducible results,
- was more equitable than the previous arrangements, and,
- was affordable.

The outcome is a system which acknowledges the impossibility of identifying either salinity benefits or polluter contributions with any precision, but:

- uses a standardised pump testing procedure to identify those landholders who are clearly within the area of influence of any groundwater pump,
- requires that all landholders within the defined area of influence contribute as either beneficiaries or polluters, and
- recognises that there are other landholders outside the defined area of influence who are either beneficiaries or polluters.

The system was subject to an intensive consultation process at a series of Tariff Workshops run by the then Rural Water Corporation in 1992, with input from the Salinity Program Advisory Council. It was agreed that the system provided a fair solution to a difficult problem, particularly when viewed in the context of the wider Plan programs and cost-sharing arrangements. The Irrigation Committee has invested heavily in negotiations with the four relevant Water Services Committees since the system was developed to secure the system's application for both the pre-existing Phase A pumps and new plan pumps. We would be reluctant to reopen negotiations on this issue in the absence of any obvious alternative which would better meet Plan objectives.

3. That the Irrigation Committee recommends cost sharing arrangements to target sites which have significant stands of remnant vegetation.

See response to Key Recommendation 3.

4. That the Irrigation committee liaises with the Lake Wellington Salinity Implementation Committee regarding the respective public pump programs.

See response to Key Recommendation 4.

5. That the Irrigation Committee develops financial performance indicators and targets for public pumps.

Irrigation Committee has directed its Sub-surface Drainage Working Group to work with G-MW to implement this recommendation.

6. That the Irrigation Committee review the standard of a public pump and consider the merit of a lower standard but cheaper groundwater pump.

The Irrigation Committee has reservations about stepping back from the current high standard works which have been demonstrated to provide a cost-effective level of service, particularly when the irrigation industry is under considerable pressure to

demonstrate that it can operate efficiently and meet stringent environmental standards. However, the Irrigation Committee has directed its Sub-surface Drainage Working Group to work with G-MW to review the current standard of works to identify any realistic options for cost savings which will not reduce the current level of service.

7. That the Irrigation Committee reviews the current contract with SKM, to determine if more detail on services provided for agreed contract fees will improve the overall service required.

Irrigation Committee considers this to be a matter for G-MW to control, as managers of this project. We have reviewed the costings in the past and found them to be reasonable. The Irrigation Committee is very conscious of the fact that any gains from the current competitive tendering arrangements could be eroded by excessive contract management costs. The Irrigation Committee considers that current working arrangements provide a good balance overall between contract management costs and quality outputs overall. However, the Irrigation Committee has asked G-MW to provide advice on this recommendation by 30 November.

8. That the Irrigation Committee review the current contract with SKM for design of public pumps and consider whether this could be let to competitive tender.

Irrigation Committee has asked G-MW to review experiences at Lake Wellington and provide advice on this issue by 30 November. G-MW is currently working under a six month extension of its current contract with SKM, pending review of alternative arrangements for the longer-term. However, the Irrigation Committee considers that the current integrated investigation and design program offers significant efficiencies. It is therefore unlikely that separating out the design of public pumps from other components of the public pump investigation program could make cost savings.

9. That the Irrigation Committee consider the possibility of contracting privately owned pumps to operate as public pumps.

Irrigation Committee believes existing processes adequately ensure optimal use of private pumps. It should be noted that, under current Plan guidelines public pumps, by definition, discharge primarily to G-MW channels or surface drains in season because groundwater salinities are too high to allow significant farm use. The Plan prefers, in general, that such pumps be in G-MW ownership to minimise the risks of uncontrolled discharges to the channels and drains.

The Plan also contains explicit funding to encourage private pump owners to increase the volumes used by installing extended pipelines and entering into water sharing agreements with neighbours. Irrigation Committee sees this as an appropriate mechanism to increase the responsible use of private pumps and reduce the need for public pumps, which require much greater off-site disposal. The implementation of the groundwater management plan in the shallow aquifer system will further emphasise the responsible use of private pumps.

10. That the Irrigation Committee:

- **recommend programs to target vegetation re-establishment in areas protected by public pumps.**

- **support on-going ecological review of sites affected by public pumps.**
- **consider recommending installing public pumps primarily for environmental protection as well as for agriculture.**

See response to Key Recommendation 3.

11. That the 60-day commissioning test to develop the rating should cease.

As discussed in response to Recommendation 2 the current rating system was developed after intensive study and consultation. Irrigation Committee is aware of the relatively high cost of implementing the Plan's Local Beneficiary rating scheme, and Sub-surface Drainage Working Group noted the costs when reviewing the public pump costs in detail in 1997.

Irrigation Committee believes, however, that it is necessary to provide landholders with realistic expectations of their rating liability prior to requesting their support for installation of the works so that they can make an informed choice about the project. As a result a substantial pump test must be completed at the feasibility stage, although the additional cost over that required to ensure that design requirements and state and federal economic criteria are met is not excessive. Irrigation Committee also believes that the final rating assessment must be based on the best available test results if the system is to be capable of withstanding potential legal challenges. We therefore believe that the additional cost of $5000 which is incurred in assessing the actual response, which occurs during the first operational period for the completed installation, is good insurance for the program. It should be noted that, G-MW's review of the results of past testing shows significant difference in the rated areas for 13 pump sites as determined from the two pump tests. The differences for individual sites ranged up to 24%. This is quite significant input on potential cost share. Obviously the variability in the assessments for individual beneficiaries would be greater again than that measured for the total rated area at each site.

12. If landholders remain unhappy with the 21-day pump test results as the basis for allocating costs between beneficiaries, they should pay for additional investigations to further define rating.

As above. It should be noted also that there are some landholders at most sites who do not support the installation of the works. Anything that reduces landholder confidence in the integrity of the rating process is likely to reduce landholder support and commitment. This could lead to increasing numbers of sites where the final proposals are not supported and consequent increase in program costs overall.

13. That the Irrigation Committee investigate the potential for reducing the pump test cost by the CMA or G-MW owning and operating pump test rigs.

The present policy of the Goulburn Broken CMA is **not** to own equipment. Irrigation Committee considers that it would be more appropriate for G-MW, as the implementing agency, to own the pump test rigs if the services are not to be provided by private contractors. It should be noted, however, that investigation costs were examined exhaustively by Sub-surface Drainage Working Group last year, and it was considered that the current costs of plant hire were very competitive. The Irrigation

Committee is also of the view that, if G-MW is to consider purchase of this equipment, it would be more sensible to do this within the context of a fully G-MW managed drilling and testing unit, given the magnitude and long-term nature of the Plan's sub-surface drainage program.

14. That efficiency savings be redirected towards accelerating the public pump program.

Irrigation Committee concurs with this recommendation, and notes that significant increases in Plan funding will be needed if this program is to meet the original Plan targets over the next 5 years. However, the present funding scenario is a reduction in available funds. As identified in the Audit report budget uncertainties take up an inordinate amount of time of key implementation staff, and make it difficult to efficiently develop annual and short-medium term work programs**.** It is our policy to maximise the works components of the budget and any efficiency savings are directed towards our priority works programs."

End of IC response dated 28 October 1998.

The responses are still considered to be appropriate and there would seem to be no need to revisit any as part of this review.

4. Future Works Program

4.1 Areas Served

The areas served by the estimated works program to 2023 are summarised in **Table 4-1 Cumulative Areas Served by Future Works Program**. More detail on the overall program assumptions, estimated costs and targets is given in **Appendix A**. The area types are described in **Section 5.2**. The works targets for the next 5 years to 2004/2005 are given in **Chapter 9 Physical Targets for Next 5** Years.

■ **Table 4-1 Cumulative Areas Served by Future Works Program**

Year	Private B Type Area	Public B Type Area	Private Horticulture
2000	39830	4200	540
2005	76670	12200	860
2010	85000	26800	1180
2015	85000	47200	1300
2023	85000	85000	1300

The program retains the original overall Plan estimates for the larger capacity private and public pumps in the B Type management areas (refer **8.13 Reliability of Plan** Projections). It has been assumed that the priority for private works will be retained and the private B Type program will be largely completed by 2010.

The timeline for the public pumping has been extended to 2023 to partly offset the relatively low rate of installation to date. However, an accelerating program is required to achieve the original estimates and the nominated target may be optimistic depending on demand and funding.

The estimates for tile drains and low capacity pumps have been restricted to horticulture pending the development of a cost effective strategy for pasture areas. However, the original Plan provision for SDEs in pasture areas has been retained in **Chapter 5** and **Appendix A** (SDE estimates from from **Appendix A** have been reproduced below).

■ **Table 4-2 SDE Estimate**

Activity	Cumulative SDE Estimates by Year End					Original Estimate (22/23)
	99/00	04/05	09/10	14/15	22/23	
Private Pasture Pumps	1.26	2.43	2.7	2.7	2.7	3.7
Private Horticultural Works	0.16	0.26	0.36	0.39	0.4	0
Private C Type	Nil	0.07	0.37	1.85	3.7	4.1
Public Pasture Pumps	0.80	2.32	3.69	5.57	8.9	8.9
Total	2.22	5.09	7.12	10.51	15.7	16.7

The original Plan projections were derived in the mid 1980's and were based on information and knowledge available at the time to provide estimates for strategic planning purposes. Information and experience obtained since that time indicates the projections are currently still valid for planning purposes to the year 2023 (refer **8.13 Reliability of Plan** Projections). The longer term mix of works

eventually implemented will be dependant, in part, on the need for drainage, the feasibility of cost effective solutions, and disposal options and constraints.

4.2 Economic Evaluation

The MDBC's Drainage Evaluation Spreadsheet Model (DESM) was run for each component of the future works program detailed in **Appendix A**. The DESM input assumptions are provided in **Appendix B**. The analysis period was 50 years using a discount rate of 5%. The results are tabulated below.

Table 4-3 DESM Discounted Cash Flow Results ($ x 1000)

	Private Pasture Pumps		Public Pasture Pumps		Total Pasture Program	Horticultural Program
	Existing	New	Reuse	Basin		
Benefits						
Salinity	38,961	65,228	56,232	6,979	167,313	8,077
Reuse	23,831	22,730	4,018	0	50,580	0
Total Benefits	62,793	87,959	60,250	6,979	217,893	8,077
Costs						
Establishment	955	16,632	18,196	4,666	40,449	1,991
Annual	13,473	12,890	8,862	952	36,176	732
Downstream	2,587	2,434	8,911	0	13,932	324
Total Costs	17,015	31,955	35,969	5,618	90,557	3,048
NPV	45,778	56,003	24,282	1,361	127,336	5,029
Benefit/Cost	3.69	2.75	1.68	1.24	2.41	2.65

The DESM returned a favourable benefit cost ratio for all of the programs. The input assumptions are based on the Plan's experience to date and are considered to be reasonable. No attempt has been made to sensitivity test the assumptions and results.

5. Salt Disposal

Groundwater disposal is fundamental to the implementation of the Region's Sub-Surface Drainage Program. The Plan has Regional salt disposal guidelines and standards set by the Victorian Government and the MDBC based on the Benchmark period (July 1975 to June 1985) for the River Murray.

Victoria earns Salt Disposal Entitlements (SDEs) by contributing financially to River Murray salt interception schemes. The entitlement is distributed across Salinity Management Plans via Salt Disposal Allocations (SDAs). The operation and maintenance of salinity mitigation works is paid by beneficiaries.

The Plan (1989) in it's original form, estimated that a Murray River salt disposal entitlement of 16.7 EC would be required to fully implement the Sub-Surface Drainage Program and 2.7 EC for new surface drainage infrastructure. The Government response in June 1990 indicated that the Region may receive 10 EC in the long term. The Government response in December 1993 to the re-submitted Campaspe West Plan revised the Shepparton expectation to 10.2 EC in the long term.

5.1 Current Allocations

The Plan (1989) estimated that Shepparton would require a total of 19.4 EC to implement the Plan in it's original form. The total EC requirement comprised 2.7 EC for new surface drainage infrastructure and 16.7 EC (refer **Table 5-1 Original Plan Estimates**) for sub-surface works.

The current SDA as at 30 June 2000 from the State for implementation of the Region's surface and sub-surface drainage infrastructure is 3.4 EC. The estimated SDA committed to established sub-surface drainage works as at 30 June 2000 is 2.22 EC comprising:

- Private pasture pumps 1.26 EC
- Private horticultural works 0.16 EC
- Public pumps 0.80 EC

SDAs are allocated to individual works based on the estimated salt load reaching the River Murray from the operation of the works. Horticultural works are assumed to operate 100 days/yr on average with the entire salt load reaching the Murray. All of the winter pumping from public and private pasture pumps is assumed to reach the Murray.

The amount of summer reuse for public pumps disposing to the Regional channel and drain network varies and depends on the point of injection, seasonal conditions and the downstream irrigation demand. Studies undertaken during the development of the Plan indicated groundwater reuse from the channel system averaged approximately 93% and ranged from 40 to 80% for the drainage system. For simplicity, an overall average summer reuse of 75% is assumed for any public pump. The 75% average summer reuse assumption is appropriate for planning purposes. However, the SDA estimates, reporting and accounting for individual constructed works should be refined and based on the actual point of discharge within the channel or drain network (recommendation in **Section 8.13)**.

Salt disposal impacts on the River Murray are dependent on the location and timing of disposal. However, current allocation and accounting of SDAs for individual works assumes 6000 t/EC for public pumps and 6500 t/EC for private works. It should be noted that the current adopted t/EC figures are less than the average 6800 t/EC indicated in **Table 5-1 Original Plan Estimates**. There is a need to review salt disposal impacts and adopt common, validated methods for allocating and accounting for SDAs (recommendation in **Section 8.13)**.

It should be noted that ECs are allocated to works on the basis that, on average, annual operating targets are met. However, winter disposal in 1997, 1998, 1999 and 2000 did not take place due to prevailing dry conditions and, consequently, un-favourable disposal conditions in the Murray. There may be above average disposal in future years.

5.2 Future Allocation Process

Victoria currently has approximately 6 EC of unallocated salt credits which is only sufficient to ensure compliance with the Salinity & Drainage Strategy for the next 3 – 5 years. In 2000, the Victorian Salt Disposal Working Group recommended a process for the allocation of remaining ECs between CMAs.

In brief, the process is a standardised request (via a pro-forma) for a 5-year salt credit allocation for proposed actions consistent with a Government endorsed Action Plan. The Goulburn-Broken CMA has requested an additional 3 ECs for the Shepparton Plan. DNRE has made a preliminary offer of 1.5 EC for the next 3 years and the CMA has accepted this in principle.

It should be noted the existing SDE of 3.4 and the preliminary offer of 1.5 amounts to 4.9 EC. This is less than the estimated requirement of 5.09 EC to 2004/2005 for sub-surface drainage works alone (refer **Table 4-2 SDE Estimate**).

Additional salt credits are required to meet the long-term expectations of the CMAs and there is some uncertainty on what ECs may be available. In addition, the future cost of EC credits is likely to increase. Actions by the Plan to generate ECs and establish groundwater reuse options that minimise EC requirements may become more pressing in the longer term This is further discussed (including recommendations) in **Section 8.16**).

5.3 Salt Disposal Requirements

In 1987, groundwater level projections to 2020 and regional scale hydrogeological mapping (covering approximately 612,000 ha) of the Upper Shepparton Formation broadly identified a number of potential sub-surface drainage management types for strategic planning purposes. The management types were designated B and C Type areas as follows;

- B1 - high groundwater levels, aquifer yields medium to high and groundwater salinities high (> 11700 EC).
- B2 - high groundwater levels, aquifer yields medium to high and groundwater salinities moderate (5000 - 11700 EC).

- B3 - high groundwater levels, aquifer yields medium to high and groundwater salinities low (< 5000 EC). The B3 type was further sub-divided into Low and High B3.
- C - high groundwater levels, aquifers non-existent or of low yield and groundwater salinities low, moderate or high.

There were also areas (approximately 270,000 ha) within the Region which had insufficient information to describe a management type and areas (approximately 80,500 ha) where no salinity problem was envisaged to 2020. The mapping and categories were coarse in scale for regional planning purposes. At the local project scale, all of the categories can be encountered within close proximity due to the high degree of variability in the Upper Shepparton Formation.

The original (August 1989) plan estimates for management area types, areas drained, salt loads and approximate EC impacts are given in **Table 5-1 Original Plan Estimates.** These were originally derived using bulk salt load schedules and the MDBC's suite of models for the Benchmark period of July 1975 to June 1985.

Torrumbarry monthly flows were used as the primary constraint in developing the bulk schedules and impacts were estimated in terms of the EC effect at Morgan. Operational guidelines for salt disposal have since been refined, as described in **Section 5.3**.

There is a reasonable degree of confidence in the EC impact over the Benchmark period of managed groundwater disposal. However, there is a need to review current and potential Plan salt disposal impacts in light of the refined operational guidelines and also in terms of the of all the Murray River salinity costs including mid-river impacts (recommendation in **Section 8.13)**.

Table 5-1 Original Plan Estimates

Management Area Type	C	Low B3	High B3 Private	High B3 Public	B2	B1	Total
Total Area (ha) 2020	71000	73000	12000	57000	18000	10000	241000
Area Drained (ha)	14000	73000	12000	57000	18000	10000	184000
Winter Salt Load (t)	28000	22000	3600	31920	16800	0	102320
Summer Salt Load (t)	0	0	0	7980	4200	0	12180
Total (t)	28000	22000	3600	39900	21000	0	114500
Approx EC Impact	4.1	3.2	0.5	5.8	3.1	0	16.7

Notes
1. Low B3, C and private High B3 assumes total farm reuse in-season.
2. High B3 & B2 assumes 75% reuse in-season via the channel & drain network (derived from an estimated 93% reuse from channels and 40 to 80% from drains depending on seasonal conditions).
3. B1 Types dispose to basins.

The original reuse assumption for channels would currently still seem to be valid however, reuse would be increased in future if water efficiency measures can reduce channel outfalls. The reuse assumptions for drains may be conservative in the longer term, as the low and high flow diversion strategies being implemented in the Region will potentially divert more of the pumped groundwater. In

addition, drain network modeling to assess and account for pumps disposing to drains (refer **Section 5.4.3**) indicate that, on average, approximately 80% of existing public pump salt loads are diverted in-season with the current level of licensed diversion. This indicates that salt disposal impacts on the Murray may currently be over estimated. The salt disposal impact review recommended in **Section 8.13** will refine the drain reuse assumptions.

The Program review undertaken in 1993/94 retained the original Plan targets for larger capacity private and public pumps. Short term (ie second 5 year) targets for tile drains and small capacity pumps were restricted to horticultural areas pending development of a cost-effective strategy for pasture.

One outcome of the 1993/94 review was that winter groundwater disposal for salt balance from existing private pumps would be voluntary and only encouraged where the groundwater salinity was >1,000 EC. A nominal 1 EC reduction in B3 salt disposal was assumed to allow for reduced EC impacts.

In addition, a groundwater salinity limit of 10,000 EC was adopted for public pumps disposing to the channel or drain network. No allowance was made at that time for the resultant decrease in EC impact for the B2 Type areas. Assuming a linear relationship with salinity ranges and area mapped as B2 Type, a salinity limit of 10,000 EC could result in a reduction of approximately 4000 ha in the area served by pumps disposing to channels and drains. This would potentially reduce the EC impact of the B2 Type works by approximately 0.7 EC and increase the area to be served by pumps disposing to basins. A more detailed assessment is not considered worthwhile at this stage. No adjustment has been made to the EC requirement for B2 areas in the table below.

Salt load estimates resulting from the 1993/94 review are summarised in **Table 5-2 Revised Plan Estimates** . The estimates include a reduced requirement of 1 EC for Low B3 areas and exclude C Type pasture activities pending development of a cost effective strategy.

- **Table 5-2 Revised Plan Estimates (as shown in the 93/94 review & excluding C Type pasture)**

Management Area Type	C	Low B3	High B3 Private	High B3 Public	B2	B1	Total
Total Area (ha) 2020	71000	73000	12000	57000	18000	10000	241000
Area Drained (ha)	1300	73000	12000	57000	18000	10000	171300
Winter Salt Load (t)	1300	15500	3600	31920	16800	0	69120
Summer Salt Load (t)	0	0	0	7980	4200	0	12180
Total (t)	1300	15500	3600	39900	21000	0	81300
Approx EC Impact	0.2	2.3	0.5	5.8	3.1	0	11.9

The estimated number of B3 and B2 Type pumps by sub-region is summarised in **Table 5-3** . Approximate B3 and B2 Types within the Lockington, Bamawm, Wharparilla and Campaspe drainage catchments (ie within the North Central Catchment Management Area) are given beneath the SIR total. The original Plan estimates for B1 Types allowed for 25 pumps and disposal basins in both the Rochester and Rodney/Tongala sub-regions resulting in 50 basins to serve 10000 ha. Approximately 3000 ha of B1 Type Area is within the North Central CMA (ie within the Rochester sub-region west of the Campaspe River).

■ **Table 5-3 Pump Distribution by Sub-Region**

Sub-Region	Private Pumps								Public Pumps			
	Exist Low B3		New Low B3		Exist High B3		New High B3		High B3		B2 Type	
	No	Area	No	Area	No	Area	No	Area	No	Area	No	Area
Murray Valley	200	25000	128	16000	20	2500	20	2500	20	4000	2.5	500
Shepparton	0	0	0	0	5	500	5	500	5	1000	10	2000
Rod/Tongala	100	10000	160	16000	20	2000	20	2000	160	32000	52.5	10500
Rochester	40	4000	20	2000	10	1000	10	1000	100	20000	25	5000
SIR Total	340	39000	308	34000	55	6000	55	6000	285	57000	90	18000
NCentral CMA	31	3060	15	1530	8	760	8	760	76	15280	11	2200

Note: NC CMA component of Rochester sub-region works are those west of the Campaspe River.

In summary, the longer term salt disposal requirement for the Region is approximately 15.7 EC compared with the original 1989 estimate of 16.7 EC. The 15.7 EC assumes a cost effective strategy will be developed and implemented for the original C Type pasture areas and that there will be a reduced requirement of 1 EC for the original B3 pumping areas.

5.4 Salt Disposal Guidelines

Operating targets for public salinity control pumps disposing to the channel and drain network are two 60 day periods of continuous operation per year (on average) to provide leaching opportunities and salinity control. One 60-day period is in season, with the other out of season when favourable disposal conditions exist.

Off-farm discharge from private pumps is generally not permitted in season (except for approved private groundwater control works for horticultural developments). However, private pumps are encouraged to discharge specified amounts for salt balance out of season when conditions allow.

Phase A works operate to maintain groundwater levels at more than 2 m below surface within target orchard areas. Pumping is undertaken when necessary to maintain groundwater pressures in nominated observation bores within specified limits. Phase A works were established prior to 1 January 1988 and do not require a salt disposal allocation.

In 1993, a range of salt disposal guidelines were suggested for the Region's streams and wetlands (DCNR, Disposal of Saline Groundwater to Natural Wetlands and Streams in the Shepparton Irrigation Region, Draft Discussion Paper, March 1993). The suggested maximum salinity limits were:

- Murray River 300 EC
- Goulburn River 500 EC
- Campaspe River 750 EC
- Broken Creek 300 EC

- Near Pristine Natural Wetlands 500 EC
- Wetlands Along Drainage Lines 1000 EC
- Artificial or Degraded Wetlands less stringent

The suggested limits were interim and conservative, as knowledge on critical salinity thresholds was limited. The limits were not adopted by the Plan at that time as it was recognised that disposal guidelines (within the Murray constraints set by the Victorian government and the MDBC) would need to be developed within the Region as implementation proceeds. The current status of salt disposal guidelines for the Region are briefly described below.

5.4.1 Regional Rivers and Streams

5.4.1.1 River Murray

The River Murray has no set upper salinity limit and groundwater pump operation is scheduled to fit within the Plan's EC limits in accordance with standards and guidelines set by the Victorian Government and the MDBC.

Early in the Plan implementation phase, out of season disposal was initiated when observed flows at Torrumbarry Weir exceeded 10000 ML/d and there was a reasonable expectation that these conditions would persist for 60 days or more. In 1998, more robust and objective operating rules for salt disposal were developed based on real time flow conditions at key points within the Murray and Goulburn River systems (refer **Table 5-6**).

5.4.1.2 Goulburn River

For the Goulburn River, out of season groundwater pump operation is in accordance with the Murray schedules. Modelling of the Goulburn River in the early 1990's estimated that average salinities due to the fully implemented Plan would increase from 192 to 257 EC and that daily salinities could exceed 500 EC about 3% of the time. A recommendation was made that the aim should be to keep the river salinity below 500 EC as a general rule. This limit was acknowledged to be conservative but has been adopted by the Plan.

5.4.1.3 Broken Creek

The lower reaches of the Broken Creek are seen as an important fishery for Murray Cod and Crays. Advice (1996) from DNRE's Kaiela Freshwater Research Station on current knowledge of freshwater fauna salinity tolerances was:

Adult fish	15000 EC
Juvenile fish, more sensitive,	tolerance unknown
Macrophytes	6000 EC
Macroinvertebrates	1600 EC

Modelling of salinity increases in the lower reaches of Broken Creek due to the Plan using the Murray disposal schedules indicated resultant salinities would be within the adopted upper salinity limit of 1500 EC (note that this is less than the 1600 EC tolerance for macroinvertebrates). However, additional rules better suited to Broken Creek flow conditions were developed by the Plan to minimise potential salt disposal impacts.

Current guidelines for out of season disposal to the Broken Creek are:

- River Murray trigger flows must be met; and
- Flows at Rice's Weir should be on a rising trend and exceed 300 ML/d for 7 consecutive days.

The summer guidelines for disposal from public pumps are rostering the 1 x 60 day operating period per pump to achieve a uniform distribution within the catchment coinciding with moderate, regulated flow conditions.

The current guidelines were developed by using a daily flow and salinity model for Rice's Weir from mid 1991 to mid 1996 (1581 days) to evaluate and adopt pumping schedules that minimised the potential salinity impact on Broken Creek. The modelled resultant salinities due to year 2020 salt disposal estimates from a fully implemented public and private pumping program are summarised below.

Table 5-4 Resultant Salinities for Year 2020 Pumped Salt Loads

Nominal Threshold EC	Periods Exceeded	Number of Days Exceeded
> 300	03/10/91 – 01/11/91 17/09/92 – 04/10/92 26/09/94 – 25/10/94 19/08/95 – 07/09/95	30 19 30 20
> 500	05/10/91 – 01/11/91 28/10/93 26/09/94 – 02/10/94 06/10/94 – 25/10/94 24/8/95 – 07/09/95	28 1 7 20 15
> 1000	16/10/94 – 18/10/94	3 (max = 1084 EC)

The observed flow weighted average salinity at Rice's Weir from mid 1991 to mid 1996 was 173 EC and the resultant salinities due to pumping were well within the adopted upper limit of 1500 EC.

The MDBC Salinity Audit (1999) indicated that flow weighted average salinities in Broken Creek upstream of the Murray could be 230 EC by the year 2020 and 970 EC by 2050 due to dryland inputs. The potential impacts of this has been assessed using the 1991 to 1996 daily flow and salinity model and year 2020 pumped salt load estimates.

The forecast salinities for 2020 and 2050 were simulated by factoring the observed daily 1991 to 1996 salinities by 230/173 and 970/173 respectively. The impacts on the dates corresponding to the > 1000 EC threshold are summarised below.

■ **Table 5-5 Resultant Salinities for > 1000 EC Threshold (91-96)**

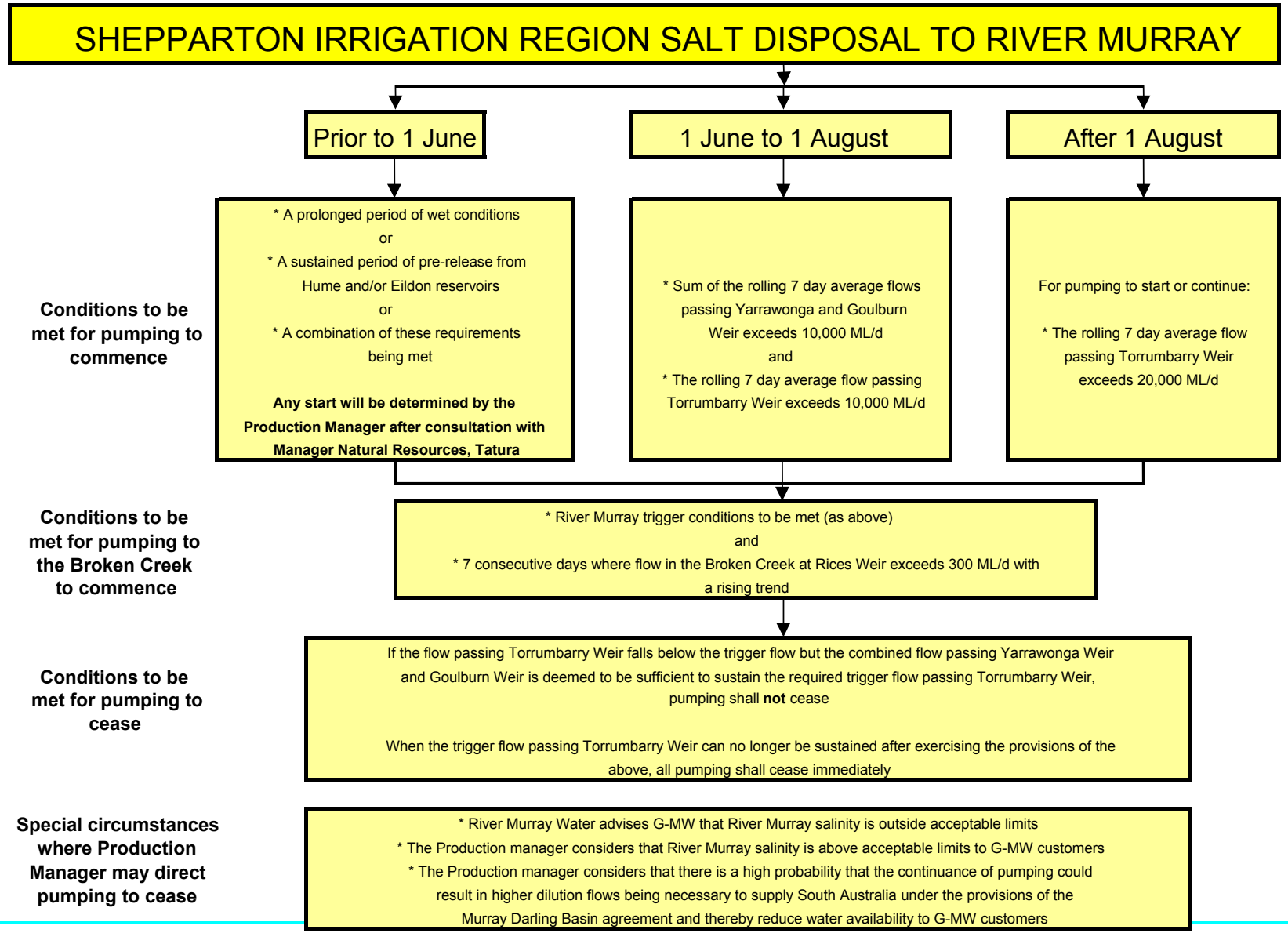
Date	Ave Annual EC	Base EC	Increase in EC	Resultant EC
16/10/94	173	97	987	1084
Year 2020	230	129	966	1095
17/10/94	173	80	987	1067
Year 2020	230	106	970	1076
18/10/94	173	79	934	1013
Year 2020	230	106	917	1023

The results using a year 2020 salinity of 230 EC indicate that the resultant salinities due to groundwater pumping would be well within the upper limit of 1500 EC. The increase in a flow weighted average base salinity from 173 to 230 EC is relatively small and increasing the 1991 to 1996 daily salinities by a constant 230/173 may be a reasonable means of assessing the potential impact of the forecast increase in salinity for 2020.

The results for the year 2050 simulation showed large fluctuations in base salinities without pumping which often exceeded the adopted upper limit of 1500 EC for the Broken Creek. Groundwater pumping with an average flow weighted salinity of 1600 EC had a relatively small impact due to the much higher base salinities in the creek. An increase in flow weighted salinity from 173 to 970 EC is large and applying a constant 970/173 to the 1991 to 1996 observed salinities may not be reasonable means of simulating potential 2050 conditions. However, further evaluation for year 2050 is not considered worthwhile at this stage given the timeframes and unknowns.

In summary, the current disposal guidelines for Broken Creek were designed to minimise the potential impact on the lower reaches of the creek. Consequently, a flow weighted average salinity of 230 EC in Broken Creek by the year 2020 would seem to have little impact on disposal opportunities. This would need to be reviewed if monitoring by the Plan identifies significant changes in Broken Creek base conditions. Further evaluation of the potential year 2050 salinity scenario is not considered worthwhile at this stage.

■ **Table 5-6 River Murray Salt Disposal Trigger Levels**



5.4.1.4 Broken and Campaspe Rivers

The Broken River and Campaspe River have no set salinity limits under the Shepparton Plan. Salt disposal to these streams is not considered a priority issue for the Plan as only minor inputs and impacts are anticipated.

5.4.2 Channels

In-season channel groundwater disposal guidelines developed during the Phase A program are still current. A flow weighted average limit of 500 EC was adopted and is based on a zero productivity loss for horticulture on a medium textured soil with adequate surface and sub-surface drainage. Current guidelines are:

- Flow weighted average seasonal salinity < 500 EC
- Maximum average for any seven consecutive days < 750 EC
- Maximum at any time 850 EC

G-MW's Irrigation Management System and System Planning Modules include a channel salinity simulation sub-system. The flow and salinity simulation model is run in conjunction with planned deliveries to manage the operation of public pumps discharging to the channel system. In practise, increases in channel salinities are incremental and the maximums would only occur in the lower end of the channel network. G-MW would not allow the maximums to occur in the upper part of the network without full consideration of the potential impacts.

The current process largely relies on operator experience and trial and error to schedule the operation of pumps. Future enhancements to the Systems may permit development of an objective optimisation process for scheduling of pump operation by G-MW.

5.4.3 Drains

Drain flows and salinities are highly variable, both spatially and temporally, within the Region. In 1998, the following upper salinity targets resulting from in-season groundwater disposal to drains were developed and adopted.

- For existing flow weighted average seasonal drain salinities less than 530 EC, an upper target of 800 EC
- For existing flow weighted average seasonal drain salinities > 530 EC, an increase of 50% with an upper target of 1700 EC

The upper targets are aligned with the salinity limit guidelines adopted for the conjunctive use of groundwater for irrigation. The 800 EC is based on zero productivity loss for perennial pasture. The upper limit of 1700 EC (estimated 15% productivity loss) is the current irrigation salinity limit guideline for private groundwater pumps installed without Plan assistance.

Average conditions over the 1994/95 to 1996/97 seasons have been adopted as base or "benchmark" conditions for the drainage system. A substantial number of sub-regional drainage catchments within the Region have

continuous flow and salinity monitoring stations at their outfalls. Currently, a simple drain network mass balance modelling approach (calibrated against monitoring stations) has been adopted to account for the effect of new pumps and also to assess potential impact of proposed pumps.

5.4.4 Wetlands

There are currently no adopted EC limits for wetlands supplied by channels or drains. However, they are implied by the adopted EC guidelines for channels and drains.

A salinity limit of 500 EC as a result of groundwater disposal has been suggested for high conservation value wetlands. However, guidelines for all types of wetlands are yet to be developed and adopted by the Plan.

6. Cost Sharing

The Plan meets the basic cost sharing principles applied by Government which include:

- Contributions by communities should reflect both the extent to which these communities derive benefits from salinity control (the beneficiary pays principle), and the relative inputs of local land-use, water management and disposal systems to the worsening of the problem (the polluter pays principle).

- Primary beneficiaries are expected to meet their full share of costs. Regional and local communities, as secondary beneficiaries, may contribute to the cost of salinity control measures on a voluntary basis.

- Government may contribute on the basis of representing broader environmental and social interests.

- Government will not assist works and measures which are not cost effective and are dependent on continued subsidy.

6.1 Works Establishment

The costs for feasibility investigations and capital establishment of public works are currently met by State and Federal funds. The State also funds the capital component of the Region's Salt Disposal Entitlement.

The Plan also provides a range of varying incentives for the investigation and establishment of private works and has a comprehensive set of policies and guidelines for new and existing works.

An outcome of the 1993/94 Program review was a progressive reduction (over three years) in the maximum level of capital grant from 80% to 65% for pasture pumps. The total maximum amount of $30000 per pump, per individual was retained. Under the current formula, $200/ML is applied to the minimum summer reuse volume derived using a number of set criteria. The grant is limited to the lowest value derived using the above criteria ie

- 65% of the capital cost, or
- $30,000 maximum, or
- $200/ML on minimum summer reuse volume

The summer reuse volume is currently limited by one of five parameters:

- the salinity limit (potential usage at the required dilution);
- the groundwater reuse intensity (currently 3 ML/ha/yr on the area irrigated by the pump);
- the dilution water available from all sources;
- the sustainable yield of the pumped aquifer; or
- the licensed extraction volume.

The current recommended safe salinity limit for the shandied groundwater and surface water is 800 EC for no production loss on flood irrigated perennial pasture on a medium textured soil. Site specific salinity limits can be varied depending on crop and soil type. In addition, current policy allows for consideration of reuse of more saline water where justified. The following guidelines have been adopted for zero productivity loss for some other crop types.

- Lucerne (flood irrigated) 1200 EC
- Fruit trees (deciduous) 500 EC
- Eucalypts (first year) 3000 EC
- Eucalypts (subsequent yrs) 5000 EC

An analysis of costs for capital grant bores installed since 1 January 1998 indicated the average Plan contribution to the capital cost was approximately 43%.

Interest and uptake of capital grants to end June 2000 does not seem to have been influenced by the current formula and the reduction in the maximum level of grant to 65%. Consequently, a review of the formula was assigned a medium priority by the Review Steering Committee on 23 August 2000 (refer **Chapter 8, Table 8-1 Issues and Priorities**).

6.2 Annual Costs

A beneficiary pays tariff structure was developed and adopted by the Plan in 1992 for annual costs (including renewals) for new public pumps installed by the Plan.

This rating structure was also adopted by Murray Valley for Phase A works and introduced over a 5 year period from 1993/94 to 1997/98. Annual costs for Phase A works were previously recovered via a drainage levy on all irrigators calculated per ML of water right in each irrigation area.

Central Goulburn also extended the beneficiary pays tariff structure to pre Plan works over a 3-year phase in period from 1996/97 to 1998/99. Rochester has no Phase A works and introduced the tariff structure new works in 1996/97.

The Shepparton Irrigation Area has adopted the principles for new works but has yet to resolve cost sharing issues for Phase A works. Shepparton has 6 Phase A pumps in the Invergordon area and 60 day pumptesting indicated that only 2 of these could be rated in accordance with the current guidelines. There are 9 private pumps under hire in Shepparton East. Their capacities are small and it is not feasible to apply the public pump rating formula due to the local hydrogeological conditions. An options paper was submitted to the Water Services Committee in July 1998 for their consideration and resolution.

■ **Table 6-1 Cost Share for Annual Costs**

Activity	Distribution Of Cost (%)		
	Local Government	Local Beneficiary	All Irrigators
Direct Costs			
Phase A	0	50	50
New Public Pumps	17	41.5	41.5
Additional Channel/Drain O&M - Phase A	0	50	50
- New	17	41.5	41.5
Private Pump & Surface Drain SDA	17	0	83
Non Operational Sites - Phase A	0	0	100
- New	17	0	83
New Sites Prior to Rating	17	0	83
Private Pump Management	17	41.5	41.5
Indirect Costs			
Land & Water Administration	17	0	83
Accounts Receivable	17	0	83
Other Indirect	17	41.5	41.5
Private Pump Concession for Private/public pump overlapping areas	0	50	50

Notes: Non operational works are those kept on care and maintenance for possible future operation and those requiring refurbishment prior to the identification of local beneficiaries/return to normal operation.

Local Government does not contribute to any direct or indirect costs associated with Phase A works.

The annual costs of the sub-surface drainage service are met by those directly benefiting from public pumps (via Local Beneficiary Fees based on water use and area served), all irrigators (via a Service Fee based on water use) and Local Government.

The 1999/2000 sub-surface drainage pricing schedule for the Region is given below.

■ **Table 6-2 Pricing Schedule 1999/2000**

	Murray Valley	Shepparton	Central Goulb	Rochester
Local Benefit Area Fee ($/area unit)	2.8703	-	2.8283	3.9264
Local Benefit Water Use Fee ($/water unit)	0.4951	-	0.5409	0.9319
Local Benefit Municipal Fee ($/area unit)	11.4812	-	11.3132	15.7055
Service Fee ($/ML water use)	0.2148	0.5645	0.4980	0.0785

The local or direct beneficiary rating liability is based on the property's average level of service. This is based on the observed groundwater drawdowns during the first 60-day period of continuous operation and applying relative benefits to areas within drawdown categories.

The principles for deriving the average level of service are not reproduced in this report (see **Chapter 12 References** for relevant document). However, for example, the 1999/2000 rating liability of an 80 ha dairy farm in Murray Valley with a water use of 440 ML and average level of service of 1.58 would be approximately $802 ($708 in local fees and $94 via the Area service fee).

Prior to July 1999, the costs of private groundwater pump management were met by Government but it was agreed that part of these costs would in future be charged to the Sub-Surface Drainage Service, subject to the removal of the current exemption from groundwater charges. All other annual costs are borne by the landholder.

The exemption was lifted in July 1999 with the implementation of the Region's Groundwater Management Plan and fixed ($49.50 per licence) and volumetric charges ($1.10 per ML of licence allocation) were introduced for 1999/2000 to partly cover management costs from users. Further shifts are likely to occur as implementation proceeds and evolves. The Local Government contribution is restricted to new works, i.e. no Phase A costs are met by Local Government.

The Government is to pay the fixed charge in 1999/2000 in recognition of the community salinity benefits from regular groundwater pumping. The Region's Water Service Committees have agreed to pay the fixed fees from the Sub-Surface Drainage Service in future years for those that meet Plan requirements.

Where a landholder has an existing private pump or tile drain system within the area of influence of a public pump, the landholder is eligible for a concession provided the private works were installed prior to the public pump and are operated in accordance with Plan guidelines. The rate applicable to the overlapping area is reduced by one service level. This reduction in the rate base and potential shortfall in revenue is recovered equally from local beneficiaries and all irrigators.

7. Data Collection and Evaluation

Data collection and evaluation are integral to the process of on-going refinement and review of Plan implementation and direction. This can be a repetitive process as knowledge, technology and priorities are continually changing.

7.1 Groundwater Levels and Salinities

Approximately 3400 Upper Shepparton Formation observation bores at approximately 2000 G-MW and DNRE (ISIA & Statewide) monitoring sites are monitored at varying frequencies for groundwater level and salinity. All of this information is entered into the State Groundwater Database (GDB).

The observation bore network provides coverage for approximately 562,340 ha (80%) of the SIR's total area of 674,400 ha (as defined by the SIR Groundwater Supply Protection Area plan boundary). The overall bore density is approximately one monitoring site per 300 ha however, this varies considerably at the local scale and there may be opportunities to rationalise the existing network (refer recommendations **Section 8.9**). The broad monitoring aims are to provide the base information to assess:

- Groundwater level trends, seasonal responses and areas at risk;
- Eligibility for Plan works and assistance;
- Priorities for the implementation of works;
- Groundwater responses to the operation of sub-surface drainage works; and
- Groundwater resource management issues.

Groundwater behaviour beneath the irrigation areas is complex and sensitive ,in part, to landuse, soil type, irrigation and drainage practices, crop type, irrigation intensity, rainfall, evapotranspiration and groundwater pumping. Evaluation of bore hydrograph data has largely been a combination of visual assessment and statistical regression analyses. Attempts to use more sophisticated models have generally been frustrated due to the lack of reliable fine scale information on the variables influencing groundwater behaviour. Detailed analyses of a sample set bores with reliable information on the variables should be undertaken to assess the most appropriate method of evaluation (refer recommendations **Section 8.9**).

Depth to groundwater contours are produced for the Region each year for August. The maps and statistics are a late winter snapshot and provide information on long term trends, areas at risk (a mechanism for works eligibility and prioritisation) and areas with potential groundwater resource management issues. A reference watertable map is used to assess eligibility and prioritisation of works. The first reference map adopted was August 1993 with the intent that the reference map be reviewed and adjusted accordingly every 5 years. The August 1998 map was not considered to be representative due to prevailing dry conditions since 1997. Consequently, the 1996 map was adopted as representative under normal conditions.

The Plan is largely aimed at providing salinity control (ie providing conditions for net leaching to occur) and groundwater levels are uncontrolled for most of the time. Consequently, the late winter snapshot, in isolation, is limited in providing a

mechanism to assess the effectiveness of works except in areas with a high degree of groundwater control (ie maintained at > 2 m below surface) such as the Ardmona area and parts of Murray Valley. Analyses of late winter to late summer groundwater level changes should be considered, as the effects of private pumping should be more evident in late summer (refer recommendations **Section 8.9**).

7.2 Private Pump Operation

Implementation of the Groundwater Management Plan (GMP) is providing more reliable information on the amount and salinity of groundwater pumped by private works. The base data can be used to assess:

- Actual volumes pumped against allocated (ie salinity guideline target) volumes;
- Changes in groundwater salinity and, potentially, the need to alter the pump use:
- Salt loads exported during favourable winter disposal conditions;
- Groundwater resource management issues: and
- The areas served by private works.

The data collected is currently stored on temporary locally held information systems, which facilitate the collation, analysis and routine reporting of statistics. A longer term storage and retrieval system is yet to be identified (refer recommendations **Section 8.13**).

Interim private Plan bore allocations prior to the GMP were mapped on a 1:25000 base to spatially identify areas served by private pumps. This mapping should be updated with the revised salinity guideline allocations to provide a more accurate representation of areas served (refer recommendations **Section 8.10**).

7.3 Public Pump Operation

Public pumpsites are visited weekly during their scheduled operating periods and operational data is generally recorded monthly (or as a result of the weekly visit if the pump was found to be stopped). Data recorded includes date and time of inspection, vacuum, pressure, flow meter reading, flow check, discharge point (if dual discharge), comments if pump was running, started or stopped and reasons for stoppage. The pumps are also routinely sampled for salinity analyses and selected observation bores are monitored in conjunction with the pump operation. In addition, chemical analyses are undertaken for 15 selected public pumps across the Region twice yearly.

The data collected is used to assess:

- Pumpsite performance;
- Pump operational problems;
- Groundwater responses to pumping;
- Volumes pumped;
- Salt loads discharged;
- Potential changes in pumped groundwater salinities; and
- Potential changes in pumped groundwater chemistry.

The data collected is currently stored on temporary locally held information systems. A longer term storage, retrieval and reporting system is yet to be identified.

7.4 Field Investigation Outcomes

Feasibility level investigations for private and public works include geophysical surveys, drilling, bore construction and formation testing. The information collected is used to evaluate pumping options and locate, design and construct works. Drill logs, bore construction details and groundwater levels and salinities are entered into the Groundwater Data Base (GDB). In addition, the investigation outcomes are classified according to potential Management Area Type and mapped on "Sub-Regional Groundwater Data" 1:25000 plans.

The Sub-Regional Groundwater Data plans cover a variety of other information including:

- Roads, channels, drains and drain diverters;
- GDB locations and numbers for D&S bores, shallow irrigation bores (<30 m) and deep irrigation bores (>30 m);
- Private Plan pumps and their nominal area of influence based on 1 ha per ML of summer reuse allocation;
- The location of known tile drainage systems (excluding Shepparton East);
- Phase A and public salinity control pump locations, their point of discharge and the area within the 0.1 m drawdown contour; and
- The GDB locations and numbers for G-MW and DNRE observation bores, their depths and monitoring frequencies.

The Sub-Regional Groundwater Data plans are currently in a microstation drafting format. It would be desirable to convert the information into a GIS format to enable the data to be combined with other spatial information available to the Plan (refer recommendations **Section 8.9**).

8. Plan Issues & Recommendations

Groundwater management and salt disposal is fundamental to the implementation of the Region's Sub-Surface Drainage Program. The Plan (1989) in it's original form, estimated that a Murray River salt disposal entitlement of 16.7 EC would be required to fully implement the Sub-Surface Drainage Program.

Implementation of the Plan has proceeded based on best bet assumptions and guidelines derived from available information and knowledge at the time, and is subject to on-going review and refinement. Some areas that may require further policy and/or technical development are listed below and briefly discussed in the subsequent sections. The Review Steering Committee at a meeting on 23 August 2000 assigned an initial priority of low, medium or high to the issues.

■ **Table 8-1 Issues and Priorities**

Item	Issue	Priority
1	Securing Salt Disposal Entitlements	High
2	Works for new & existing horticultural (or other high value) development	High
3	Public and private disposal basin management and cost sharing guidelines	High
4	Works for protection of environmental features	High
5	Impacts of increasing irrigation supply salinities	High
6	Alternative disposal methods for moderate to high salinity groundwater	High
7	The optimum amount of pumping for groundwater and/or salinity control	High
8	Operational guidelines and schedules for disposal to channels and drains	High
9	Criteria for effectiveness of works	High
10	Farm management of pumped groundwater	High
11	Prioritisation of works at the drainage catchment scale	High
12	Plan Resource Requirements	High
13	Reliability of Plan projections - Salt disposal impacts - Watertable projections - Management Area Types	 High Low Low
14	Capital Grants and level of assistance	Medium
15	Tile drains and low capacity groundwater pumps in pasture	Medium
16	Options for generation of salt credits	Medium
17	Safe groundwater reuse intensity	Medium
18	Role of the Deep Lead	Low

8.1 Securing SDEs

Shepparton currently has 3.4 EC and the Government response in June 1990 and December 1993 indicated that the Region may receive 10.2 EC in the long term, plus part of 0.3 EC pending Campaspe West's requirements. The current estimated long term SDE requirement for the sub-surface drainage program (including works for C Type pasture areas) is 15.7 EC.

The most critical issue for the Plan is securing SDE in the future for implementation. Means of securing SDEs may include alternative disposal methods, enhanced reuse, changes in drainage management and requirements, purchase of SDE or salt interception schemes. The cost of future SDE may be considerably more than in the past. The potentially higher cost of purchasing future SDE would impact on the economics of the works.

Recommendation

- Continue with (and enhance when knowledge becomes available) current drainage management strategies (surface and sub-surface) and pursue opportunities for gaining additional SDE when identified.

8.2 New & Existing Horticultural (or other high value) Developments

There has been an expansion in horticultural development within the Region in recent years. Ideally, this expansion would occur in areas served by existing Phase A groundwater control pumps.

Identification of direct beneficiaries of the Phase A pumps was completed in 1994/1995. At that time, the total area subject to local rates in Murray Valley and Central Goulburn was approximately 15,570 ha of which, 3520 ha was existing orchard (1992 orchard census) provided with groundwater control.

The Plan currently has a horticultural program largely aimed at private groundwater control works for existing "C Type" orchard areas. To date, larger capacity Plan public pumps have been installed and operated to provide salinity control rather than groundwater control even where orchards are within the pump's area of influence.

Current **Policy 5.1.1** states that "Subject to cost sharing policy, groundwater control can be provided by public pumps, private pumps or tile drains to horticultural plantings in existing horticultural areas which are to be defined by the SIR IC in consultation with the horticultural industry. Public pumps will only operate to salinity control guidelines in other areas."

One of the Plan's stated objectives is to provide groundwater control for high value crops which are sensitive to waterlogging. There may be a need to review and clarify the Plan's position on existing and new horticultural developments. There may also be a need to review land use within the area served by Phase A pumps due to changes in areas under horticulture.

It should be noted that existing and new horticultural developments are utilising more efficient farm irrigation and drainage management practices than those in place during the implementation of the Phase A groundwater control program. The drainage requirements and effectiveness of the improved management practices in reducing drainage requirements under average or above rainfall conditions are largely unknown.

Note: New horticultural (or other high value) developments relate to changes in landuse for areas currently irrigated. It does not include new irrigation developments which should make there own provisions for drainage.

Recommendations

- Develop guidelines for new high value enterprises (Note: work initiated September 2000 in response to a developer's query on drainage options and guidelines).
- Capture and map areas planted to horticulture on ISIA's GIS system.
- Initiate review of distribution of horticultural plantings and Phase A rate base.
- Evaluate horticultural drainage (and SDA) requirements under improved farm irrigation and drainage management practices.
- Review Phase A program performance after a return to average seasonal conditions.
- A review be undertaken on urban encroachment and planned urban development in the Shepparton East area to identify and evaluate any implications for the private horticultural program.

8.3 Disposal Basins

The Girgarre Basin trial has been very successful and the Plan has allowed for a nominal 50 additional basins. However, there has been no uptake to date on basin disposal options. This may change with time as salinity problems become more advanced and community perceptions change.

Plan guidelines for basins are yet to be developed. A CSIRO/CRC project has developed broad guidelines for farm and community scale disposal basins on the Riverine Plain. These would be considered when developing specific guidelines for basin management and cost sharing.

The development of guidelines should be initiated before a potential basin with strong community support is identified due to the timelines that may be required to resolve potential issues. Opportunities for other potential uses of basins should also be considered to offset costs.

Recommendations

- Initiate development of cost sharing, implementation and management guidelines. Current broad technical guidelines are adequate.
- Promote and initiate a scheme with a basin if an opportunity is identified with Groups or individuals.

8.4 Environmental Features

The Plan has provision for sub-surface drainage works to protect significant environmental features. Public pumps to date have focussed on protecting agricultural land with any potential environmental benefits or disbenefits being considered with establishing the works. However, the works to date have provided significant benefits to small stands (0.5 ha on average) of remnant vegetation on private land and road reserves. This equates to a combined area of 10.5 ha for the 21 public pumps installed to end June 2000.

The combined area of remnant vegetation protected by new private pumps (194 to end June 2000) and existing private pumps (approx 400) that pump on a regular basis is unknown. However, assuming 0.5 ha on average as for the public pumps, the combined area could be in the order of 300 ha.

Cost sharing principles for works specifically targeting environmental features are yet to be developed. In addition, the level of sub-surface drainage service required for features such as remnant vegetation, wetlands and streams is largely unknown.

Recommendations

- Enhance the Program's stated principles to include the installation of sub-surface drainage works to protect environmental features where necessary, feasible and consistent with Plan criteria.
- Develop criteria and guidelines for the protection of environmental features such as wetlands, streams and remnant vegetation (Note: work on guidelines for remnant vegetation initiated in September 2000).
- Undertake risk assessments for high value environmental features.
- Salt disposal guidelines be developed and adopted for wetlands within the Region.

8.5 Increasing Channel Salinities

Groundwater disposal to the channel network from public pumps in season will increase downstream irrigation supply salinities. This has potential to:

- reduce the volume of downstream conjunctive use;
- aggravate salinity problems downstream, particularly where pumping is not feasible; and
- cause concerns regarding soil sodicity.

The current target pumping rates adopted for public and private pumps are in excess of theoretical minimum leaching requirements and should provide adequate leaching for some areas receiving higher salinity channel water. However, this will need to be reviewed as implementation of the public pump program proceeds and current salinity limits (average 500 EC) for channel are approached in parts of the system.

The implications of increased channel salinity and soil sodicity are currently unclear. An initial review to quantify the potential problems associated with increased channel salinities and remedial measures may be warranted.

Recommendation

- Initiate review to quantify potential sodicity problems and remedial measures, impact on conjunctive use of groundwater and salt disposal requirements

8.6 Alternative Disposal Methods

The current disposal strategy for groundwater (>3500 and <10,000 EC) which can not be used productively on pasture based enterprises is pumping to the Regional channel and drain network. Limited SDEs are likely to restrict full implementation of the Program in its original form.

Development of land based disposal options (full eg basins or partial eg trees in summer and off-site in winter) may reduce the overall need for SDEs to implement the Program. Research in this area should continue and development of an implementation strategy should be considered when viable options are identified.

The "serial biological concentration" trial and the Mt Scobie saline reuse trial may provide some options. In addition, there is some interest within the Wyuna Landcare Group in the concept of a community land based disposal scheme.

Recommendations

- Monitor outcomes of "serial biological concentration" and Mt Scobie trials and develop an appropriate implementation package if viable options are identified.
- Monitor the interest of the Wyuna Group in a broader land based disposal scheme for private or public works, and initiate a project if an opportunity is identified.

8.7 Amount of Pumping Required

The volume, and timing, of pumping required for groundwater and/or local salinity control is site specific and depends on hydrogeological conditions, soil types, land use, irrigation management and seasonal conditions. Due to the high variability in physical conditions within the Region, simple operating rules and pumping rates were adopted for private and public pumps.

The adopted pumping rates were initially used for planning purposes and the same pumping rate for private pumps is still used to provide targets and achievements for annual reports. Public pump progress reports are based on the net area within the 0.1 m drawdown contour and subject to local beneficiary rates. The reported area for public pumps may not be appropriate when considering total area of influence and potential Regional benefits. It is proposed that the original Plan assumption of 200 ha/pump on average be retained for planning purposes until a larger sample set (currently 21) is available to review the original assumptions. Some background on the development of the adopted Plan operating rules and pumping rates is provided below.

8.7.1 Private Pumps

During the development of the Plan (1989), studies at the Regional and farm scale estimated the amount of private pumping required to provide a reasonable degree of farm groundwater control, leaching opportunities and off-farm disposal for salt balance. Theoretical pumping rates ranged from approximately 12.5 to 87 mm/yr depending on soil types, irrigation

application, groundwater salinity and incoming channel salinities. A single conservative pumping rate of 100 mm/yr was adopted for Plan purposes. This may still be a reasonable "rule of thumb" for broad strategic planning but should be monitored and reviewed when better information and knowledge is available.

8.7.2 Public Pumps

The theoretical pumping requirement to provide leaching for High B3 and B2 Type management areas was estimated to be approximately 21 mm/yr for low salinity irrigation water. The Plan proposed public pumping in two equal parts in winter and in summer to:

- ensure a reasonable leaching opportunity for all land, irrigated and dry, during the winter with disposal to the Murray; and
- provide a second leaching opportunity in season for irrigated land and also reduce the opportunity for groundwater discharge from dry and annual pasture during summer.

For Plan purposes, an average annual operating schedule of 2 x 60 day periods (1 in winter and 1 in summer) and an extraction rate of 50 mm/ha/yr was adopted for public pumps. It was considered that the higher pumping rate would provide adequate leaching in areas receiving higher salinity water (up to 300 EC) from the channel system.

The 2 x 60 day operating schedule was adopted for the Girgarre Project public pumps in 1990. These pumps had previously operated for longer periods and had achieved full reclamation of trial paddocks after 3 years. An analysis by the ISIA of soil salinity, soil sodicity and pasture production data to 1993, identified no adverse effects on irrigated land due to the operating schedules. However, it was observed that dryland paddocks close to the pumps and paddocks more than 800 m from the pumps showed increasing fluctuations in soil salinity and soil sodicity with reduced pumping.

Winter pumping for public salinity control pumps has not occurred since the winter of 1996 due to unfavourable disposal conditions. It may be worthwhile reviewing responses at Girgarre and other locations due to pumping being restricted to one 60 day period in season from 1996/97 to 1999/2000. The outcome may identify the need to review the target pumping rates and determine if extra or "catch-up" pumping is required.

Recommendations

- Initiate review for the Girgarre public pumps given restricted operation in recent years due to disposal constraints.
- Review the performance of the Tongala private groundwater pumping/reuse project.

8.8 Schedules for Disposal to Channels and Drains

In season groundwater disposal to channels and drains from public salinity control pumps (21 sites as at June 2000) currently commences when it is apparent that there is a steady demand for water. As implementation proceeds and disposal capacity is approached, it would be desirable to develop more objective pump operational guidelines and schedules to maximise disposal.

For some Phase A pumps disposing to channels, G-MW have a network flow and salinity simulation model which is run in conjunction with planned deliveries in order to schedule pump operation. The current process largely relies on operator experience and trial and error to schedule the operation of pumps. Future enhancements to the model may include an objective optimisation process for scheduling of pump operation.

Recommendation

- G-MW to look for opportunities to refine operational guidelines and optimise schedules for disposal as part of on-going system planning and monitoring enhancements.

8.9 Effectiveness of Works

The Plan largely aims to provide salinity control by providing conditions for adequate leaching of land rather than large scale dewatering or groundwater control. Groundwater levels will be uncontrolled for much of the time and areas will remain subject to high groundwater levels. Consequently, monitoring trends in groundwater levels and areas subject to high groundwater levels in isolation may not be an adequate means of tracking the implementation and effectiveness of salinity control works.

Groundwater behaviour in the Shepparton Irrigation Region is complex once levels approach 2 m below surface and is dependent on seasonal conditions, land use, water use, the amount of pumping and local recharge and discharge processes. Some work has been undertaken analysing groundwater behaviour using the General Additive Modelling technique (GAMS). This technique has been used successfully in analysing seasonal responses and underlying trends in stream flow data and dryland groundwater level data where levels are deep ie > 2 m below surface. There is some uncertainty on the current effectiveness of the technique in the Region due to data limitations for the variables.

A series of "Sub-Regional Groundwater Data" mapsheets are currently used to track new and existing private pumps and their agreed volumes (if known), public pumps and their rated areas, and the outcomes of works feasibility investigations ie the sub-surface drainage management area type. Ideally, simple and robust spatial and time series analytical techniques could be developed and used in conjunction with the mapsheets and other spatial data. The likely appropriate techniques should be identified early in the next 5 years to ensure appropriate monitoring is in place.

Recommendations

- Identify requirements and appropriate analytical techniques.
- Undertake analyses of groundwater behaviour and driving variables for selected sub-sets of bores to develop simple and robust evaluation techniques.
- Trial analyses of late winter to late summer groundwater level contours to identify the effects of private pumping.
- The Regional observation bore network be reviewed and rationalised, both spatially and temporally, once appropriate analytical techniques to monitor program effectiveness have been developed.
- The current 1:25000 "Sub-Regional Groundwater Data" mapsheets be converted to a GIS format.

8.10 Farm Management of Pumped Groundwater

The Groundwater Management Plan has a range of groundwater allocation and management guidelines aimed at integrating the principles of the Statewide Groundwater Management Strategy with the Plan's guidelines for salinity control. Specific farm management guidelines for shallow pumped groundwater are:

- The specified salinity limit; and
- The groundwater reuse intensity.

The average applied irrigation salinity limit is currently 800 EC for Capital Grant bores and 1700 EC for bores totally privately funded. The groundwater reuse intensity for Capital Grant bores and other bores installed after 1 July 1999 is 3 ML/ha/yr on the area irrigated by the bore. The reuse intensity limit is currently not applied to non Grant bores installed prior to 1 July 1999.

Extension staff and extension materials have promoted responsible farm pumping and reuse of groundwater since implementation of the Plan commenced. However, there is some anecdotal evidence that much of the current groundwater use (deep and shallow) may not conform with the appropriate guidelines.

The GMP offers an incentive to operate within the guidelines by meeting the fixed annual charge for the bores that become Salinity Bores (ie operate within the guidelines). The remaining bores may still deliver some salinity benefits without meeting the Salinity Bore definition and GMP licence conditions should limit the inappropriate use of these pumps.

Recommendations

- Address via the Groundwater Management Plan through review of all licence conditions in accordance with salinity guidelines.
- Map reviewed licence allocations to assist in effectiveness/progress monitoring.
- Retain current level of extension.

8.11 Prioritisation of Works

The current process for prioritising works ensures that private works are implemented in areas subject to high groundwater levels and that public works are implemented in areas where salinity problems are evident. The current process for public works largely focuses on small groups of properties at the local scale on the basis of the order in which applications are received.

As implementation of public works proceeds, there may arise a need to prioritise works at a sub-catchment scale to maximise the overall area served within the disposal constraints of the channel and drain network within the catchment.

In 1999/2000, a project commenced with the Wyuna Landcare Group to develop a sub-regional scale, sub-surface drainage plan, to complement and address the salinity component of their Local Area Plan. The project aims to present spatial information that facilitates targeting, prioritisation and implementation of integrated private and public works including disposal options and constraints at a catchment scale.

Recommendations

- Continue current development of a sub-regional sub-surface drainage plan with the Wyuna Landcare Group.
- Develop sub-surface drainage plans for other Landcare Groups.
- Evaluate the likely achievable level of works within the channel and drain network disposal capacities.

8.12 Plan Resource Requirements

Staff changes, shortages and potential de-skilling within the Agencies have, at times, slowed non-works related and, at the time, lower priority activities including longer term planning and review. There is a need to develop and adopt a resourcing strategy to ensure that these activities are advanced.

Recommendation

- Develop a strategy to address potential staff shortages and de-skilling within the implementation Agencies.

8.13 Reliability of Plan Projections

Some current elements of the Sub-Surface Drainage Program are based on work undertaken in the mid 1980's in the development of the Plan (1989) using information and knowledge available at that time. It should be noted that substantial areas within the Region at that time (approximately 270,000 ha) had insufficient drilling or groundwater level data available to nominate management area types and potential drainage requirements.

8.13.1 Year 2020 Watertable Areas

The original Plan estimates (**Table 8-2 Original Plan (1989) Watertable Projections**) for the area that may be subject to groundwater levels within 2 m of surface by the year 2020 were based on extrapolation of observation bore data from the period 1980 to 1986. A simple visual assessment of trends over the period was used to derive the projections. This was supported by statistical analyses using linear regression for a sample set of 36 bores, which concluded the simple assessment was justified.

■ **Table 8-2 Original Plan (1989) Watertable Projections**

Study Area	Area (ha) Within 2 m Contour	
	Year 2000	Year 2020
Murray Valley	45,300	61,000
Shepparton	9,000	20,700
Rochester & Campaspe	54,600	70,000
Rodney & Tongala	109,000	122,100
Total	218,200	273,800

Statistics from the annual August watertable study showing the areas within the 2 m groundwater level contour are summarised below.

■ **Table 8-3 August 2 m Watertable Areas**

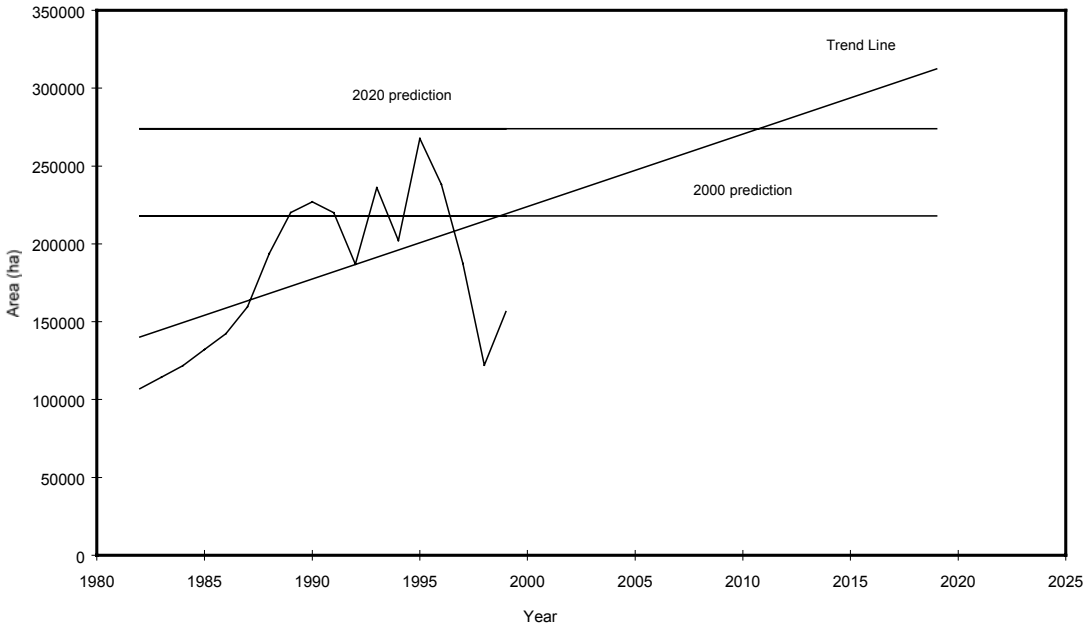
Year	Actual Area (ha) Within 2 m Contour				
	Murray Valley	Shepparton	Rochester & Campaspe	Rodney & Tongala	Region
1982	10100	500	38300	58100	107000
1983	11050	1050	37050	65250	114400
1984	12000	1600	35800	72400	121800
1985	17500	3950	36200	74450	132100
1986	23000	6300	36600	76500	142400
1987	22670	2260	45880	88890	159700
1988	31280	5170	58530	98780	193760
1989	38000	10800	54300	117000	220100
1990	50000	7200	55200	114600	227000
1991	28530	8340	56170	126930	219970
1992	19580	4780	46870	115720	186950
1993	36000	8680	56180	135330	236190
1994	22730	4980	50380	124010	202100
1995	39361	12363	64258	151724	267706
1996	31025	9321	54765	142984	238095
1997	18257	1807	45662	121729	187455
1998	7317	1261	34081	79452	122111
1999	15785	1619	33946	105218	156568

From **Table 8-2** and **Table 8-3** it can be seen that Murray Valley exceeded the year 2000 prediction of 45,000 ha in August 1990. Since 1990, the 2 m areas in Murray Valley have remained below 40,000 and have fluctuated in response to a combination of seasonal conditions and groundwater pumping.

Areas subject to high groundwater levels in the other sub-regions have consistently approached or exceeded the original year 2000 predictions in the last 10 years. In addition, the Rodney and Tongala sub-region statistics have consistently exceeded the original year 2020 prediction of 122,100 ha between 1991 and 1997.

The areas within 2 m for the Region as a whole have been plotted in **Figure 8-1 Regional August 2 m Watertable Areas** and a trend line (linear regression) has been fitted to all of the statistics including those associated with the dry conditions experienced since 1997. The plot shows that the year 2000 forecast for the region has been exceeded on a number of occasions since 1989 and an overall rising trend is apparent for the data set.

■ **Figure 8-1 Regional August 2 m Watertable Areas**



A rigorous review of groundwater level projections is not considered necessary in the short to medium term as the original forecasts would still seem to be valid. The current program prioritisation process also ensures that works are implemented in high groundwater level areas. In addition, the prevailing dry conditions since 1997 would make groundwater trend analyses difficult unless seasonal influences could be identified and accounted for with confidence.

8.13.2 Management Areas

The 2020 watertable projections were used in conjunction with coarse scale hydrogeological interpretation to estimate potential sub-surface drainage management options and disposal salt loads at the Regional scale. The contour style interpretation and mapping was coarse and generalised in scale with the aim of providing statistics for strategic planning purposes rather than a mechanism for implementing works at the local scale.

Substantial additional drilling information (predominantly via FEDS) is available since the original mapping was undertaken in 1987. As mentioned in **Section 7.4 Field Investigation Outcomes**, the results of investigations

are classified according to Management Area Type. This is considered to be more reliable than the coarse scale Regional interpretation as the information and interpretation is at a much finer scale.

The results of approximately 562 FEDS investigations undertaken to the end of 1998/99 are summarised in **Table 8-4 Management Area Type & FEDS Outcomes** for comparison with the original 1989 estimate of Management Area Types. The area associated with individual farm investigations is not readily available. However, a brief comparison of the number of investigations within each Area Type may provide an indication on the reliability of the original estimates.

■ **Table 8-4 Management Area Type & FEDS Outcomes**

Management Area Type	Management Areas 1989		FEDS Outcomes	
	Area (ha)	% of Total Area	Number	% of Total No
Private <3500 EC	34000	17	139	25
Private > 3500 EC	6000	3	5	1
Potential Public	85000	43	264	51
C Type	71000	36	134	24
Total	196000	100	562	100

The information in **Table 8-4** indicates that the number of potential pumpsites located to 1998/99 is currently more than originally estimated for strategic planning purposes. The data relates only to FEDS outcomes and does not include approximately 59 successful sites and an unknown number of unsuccessful sites via private exploratory drilling. The results (ie Management Area Type) for the unsuccessful private drilling sites are not known. Consequently, all private drilling has been excluded from the above table in order to avoid any bias.

The FEDS outcomes to date are not significantly different to the original numbers derived for strategic planning purposes. The derivation of the original Management Area Types was a major exercise and a similar approach to revise the estimates is not considered worthwhile at this stage.

In 1997, a preliminary GIS based system was developed to map shallow drilling information as coded point data identifying the presence of any aquifers and the groundwater salinity range. This had the advantage of being simple to produce, did not rely on interpretation, and captured all the information and variability at the local scale.

In 2000, a project commenced on a sub-catchment scale to determine if current hydrogeological interpretation, mapping and modelling software could provide more effective means for targeting, prioritising and implementing sub-surface works than the simple coded point data. The outcomes from this project should be available in 2000/2001.

8.13.3 Salt Disposal Impacts

In developing the Plan (1989), potential River Murray salinity impacts were estimated using bulk salt load schedules against the MDBC Benchmark period of July 1975 to June 1985. Torrumbarry monthly flows were used as

the primary constraint in developing the bulk schedules and impacts were estimated in terms of the EC effect at Morgan.

Guidelines for winter salt disposal to the River Murray based on satisfying real time flow condition criteria in the system were developed and adopted in June 1998. There is a need to review current and potential Plan salt disposal impacts in terms of all the Murray River salinity costs including mid-river impacts. The outcomes of this review is likely to change reporting and accounting for utilisation of SDEs.

Recommendations

- Initiate review of potential River Murray salt disposal impacts in light of current real time operational guidelines for salt disposal (Note: initiated December 2000).
- Retain current groundwater level projections and area types requiring drainage.
- The SDA for constructed and commissioned individual public pumps be based on the actual point of discharge in the channel or drain network rather than on the Regional reuse assumptions used for planning purposes.
- G-MW review their sub-surface drainage information storage, retrieval and reporting systems.

8.14 Capital Grants

An outcome of the 1993/94 Program review was a progressive reduction (over three years) in the maximum level of capital grant from 80% to 65%. The total maximum amount of $30 000 per pump, per individual was retained.

Under the current formula, $200/ML is applied to the minimum summer reuse volume derived using a number of set criteria. An analysis of costs for capital grant bores installed since 1 January 1998 indicated the average Plan contribution to the capital cost was approximately 43%.

Interest and uptake of capital incentives does not seem to have been influenced by reducing the maximum level of grant to 65%. This may be partly due to the dry conditions experienced since 1997. The $200/ML and $30000 cap have not changed from the original values derived by the Plan. However, review of the values and the current formula for capital grants would not seem to be warranted at this stage. These should be re-considered at the next 5-year review of the program.

Recommendation

- Retain current guidelines for Capital Grants and level of assistance.

8.15 Tile Drains and Low Capacity Pumps

The Plan has provision for tile drainage or low capacity pumps in areas where aquifers are limited or non-existent. However, tile drainage or low capacity

pumping is currently restricted to horticultural areas pending the development of a cost-effective strategy for pasture areas. The latter has had a low priority to date.

When the Plan was developed, a large area (71,000ha) was mapped as having high groundwater levels by 2020 and limited pumping potential. In addition, FEDS investigations to date have identified a number of properties with limited pumping potential. An evaluation of the results of 562 FEDS investigations to 1998/99 (refer **Table 8-4 Management Area Type & FEDS Outcomes**) indicate that the C Type areas to date may be less than originally estimated. However, the results are not considered different enough to warrant a more detailed review at this stage.

The Plan funded a tile drainage trial at Katandra which was established in late 1992. Results to date confirmed that significant salinity problems are occurring in an area where groundwater pumping is not technically feasible and that tile drainage appears to be effective. However, final evaluation is dependent on the completion of financial surveys and an economic evaluation.

Tile drains have traditionally been installed for groundwater control beneath high value crops sensitive to waterlogging and, to a lesser extent, salinity. Consideration could be given to trials (on existing tiles under pasture) aimed at achieving salinity control rather than full groundwater control. This may reduce the cost of works and the volume of drainage that needs to be managed.

In the early 1990's, a low volume pumpsite (< 0.5 ML/d) and small turkey nest storage was installed at Harston to demonstrate that small systems could produce viable quantities of groundwater. The system targeted a largely unconfined shallow aquifer with salinities less than 1000 EC to mitigate localised waterlogging problems. However, the site is underlain by a deeper, more extensive aquifer with public pumping potential and is not considered consistent with the C Type definition.

In February 1996, work commenced with the Girgarre-Stanhope Landcare Group to identify a low volume pumpsite suitable for the establishment of a second C Type trial in addition to Katandra. Key selection criteria at that time were:

- A well managed, intensively developed property with reuse potential;
- Existing salinity problems;
- Landholder interest in establishing a trial; and
- No prospects of moderate to high capacity pumping.

In consultation with the Group, the two sites tentatively identified in the 1995/1996 Community Groups NLP bid to demonstrate a range of low capacity pumping systems were considered not suitable.

The Group subsequently identified two other sites. Both were previously unsuccessful FEDS projects classified as having limited pumping prospects. One property seemed to satisfy all the criteria and first pass drilling was undertaken aimed at delineating a moderately saline (approximately 6000 EC), thin sand lens within 10 m of surface. However, one of the drill sites located 6 m of sand

between about 8.4 and 14.4 m below surface with a groundwater salinity of about 6400 EC indicating that a potential public pumpsite may exist. Consequently, implementation/extension staff were notified and low volume pumping aspects were abandoned.

A review of existing information in the vicinity of the second property identified by the Group, showed that 2 high yielding private sites had been located in the vicinity since the unsuccessful FEDS in 1993. In addition, the FEDS investigation, although unsuccessful in terms of the agreement, located a moderate yielding site (0.5 – 0.8 ML/d) that was capable of producing viable quantities of groundwater (about 2200 EC), particularly if used in conjunction with an existing recycle/storage dam on the property. At that time, the landholder was encouraged to develop the site privately as it was outside the grant criteria of the time. Efforts to establish a low volume pumping trial were subsequently abandoned. There is currently some interest in low capacity pumping within the Wyuna Landcare Group that may provide the opportunity for a trial.

A "serial biological concentration" trial is in progress at Undera that may have potential for C Type areas and also the reuse of moderate to high salinity groundwater. The concept involves groundwater pumping and irrigation of salt tolerant crops which are tile drained. The tile drain effluent is then disposed to a series of evaporation basins. Aquaculture potential within the basins is also being evaluated as a means of offsetting the high establishment costs.

A "bio-polymer" deep drainage trial is currently being considered by the Plan as it may offer a new technique for draining predominantly low permeability materials such as those in C Type areas. The technique involves excavating a deep trench (up to 25 m) and using a bio-polymer slurry to stabilise the walls while the drainage system is installed. Drainage pipe is installed along the base of the trench, which is then backfilled with permeable material. Vertical pumping wells are installed in the lateral drain and submersible pumps are used to dewater the drain.

Recommendations

- Finalise Katandra tile drainage trial economics and develop an appropriate implementation package if the works are viable.
- Evaluate options to reduce the cost of tile drainage systems and the volume of drainage that needs to be managed.
- Monitor outcomes of "serial biological concentration", and "bio-polymer" drainage trials and develop implementation strategies if the schemes are viable.
- Identify potential for a low capacity pumpsite within the Wyuna Landcare Group.
- The current success criteria for FEDS comprising a minimum capacity of 1 ML/d and a groundwater salinity not to exceed 3500 EC be reviewed. The current definitions do not recognise the overlap with low capacity and saline reuse sites where viable quantities of groundwater could be used productively.

8.16 Options for Generation of SDEs

Works and disposal practices established prior to 1 January 1988 do not require a salt disposal allocation. There may be opportunities to generate some SDE by establishing alternative disposal methods when viable options become available or decommissioning works no longer required. A review of the operation of Phase A pumps may identify opportunities for additional SDEs.

Managed changes to the water regime since 1 January 1988, such as drain management strategies and land disposal for treated urban waste water currently discharging to streams, could also potentially earn some SDE. In addition, salt interception schemes within the Region may become viable as SDE costs increase.

The River Murray salinity implications of the new irrigation development (eg Prime Development Zones) and transfer of water warrant further consideration. The transfer of large volumes of water from saline areas to more efficient irrigation developments may result in a net reduction of drainage requirements. In addition, the SDE implications of the potential to transfer more water in total back from Tragowel to Rochester and Central Goulburn warrants consideration.

Recommendation

- No specific actions recommended in the short term. However, evaluate any significant opportunities if identified.

8.17 Safe Groundwater Reuse Intensity

Potential changes in pumped groundwater salinities are site specific and dependent on the salinity in the pumped aquifer, the salinity of the overburden, salinity and degree of connection with adjacent aquifers (horizontally and vertically), the amount of reuse and disposal, and the level of pumping. The 1993/1994 review of the Program imposed an additional allocation restriction of 3 ML/ha/yr on the area irrigated for private grant pumps in an effort to reduce the potential risk of rapid increases in pumped groundwater salinities.

A review of available private pump salinity data was undertaken in 1996 to identify any trends at the Regional scale. The results were varied with some increasing, some decreasing and some showing no change in pumped groundwater salinities. However, the data set was limited and the results inconclusive.

It may be worthwhile reviewing the data for a selected number of sites for which a reasonable record may be available eg Capital Grant bores and the Tongala private pumping project. A project commenced in 1999/2000 with the aim of developing a means of predicting pumped groundwater salinity changes (at the pump scale) based on feasibility level drilling results. The outcomes of this project (expected in 2000/2001) may be useful in reviewing the historical salinity data for selected private pumps.

In 1995, a review of salinity data was undertaken for 19 selected Phase A pumps that had been part of a biannual groundwater chemistry sampling program since the mid 1970's. Three sites indicated a falling trend, 4 indicated a rising trend and 12 indicated no trend in pumped groundwater salinities.

It is difficult to confidently specify safe private groundwater reuse intensity at the Regional scale due to the high degree of variability across the Region. In addition, there is no reliable site specific data available to restrict allocations based on pumping intensities in the initial license review being undertaken by the Groundwater Management Plan. Allocation changes would be made in subsequent 5 year license reviews based on more reliable data on volumes pumped and pumped groundwater salinities.

Recommendation

- Initiate review of Capital Grant bore data.

8.18 Role of the Deep Lead

The Riverine Plains of the Shepparton Irrigation Region comprise unconsolidated alluvial deposits having a comparatively flat surface and gentle north westerly slope of around 1 in 2500. The depth of the unconsolidated deposits above bedrock varies, typically ranging from 20 to 150 m thick with a maximum recorded thickness of about 200 m.

The sedimentary sequence is complex and changes with depth, with the deeper deposits generally being coarser grained. The deepest formation, called the Renmark Group, mostly occurs to the north and west of the area. The overlying Calivil Formation is more extensive in the Shepparton Irrigation Region and generally follows the present day courses of the Murray, Goulburn and Campaspe rivers. The hydraulically undifferentiated Calivil Formation and Renmark Group aquifers are commonly referred to as the "Deep Lead".

Alluvial sediments of the Shepparton Formation overly the Calivil/Renmark aquifer and extend from surface to typically 80 m deep. Although the Shepparton Formation is often thought of as one hydrogeological unit, the mixture of predominantly clays and silts interspersed with lesser quantities of sand and gravel form a complex system of aquifers and aquitards. The unit is often divided hydrogeologically into the Upper (< 25 m) and Lower Shepparton Formations.

Local scale recharge and discharge processes in the Upper Shepparton Formation are the dominant contributors to salinity problems in the Region. Consequently, works targeting the aquifers and aquitards in the Upper Shepparton Formation have been demonstrated to be effective in salinity mitigation and reclamation.

The hydraulic connection between the Deep Lead and the shallow systems is generally poor beneath the Shepparton Irrigation Region. Thirty-day pumptests were undertaken on two existing private Deep Lead bores during August/September 1996, one near Rochester and the other near Katunga in the Murray Valley. In both of the tests, groundwater levels in the Upper Shepparton Formation were not seen to respond notably to the Deep Lead pumping.

Analyses indicated that, at best, downward fluxes were 9 and 1.8 mm/yr for the Rochester and Katunga sites respectively.

The results from the tests indicated that deep aquifer pumping, although maintaining vertical gradients and the potential for some deep drainage, was not an effective management option for groundwater and salinity control in the Shepparton Irrigation Region.

The low leakage rates indicate the priority for salinity mitigation works should remain with the shallow systems of the Upper Shepparton Formation. However, the leakage volumes may be significant from a Deep Lead resource perspective and may also provide some minor benefits to the shallow systems.

Campaspe and Katunga Deep Lead pressure rises have stabilised or been reversed in recent years and management plans are being prepared. The Shepparton Irrigation Region Land and Water Management Plan needs to have effective communication with these plans as well as the SIR Groundwater Management Plan.

Recommendation

- No specific action recommended. However, monitor outcomes from Deep Lead management and monitoring activities in Groundwater Management Areas.

8.19 Summary of Recommendations

A summary of the recommendations is provided below. A number of the activities are closely related and need to be considered together. The list of issues has been reproduced for ease of reference.

- **Issues and Priorities**

Item	Issue	Priority
1	Securing Salt Disposal Entitlements	High
2	Works for new & existing horticultural (or other high value) development	High
3	Public and private disposal basin management and cost sharing guidelines	High
4	Works for protection of environmental features	High
5	Impacts of increasing irrigation supply salinities	High
6	Alternative disposal methods for moderate to high salinity groundwater	High
7	The optimum amount of pumping for groundwater and/or salinity control	High
8	Operational guidelines and schedules for disposal to channels and drains	High
9	Criteria for effectiveness of works	High
10	Farm management of pumped groundwater	High
11	Prioritisation of works at the drainage catchment scale	High
12	Plan Resource Requirements	High
13	Reliability of Plan projections - Salt disposal impacts - Watertable projections - Management Area Types	 High Low Low
14	Capital Grants and level of assistance	Medium
15	Tile drains and low capacity groundwater pumps in pasture	Medium
16	Options for generation of salt credits	Medium
17	Safe groundwater reuse intensity	Medium
18	Role of the Deep Lead	Low

- **Securing SDEs**

- Continue with (and enhance when knowledge becomes available) current drainage management strategies (surface and sub-surface) and pursue opportunities for gaining additional SDEs when identified.

- **New and existing horticultural (or other high value) development**

- Develop guidelines for new high value enterprises (Note: work initiated September 2000 in response to a developer's query on drainage options and guidelines).
- Capture and map areas planted to horticulture on ISIA's GIS system.
- Initiate review of distribution of horticultural plantings and Phase A rate base
- Evaluate horticultural drainage requirements under improved farm irrigation and drainage management practices.
- Review Phase A program performance after a return to average seasonal conditions.
- A review be undertaken on urban encroachment and planned urban development in the Shepparton East area to identify and evaluate any implications for the private horticultural program.

- **Public and private disposal basin management and cost sharing guidelines**
  - Initiate development of implementation guidelines. Current broad technical guidelines are adequate.
  - Promote and initiate a scheme with a basin if an opportunity is identified with Groups or individuals.

- **Protection of environmental features**
  - Enhance the Program's stated principles to include the installation of sub-surface drainage works to protect environmental features where necessary, feasible and consistent with Plan criteria.
  - Develop criteria and guidelines for the protection of environmental features such as wetlands, streams and remnant vegetation (Note: work on guidelines for remnant vegetation initiated in September 2000).
  - Undertake risk assessments for high value environmental features.
  - Salt disposal guidelines be developed and adopted for wetlands within the Region.

- **Impacts of increasing irrigation supply salinities**
  - Initiate review to quantify potential sodicity problems and remedial measures, impact on conjunctive use of groundwater and salt disposal requirements

- **Alternative disposal methods for moderate to high salinity groundwater**
  - Monitor outcomes of "serial biological concentration" and Mt Scobie trials and develop an appropriate implementation package if viable options are identified.
  - Monitor the interest of the Wyuna Group in a broader land based disposal scheme for private or public works, and initiate a project if an opportunity is identified.

- **The amount of pumping required for groundwater and/or salinity control**
  - Initiate review for the Girgarre public pumps given restricted operation in recent years due to disposal constraints.
  - Review the performance of the Tongala private groundwater pumping/reuse project.

- **Operational guidelines and schedules for disposal to channels and drains**
  - G-MW to look for opportunities to refine operational guidelines and optimise schedules for disposal as part of on-going system planning and monitoring enhancements.

- **Effectiveness of works**
  - Identify requirements and appropriate analytical techniques.
  - Undertake analyses of groundwater behaviour and driving variables for selected sub-sets of bores to develop simple and robust evaluation techniques.
  - Trial analyses of late winter to late summer groundwater level contours to identify the effects of private pumping.
  - The Regional observation bore network be reviewed and rationalised, both spatially and temporally, once appropriate analytical techniques to monitor program effectiveness have been developed.
  - The current 1:25000 "Sub-Regional Groundwater Data" mapsheets be converted to a GIS format.

- **Farm management of pumped groundwater**
  - Address via the Groundwater Management Plan through review of all licence conditions in accordance with salinity guidelines.
  - Map reviewed licence allocations to assist in effectiveness/progress monitoring.
  - Retain current level of extension.

- **Prioritisation of works at the drainage catchment scale**
  - Continue current development of a sub-regional sub-surface drainage plan with the Wyuna Landcare Group.
  - Develop surface drainage plans with other Landcare Groups.
  - Evaluate the likely achievable level of works within the channel and drain network disposal capacities.

- **Plan Resource Requirements**
  - Develop a strategy to address potential staff shortages and de-skilling within the implementation Agencies.

- **Reliability of Plan projections**
  - Initiate review of potential River Murray salt disposal impacts in light of current real time operational guidelines for salt disposal (Note: initiated December 2000).
  - Retain current groundwater level projections and area types requiring drainage.
  - The SDA for constructed and commissioned individual public pumps be based on the actual point of discharge in the channel or drain network rather than on the Regional reuse assumptions used for planning purposes.
  - G-MW review their sub-surface drainage information storage, retrieval and reporting systems.

- **Capital Grants and level of assistance**
  - Retain current guidelines for Capital Grants and level of assistance.

- **Tile drains and low capacity groundwater pumps in pasture**
  - Finalise Katandra tile drainage trial economics and develop an appropriate implementation package if the works are viable.
  - Evaluate options to reduce the cost of tile drainage systems and the volume of drainage that needs to be managed.
  - Monitor outcomes of “serial biological concentration”, and “bio-polymer” drainage trials and develop implementation strategies if the schemes are viable.
  - Identify potential for a low capacity pumpsite within the Wyuna Landcare Group.
  - The current success criteria for FEDS comprising a minimum capacity of 1 ML/d and a groundwater salinity not to exceed 3500 EC be reviewed. The current definitions do not recognise the overlap with low capacity and saline reuse sites where viable quantities of groundwater could be used productively.

- **Options for generation of salt credits**
  - No specific actions recommended in the short term. However, evaluate any significant opportunities if identified.

- **Safe groundwater reuse intensity**
  - Initiate review of Capital Grant bore data.

- **Role of the Deep Lead**
  - No specific action recommended. However, monitor outcomes from Deep Lead management and monitoring activities in Groundwater Management Areas.

The issues identified for evaluation in the next 5 years are many, potentially complex and are inter-related in some cases. The program is subject to ongoing refinement and review in light of changing knowledge, technology and priorities. It is recommended that Implementation Committee adopt a workplan for the next 5 years. This would assist in providing a focussed, efficient and manageable process to address areas requiring further development and set strategic directions.

A broad draft workplan is provided in **Chapter 10 SSDWG Draft Workplan for Next 5 Years** to initiate the process. No attempt has been made to allocate resources to activities at this stage as this can not be confidently done until requirements and methodologies have been better identified. The workplan would be an evolving one that is amended in line with priorities and the availability of resources.

9. Physical Targets for Next 5 Years

A summary of sub-surface drainage works targets is given below.

Activity	Five Year Target to 2005	2005 Cumulative Target	2023 Cumulative Target
1 Consistent pumping and reuse by existing pumps	Complete metering/licence review for 395 pumps	395 pumps reusing 45000 ML/year to serve 45000 ha	395 pumps reusing 45000 ML/year to protect 45000 ha
2 Installation of new private pumps	95 pumps reusing 10820 ML/year to serve 10820 ha	289 pumps reusing 31670 ML/year to serve 31670 ha	365 pumps reusing 40000 ML/year to protect 40000 ha
3 Installation of tile drains/low capacity pumps to protect non-horticultural areas	Develop and adopt a cost effective strategy	Develop and adopt a cost effective strategy	14000 ha to protect the productive capacity of 43000 ha
4 Installation of tile drains to protect existing horticulture areas (mainly at Shepparton East)	69.1 ha	85 ha	300 ha
5 Installation of groundwater pumps to protect existing horticulture areas (mainly at Shepparton East)	12 pumps to serve 300 ha	31 pumps to serve 775 ha	40 pumps to protect 1000 ha
6 Provide salinity and waterlogging control for new high value crops in the region	Develop and adopt a cost effective strategy	Develop and adopt a cost effective strategy	Yet to be determined
7 Continue operation of Phase A pumps where technically appropriate	Ongoing operation – review performance of scheme	Ongoing	Ongoing
8 Install new public pumps discharging to regional channels or drains	40 pumps to serve 8000 ha	61 pumps to serve 12200 ha	375 pumps to protect 75000 ha
9 Install new public pumps discharging to evaporation basins	Develop criteria and guidelines and install 1 basin	1 pump and basin to serve 200 ha	50 to serve 10000 ha
10 Regulated discharge of pumped groundwater to regional channels, drains and streams within agreed guidelines	As needed	As needed	As needed
11 Regulated discharge of pumped groundwater to River Murray to avoid or minimise salt accumulation within the Region's soils and aquifers	2.87 EC	5.09 EC	15.7 EC (including an allowance of 3.7 EC for tiles/low capacity pumps in non-horticultural areas)
12 Protection of environmental features (such as remnant vegetation, wetlands and steams)	Develop criteria and guidelines and install 1 pump	1 pump primarily serving an environmental Feature	Yet to be determined

10. SSDWG Draft Workplan for Next 5 Years

Activity	Year				
	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005
Securing Salt Disposal Entitlements	ongoing				
New/Existing Horticulture/High Value					
-guidelines for new development	initiated				
-map horticultural areas on GIS					
-review Phase A rate base					
-review Phase A performance					
-review urban encroachment in Shepparton E					
Disposal Basins					
-initiate development of guidelines					
-promote & initiate a scheme	ongoing				
Works for Environmental Features					
-works guidelines for remnant vegetation	initiated				
-works guidelines for streams					
-works guidelines for wetlands					
-risk assessments for environmental features					
-salt disposal guidelines for wetlands					
Impacts of Increase Channel EC					
Alternative Disposal Methods	ongoing				
Amount of Pumping Required					
-review Girgarre pumps					
-review Tongala pumping project					
-review Capital Grant bores					
Enhance Salt Disposal Guidelines	ongoing				
Effectiveness of Works					
-identify requirements					
-analyses of selected obs bores					
-review observation bore network					
-analysis of winter to summer levels					
-map GMP licence review allocations	ongoing				
-convert Sub-Regional Maps to GIS					
Farm Management of Pumped Groundwater	ongoing				
Wyuna LAP Sub-Surface Plan	initiated				
- sub-surface plans for other areas					
- evaluate level of works within disposal capacity					
Plan Resource Requirements	ongoing				
Reliability of Plan Projections					
-review Murray salt disposal impacts	initiated				
-review sub-surface drainage info systems					
Review Level of Capital Grants					
Tile Drains/Low Capacity Pumps					
-finalise Katandra economics					
-develop implementation package					
-identify opportunity in Wyuna LAP					
-review tile drain design & operation criteria					
-review FEDS criteria					
-drainage under improved farm practices					
-monitor outcomes of SBC & biopolymer drain	ongoing				
Options for Generation of EC Credits	ongoing				

11. Research Activities

A summary of main research activities undertaken from 1995 to 2000 is provide below. A listing of technical reports and papers is given in **Appendix C**. The summary below, and a large proportion of the listing in **Appendix C,** was compiled and provided by Matthew Bethune of the Institute of Sustainable Agriculture in Tatura.

11.1 Managing Salinity in Areas of Low Groundwater Salinity

11.1.1 Tongala Groundwater Pumping and Reuse Project

The Tongala project was established in 1980 as part of a pilot scheme for salinity control that was based on sub-surface drainage through private groundwater pumping and the conjunctive use of groundwater with channel water. The pilot scheme involved a group of farmers with adjoining properties near Tongala, covering an area of 610 hectares. The overall aim of the project was to monitor and evaluate on-farm groundwater management as applied within the Tongala project area, with respect to the four key issues listed below:

- the volume of groundwater required to be pumped in order to achieve watertable and salinity control;
- the volume of groundwater that could be safely integrated into farm irrigation practices;
- the potential long term impacts of conjunctive use on soils and on productivity; and
- the rate of inevitable salinisation of the groundwater resource

Over 20 years of project operation considerable knowledge and experience has been gained from the close observation of the Conjunctive Water Use management system (CWU) at a sub-regional field scale.

Monitoring of soil salinity on one property highlights the continuing control of soil salinity resulting from the installation of a groundwater pumping in 1982. Soil salinity was at a minimum in 1987. Small increases in soil salinity have occurred since this time but soil salinity levels are still less than pre-groundwater pumping levels. A soil survey conducted over the whole project area in 1996 found that 25% of the area has soil salinity high enough to influence pasture growth. However, the reduction in growth in these areas would generally be less than 10%.

A slow but steady increase in salinity in the majority of the groundwater pumps has been observed. Some of the pumps have now reached levels that make CWU a marginal proposition. No difference in rates of degradation was observed in areas with different soil types, although groundwater salinity is much lower in areas of lighter soils.

The irrigation water-use data for farms with and without groundwater pumps highlights that groundwater pumping continues to be used primarily to supplement, rather than replace, available irrigation supplies. In any year,

farmers with groundwater pumps at Tongala have demonstrated their ability to utilise an extra 2 - 4 ML/ha over non-pumpers.

Present guidelines recommend that groundwater should be diluted to 800 EC prior to irrigation. However, farmers do not appear to adhere to application threshold guidelines. Monitoring of either soil salinities or pasture productivity to check if this has impacted on productivity has not taken place in the project area.

Groundwater pumping had little impact on watertable depth. Average watertable levels in 1982/83 (with 1800 ML pumped) were similar to 1998-2000 (with only about 1400 ML pumped during these two consecutive seasons). From the point of view of soil salinisation, hydraulic gradients rather than watertable depth, provides a better measurement of the impact of pumping on salinisation.

11.1.2 Impact of Pumping on Groundwater Quality

A conceptual modelling framework was developed to assess the impact of management and hydrogeology on groundwater quality. This highlighted that under current groundwater pumping and reuse practices, groundwater salinity is increasing at non-sustainable rates in many areas. A framework to categorise aquifers was developed based on their perceived risk of salinisation. The categorisation was based on likely interactions with deeper aquifers and the quality of deeper aquifers. Distributed parameter and conceptual models of water and salt movement were used to evaluate management options for reducing groundwater degradation. One key finding was that reduced pumping rates would reduce salt intrusion from deeper more saline aquifers into the pumped aquifer, and thus the rate of groundwater degradation. Slowing the rate of groundwater degradation will delay the need for alternative methods of disposing saline effluent.

11.1.3 Groundwater Recharge

Soil sampling was undertaken to determine groundwater recharge in an area where groundwater pumping and reuse for irrigation of pasture has been practiced for more than 10 years. Factors affecting recharge (viz. irrigation management, soil type, soil chemistry and groundwater pumping) in these areas were investigated. Recharge rates were on average 38 mm/yr, varying between 2 and 190 mm/yr. Applied water salinity had the greatest impact on recharge. Soil type, irrigation intensity and soil sodicity also impacted on recharge, but to a lesser degree. No relationship between groundwater pumping and recharge was observed.

11.1.4 Prediction of Trends in Rootzone Salinity

Groundwater salinity and rootzone salinity trends were predicted for the aquifer categories identified above. Groundwater salinity increased at rates up to 20 EC per year, depending on salt imports at the site. However, the predicted increases in groundwater salinity had only small impacts on rootzone salinity and therefore productivity.

11.2 Managing Salinity Problems in Areas with Moderate to High Groundwater Salinity

Groundwater pumping with farm reuse is a widespread practice in the southern Murray Darling Basin. This practice is the preferred option in Land and Water Management Plans in these areas for controlling irrigation salinity where irrigated pasture is the main crop. However, farm reuse of groundwater on pasture is limited in areas where groundwater salinity exceeds 5 dS/m. Options contained in Management Plans for controlling salinity in these areas are limited to groundwater pumping with either farm export of salt or groundwater pumping with disposal to evaporation basins.

11.2.1 Conceptual Modelling

Options currently recommended to farmers in the southern Murray Darling Basin for disposal of saline (>5 dS/m) groundwater include salt export or disposal to an evaporation basin. However, there is potential for farm reuse of groundwater at salinities greater than 5 dS/m, although small reductions in production may result from high irrigation water salinity. The cost of this reduced production may be less than the cost of salt export, or construction of an evaporation basin. Therefore, an evaluation of potential options for farm management of saline groundwater was conducted.

A conceptual model of the groundwater and farm management system was developed to assess the impact on pasture yield of different farm salt management options. These response functions were used to investigate economic aspects of farm management of saline groundwater. This farm scale study does not necessarily reflect regional costs and benefits.

On the basis of the assumptions used in this study, total conjunctive use with surface channel supplies is the cheapest disposal option for groundwater up to 10dS/m salinity. Given the restrictions on implementing river disposal, annualised savings are around $25,000 per 100 ha perennial pasture by using conjunctive water use rather than on-farm evaporative disposal for groundwater salinity up to 5 dS/m. Savings decrease at higher groundwater salinity as the productivity of forage production under conjunctive use declines. While total conjunctive use becomes more expensive than total evaporation above 15 dS/m, partial conjunctive use with disposal of excess groundwater to salt tolerant forage is approximately $9000 p.a. less expensive than total on-farm evaporation.

11.2.2 Mt Scobie Pilot Site

The site at Mt Scobie, near Kyabram in northern Victoria, was established in 1998 to assess the impact of farm management of saline groundwater. Prior to establishment, the site had high watertables and showed evident salinity problems. Groundwater salinity at the site is 10 dS/m. A groundwater pump was installed at the site to provide salinity control. The groundwater is too saline for complete reuse on irrigated pasture within the property. Therefore, part of the pumped groundwater is diluted to 0.8 dS/m to irrigate pasture. Pasture yield should not be affected at this irrigation water salinity. The remaining groundwater is reused to irrigate a 4 Ha tree plantation. All

groundwater reuse is contained within the area of influence of the groundwater pump. This should ensure that salinity control is provided to areas receiving saline irrigation waters and that salt export is minimal over time. It is hoped that this management option will serve the dual objectives of minimising salt export off farm and providing salinity control to the irrigated pastures

Two additional trials were conducted at the pilot site. The first trial was a species-provenance salinity resistance trial of Casuarina cunninghamiana, Casuarina glauca and Eucalyptus occidentalis. A separate field trial of eucalypt hybrids produced under the Xylonova Research and Development Program was also run at the site.

The pilot site will be monitored from 1999 to 2004 for farm impacts on rootzone salinity, soil sodicity and groundwater salinity. This data will then be used to provide an assessment of the farm impacts of managing saline groundwater to control salinity. The outcome from this assessment may be used to modify components of the Sub-Surface Drainage Program of the Land and Water Management Plan.

11.2.3 Serial Biological Concentration

Serial Biological Concentration (SBC) uses the ability of plants to concentrate salts and thus reduce the volume of saline drainage effluent for disposal. A farm scale SBC site commenced in 1994 on a dairy farm at Undera, 20 kilometres north-west of Shepparton. The project was run in co-operation with the Undera Landcare Group and the landholder. Some parts of the property are severely affected by salinity and some have been retired from productive use with bare patches, dead trees and barley grass dominant. The site layout consists of a groundwater pump, pumping 8.5 dS/m groundwater to a 3 ha tile drained area, 600 m away from the pump site. The tile-drained site is planted to a range of tree and salt bush, which were established with fresh irrigation water (one season), and subsequently received straight bore water for irrigation. The tile drain effluent is disposed into a series of small evaporation ponds. A range of fresh and saline aquaculture species (oysters, prawns and fish) were tested in the evaporation basins for their growth potential under these conditions. The following points summarise key findings from the SBC site:

- Salt balance was achieved in the tile-drained block after four years of irrigation (8-10 dS/m).
- Watertable levels in the tile area were responsive to climatic conditions, however on average they dropped over the four years of measurement.
- Watertable EC and tile drainage effluent did not change significantly over the reporting period.
- There was no change in the total salt storage in the 0-1.5 m soil profile under the plantation over the four-year observation period. A Leaching Fraction between 25 and 30% has been achieved at the trial site.
- The tiles had a clear impact on the redgum growth performance with the near-tile trees being the highest and the mid-tile trees the lowest. The spring-planted trees outperformed the autumn- planted trees.

- Salt balance through harvesting of plants (salt bush) does not appear to be an option.
- Significant leakage of salt from the basins was measured even though the basins were lined.
- The composition of the salts at the site would allow the production of good quality salts. However, the relatively low evaporation rates (about 1400 mm/yr) in combination with low initial EC of the drainage effluent (18 dS/m) limits the scope for salt production.
- A total of 51 bird species were observed at the site showing the excellent bio-diversity potential of small revegetation areas with mixed tree/bush/grass habitat on irrigation farms.
- Commercial volumes of oil were produced by eucalyptus and melaleuca species. The quality of the melaleuca oil was not good enough to qualify as 'Tea Tree Oil'; the quality of the eucalypt oil was commercially acceptable.
- Under the mariculture investigations, Atlantic salmon, rainbow trout (winter), silver perch and Australian bass (summer) were the most promising of the species tested in the evaporation ponds, all achieving good commercial growth rates in cage trials in the two test ponds.
- The project received a high level of public interest with television (ABC Landline), regional press and a more than 500 other visitors visiting the site during the project period.

11.3 Impact of Groundwater Reuse on Soil Properties.

Irrigation-induced salinity is a serious problem facing irrigated areas in the Murray Darling Basin of Australia. Groundwater pumping with farm reuse for irrigation is a key strategy for controlling salinity in these irrigation areas. However, the reuse of highly saline-sodic groundwater for irrigation leads to accumulation of sodium in the soil profile and can result in sodic soils.

Sodic soils in Australia are defined as having an exchangeable sodium percentage (ESP) greater than 6. Many soils (30% of land area) are naturally sodic in either surface or subsurface horizons – this cannot be considered a soil health issue, but one that requires the land is used within its capability. Induced sodic soils i.e., produced by rising water tables and saline-sodic irrigation (ground water/wastewater), as is in the case of southern Murray-Darling Basin, should be considered as a soil health issue. Since we expect the use of saline-sodic groundwater and municipal wastewaters for irrigation increase with time, a better understanding of the fate of sodium under saline-sodic groundwater and wastewater re-use is necessary, with the expectation that the information gained be used to formulate management guidelines.

11.3.1 Interactions of Saline Water and Soil Sodicity

Replicated field trials were carried out at Tatura (northern Victoria) and Deniliquin (southern NSW) to determine the fate of sodium and behaviour of soils under saline-sodic irrigation in pasture and rice-based production systems respectively. Two on-farm demonstration trials were also conducted with an emphasis on amelioration of pasture soils which were inherently sodic (demonstration trial at Tongala) and sodified under wastewater

irrigation (demonstration trial at Mooroopna). Laboratory experiments at Tatura and RMIT (Melbourne) were run to explore the interactions between irrigation water quality (salinity, sodicity and alkalinity) on soil chemical, hydraulic and dispersive properties.

Results from field experiments at Tatura suggested that the recommended irrigation salinity threshold (EC 0.8 dS/m) in the Shepparton Irrigation Region did not result in significant increase in exchangeable sodium percentage (ESP) in both topsoil (0-15 cm) and subsoil (15-30 cm). ESP of topsoil did not increase to levels that can be classified as 'sodic' (ESP $\geq$ 6). However, ESP increased above 6 where irrigation water salinity exceeded 0.8 dS/m. Winter rainfall and freshwater irrigation, on previously sodified plots, did not lead to a reduction of ESP in the subsoil. ESP was reduced in the topsoil, but not to 'non-sodic' levels. Significant effects of gypsum application in reducing ESP ($p < 0.05$) were restricted to top 20 cm of soil depth only. These results imply that pasture soils under conjunctive water use risk sodification if the recommended irrigation water salinity is not adhered to in the Shepparton Irrigation Region. Furthermore, subsoil reclamation might not be achievable using current gypsum application method (broadcasting).

Results from the Deniliquin study suggested that salinity could be manageable by leaching with channel water. Rice growing provides the leaching needed to control salinity. However, sodicity can not be managed by leaching alone. Any reclamation technique under rice growing conditions should be considered in relation to the delicate balance between increasing permeability that will contribute to recharge and decreasing sodicity that will control turbidity of ponded water.

The on-farm demonstration trial at Mooroopna showed no significant reduction in ESP after gypsum application on a sodified pasture soil under wastewater irrigation. However, gypsum increased Ca:Mg ratio of top and subsoil, increased total porosity of topsoil, and resulted in drier sub-surface layers following a drainage event. These results suggest that wastewater authorities should encourage third party users (farmers who use wastewater for irrigation purposes) to incorporate gypsum applications in their whole farm plan right from the onset. In particular, gypsum should be applied prior to pasture re-establishment.

The on-farm demonstration trial at Tongala showed that none of the three calcium products (mined gypsum, phosphogypsum and an imported product called N-Cal) resulted in significant reductions in inherent sodicity. Two of these (mined and phospho gypsum) are commonly used worldwide to ameliorate sodic soils. Techniques that increase the efficiency of gypsum application in terms of sodium exchange reactions in red-duplex soils of Shepparton Irrigation Region need to be further investigated.

Laboratory experiments showed that soil sodification was more efficient with increasing salinity of irrigation water. Soil hydraulic properties were most affected by soil salinity followed by sodicity and then alkalinity. The dispersive properties of soil aggregates irrigated with wastewater differed

from those irrigated with groundwater. The role of organic loads in wastewater and their effects on sodic soil behaviour will require further exploration.

Increased soil sodicity could have negative impacts on land values. To avoid this situation, effective ameliorative measures should be developed. Topsoils under pasture appeared resilient to changes in microaggregate stability following soil sodification but subsoils were not. Changes in land use, from pasture to cropping, might make topsoils sensitive to high levels of ESP. Whether sodification results in large scale yield losses and economic downturn under pasture needs to be assessed under real world conditions (grazed pastures). Sodicity-related experiments should be conducted on commercial farms in future.

A desktop study by an internationally recognised soil scientist from the USA (Dr Jim Oster, University of California) independently assessed sodicity research in northern Victoria (dairy based systems) and in southern NSW (rice based systems), and gave recommendations for further action and research.

The International Sodicity Conference organised at Tatura (28 February-1 March 2000) under the umbrella of this project provided future directions for sodicity research in all major agricultural industries in Australia. A set of specific directions will be published in a special issue of Australian Journal of Experimental Agriculture in late 2001.

This project increased awareness of (a) sodicity related issues in the southern Murray-Darling Basin, (b) the need for modelling tools to predict long term trends in soil sodicity under different management conditions, (c) the need for modelling tools to predict implication of changing current pasture based production systems under conjunctive water use to high value horticulture based systems, (d) the need for efficient reclamation techniques, and (e) the importance of animal/machinery traffic in sodicity-soil-water interactions.

11.4 Impact of Groundwater Reuse on Hydraulic Properties

A replicated plot experiment was conducted to examine the long-term impact of irrigation with saline-sodic water on soil permeability. High soil sodicity (ESP up to 45 %) resulted from ten years of saline irrigation. Over this period, leaching by winter rainfall did not result in long term impacts on soil hydraulic properties. Measured soil hydraulic properties increased linearly with the salinity of the applied irrigation water. Leaching by irrigating with low salinity water for 13 months decreased soil salinity and sodicity in the topsoil. The resulting reduction in steady state infiltration indicates soil structural decline of the topsoil.

This trial shows that groundwater reuse on pasture will result in high sodium levels in the soil. Sodicity related soil structural problems are unlikely to develop where there is consistent groundwater irrigation of pasture. However, structural decline of these soils is likely following the cessation of groundwater reuse.

Effect of Salinity and Waterlogging on the Productivity of Irrigated Forage Species

Many forage species are sensitive to salinity and/or waterlogging and suffer significant yield reductions when exposed to these adverse conditions. This research program is focussed on evaluating the salt and waterlogging tolerances of a wide range of forage legumes, grasses and shrubs and assessing management strategies that optimise plant production. The information obtained will provide farmers with options to ensure that production is maintained in areas that are saline and/or waterlogged, and in areas where pumped, saline groundwater is used for irrigation.

The salt tolerance of more than 80 cultivars, lines and species of forage legumes, and 25 species and cultivars of grasses has been quantified in both greenhouse and field experiments. This research includes detailed studies on the salt tolerance of commercial cultivars of white clover and lucerne. Material that has been found to have superior salt tolerance, and that offers useful alternatives to existing species and cultivars has been recommended for use in saline areas and in areas where pumped saline groundwater is used for irrigation.

A recent field experiment (1997-2001) conducted at ISIA Tatura, has examined the performance of two native Austrodanthonia species (wallaby grass) to saline irrigation following promising research results in the greenhouse. These two species were compared with perennial ryegrass and tall wheat grass. Cumulative plant dry matter was greater in the Austrodanthonia species compared with perennial ryegrass or tall wheat grass, but in relative terms, there was no difference in the salt tolerance between any of the four species. Leaf tissue concentrations of Na and Cl were significantly lower in the two wallaby grass species than in the other two species. This information may be useful when locating and isolating physiological tolerance mechanisms in plants that perform well in saline soil conditions and linking such research to biotechnology programs.

A field experiment evaluating the suitability of the salt tolerant grass Distichlis spicata var. yensen-4a (NyPa forage) to Australian conditions commenced in October 2000 at a site in Undera previously used for serial biological concentration research and where it is possible to irrigate with extremely saline water from evaporation basins. It is hoped that this species may have a role in highly saline and waterlogged conditions or in the disposal of highly saline groundwater or drainage water. To date, the plots at Undera have established well. One limitation to this species however, is that it does not produce seed and consequently it is difficult to establish in the field. Recent greenhouse research investigated methods of propagation and establishment for this species and has shown that Distichlis spicata can be successfully established vegetatively using shoot cuttings of around 10 cm in length. This information will assist in the adoption of this species in saline areas.

Further agronomic research has concentrated on management strategies that may reduce the impact of saline irrigation water on pasture production and soil chemistry. A long-term field experiment involving studies on the effect of the timing of the application of saline water throughout the irrigation season, on perennial pasture growth pasture composition and soil chemistry, was completed in May 2000. The results confirmed the current guideline recommendations that

salinity levels of irrigation water should not exceed 800 EC units (0.8 dS/m). However, it was concluded that the soils and pastures were relatively insensitive to the pattern of salt application throughout the irrigation season. Therefore, provided farmers stay within the guideline recommendations on the basis of seasonal salt loads and continue to monitor the salinity levels of their irrigation water to avoid soil sodicity and salinity effects, farm irrigation management can be tailored to suit farm programs and individual circumstances.

Nutrition can significantly influence a plant's response to saline conditions. The interaction between salinity and P nutrition is particularly complex and plant responses can vary according to many agronomic, genetic and environmental factors. Recent greenhouse research studying the combined effects of nutrients and salinity on plant growth (predominantly lucerne species) is aimed at obtaining a better understanding on how to dispose of saline-nutrient rich wastewater as well as the identification of fertilizer requirements for agricultural species irrigated with saline groundwater. Research to date suggests that high, or non-limiting concentrations of P do not affect lucerne's response to NaCl and confirm the complex relationship that exists between NaCl and P.

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Appendix A Future Works Program

The works programs to year 2023 for the Regional private and public pasture pumping programs and the private horticultural program are given in tables A-1 to A-3. The targets are at the Plan scale and actual achievements would be dependent on community interest and budget availability. Targets for tile drains and low capacity pumps have been restricted to horticultural areas pending development of a cost effective strategy for pasture areas.

The works program assumptions are briefly described in the following sections. They are largely based on the original Plan assumptions and projections to the year 2020. These assumptions and projections should be reviewed and refined over the next five years in light of more reliable information resulting from the implementation of the Region's Groundwater Management Plan and level of interest in public pumping.

The cost estimates for works implemented to date and the future works program are in 1998/1999 values. Salt disposal costs associated with the works have not been itemised as the MDBC's Drainage Evaluation Spreadsheet Model (DESM) used to assess the economics also calculates salt disposal costs (refer **Appendix B.9 Downstream Impacts**).

A.1 Private Pumps

A.1.1 New Pumps

The original Plan target was to install 365 new private pumps by the year 2020 to serve approximately 40000 ha of land with groundwater levels within 2 m of surface. The Plan has favoured private works and 194 new pumps (as at 30 June 2000) have been installed in areas subject to groundwater levels within 2 m of surface. The forward look program assumes that the current funding and level of activity for private works remains and the original targets are largely achieved by 2010.

A.1.2 Existing Pumps

The Plan (1989) objective for existing pumps (thought to be approximately 800 at the time) was to implement management arrangements to encourage consistent operation for 395 pumps in existing and future high groundwater level areas to serve approximately 45000 ha. The remaining existing pumps, some of which were assumed to be used for drought relief only, were largely ignored on the assumption that, by comparison, their salinity benefits would be small within the Plan timeframe.

By end June 1998, some 380 existing private pumps throughout the Region were listed as having participated in the Plan to varying degrees since the early 1990's (ie involved in the Groundwater Pumping Incentive Scheme and/or allocated interim SDAs). However, formal agreements were not in place and there was limited confidence in the reliability of the numbers and pumped volume and salinity data.

Implementation of the Groundwater Management Plan (GMP) commenced in July 1999 with the aim to provide a means of encouraging groundwater

pumping in accordance with Plan guidelines via groundwater extraction license conditions and also obtaining more reliable data. The GMP provides "salinity bore" status to any shallow groundwater pump in the Region that undertakes to operate in accordance with GMP guidelines. This is inconsistent with the original Plan works targets which primarily focussed on existing pumps in high groundwater level areas. However, it is consistent with the original Plan intent to encourage regular and responsible pumping in the Region as a whole and extends the Plan benefits to areas not thought to be at risk by 2020. No attempt has been made to quantify and include these additional benefits in this exercise.

To the end of June 2000, 104 non-capital grant (new and upgrade) private groundwater pumps had registered as salinity bores within the GMP definition in response to a mailout by G-MW. A reliable estimate of private salinity bores will not be available until the GMP license review process is largely complete. For the future works program, the original Plan target of 395 bores in existing and future high groundwater level areas has been retained at this stage, starting with 104 non-grant bores in 1999/2000 (in addition to upgrade bores) and reaching the 395 target by June 2005. This will need to be reviewed over the next 5 years in conjunction with progress on license reviews for existing bores.

A.1.3 Private Pump Cost Estimates

Average private pump cost estimates in 1998/1999 values and explanatory notes are provided below. In order to simplify the benefit cost analysis, 1998/1999 values have been applied to works since 1990/1991 and to future works.

- New pumpsites $73,850/site
- Upgrade for existing pumps $8,650/site
- O&M for existing pumps $20/ML
- GMP volumetric charge $1.50/ML
- GMP fixed charge $200/site
- Metering costs $1,150/site
- License review costs $150/site

New pumpsite establishment costs are as reported in the 1998/1999 annual report for the Plan. The costs include investigation, capital contribution by the Plan and the landholder, administration costs, and the costs of unsuccessful investigations. The long term average success rate for investigations to 1998/1999 has been 25%.

Upgrade costs include the Plan and landholder capital contribution. Administration costs associated with upgrades are included in new site establishment costs.

The annual operation and maintenance cost, including renewals, has been assumed to be $20/ML. This is comprised of $12/ML for operating and $8/ML for maintenance and depreciation.

The annual bore license (GMP) charges for 1999/2000 have been set at $49.50/site and $1.10/ML of allocation. These have been estimated to increase to $190.75/site and $1.34/ML respectively when the GMP and associated management services are fully implemented. For this exercise, costs of $200/site and $1.50/ML have been adopted.

Bore metering costs are based on 1999/2000 actual costs comprising a site cost of $900 and a metering assessment, specification and project management cost of $250/site. This has not been adjusted to 1998/1999 values.

A.1.4 Plan Costs and Areas Served

The current prioritisation process ensures that new pump installations and upgrades are in areas subject to groundwater levels within 2 m of surface. All of the establishment costs, annual costs, and resource and salinity benefits associated with the 40000 ML pumped in-season by new sites to serve 40000 ha have been attributed to the Plan. Winter SDA pumping has been assumed to be 25% of total in season pumping.

The 1993/1994 review assumed that there would be a proportion of existing pumps that operated reasonably consistently prior to the Plan to serve a proportion of the Region. The number of pumps and volumes are unknown however, a nominal allowance of 20000 ML serving 20000 ha was used and has been retained for this review. The salinity benefits associated with these volumes and areas have not been attributed to the Plan. That is, all of the annual costs and resource benefits associated with the 45000 ML pumped by the 395 existing bores have been included but salinity benefits for only 25000 ha have been included rather than the gross area of 45000 ha.

The GMP metering program commenced in July 1999 for existing bores identified in the State Groundwater Database, G-MW's private pump database and G-MW's billing system as at 28 October 1998. By end June 2000, 582 of the bores were listed as having meters fitted. This comprised 205 fitted during 1999/2000, some 150 via capital grants for new and upgraded sites and the remainder fitted by the Plan under past low budget annual metering programs.

The metering program is scheduled for completion by June 2002. As at 2 August 2000, 129 meters remained to be fitted to bores already inspected and metering inspections were required for 259 sites. Assuming 60% of the sites to be inspected will require meters, 284 meters remain to be fitted from the October 1998 list of bores. The works program has assumed 200 of these will be fitted in 2000/2001 with the remaining 84 in 2001/2002. The estimate for the number of bores to be metered is based on metering activities to date and is independent of the 395 existing bore target.

Bore licensing revenue contributed about 50% of the cost of metering in 1999/2000 and this level of contribution has been assumed for the remainder of the program. Prior to 1999/2000, the full cost of metering existing bores has been attributed to the Plan.

The GMP aims to review all existing extraction licenses by June 2005. This will be done by reviewing licenses due for renewal within the timeframe (at license holder cost) and offering incentives for early voluntary review of licenses due for renewal after 2005. The works program has assumed 50% of the license review cost for the 395 salinity bores will be a Plan cost. The costs for the remaining bores will be met by bore licensing revenue.

A.2 Public Pumps

To the end of June 2000, 21 public pumps had been installed where salinity problems were evident and private pumping was demonstrated not to be feasible. This is about half of the target number set by the Strategic Plan (July 1995). However, the 1995 target was later revised to 4 sites/year on average due to budget constraints and the higher priority for private works.

At this stage, the future works program has retained the original Plan target of 425 pumps (including 50 pumps disposing to basins) to serve approximately 85000 ha by the year 2023. An accelerated program will be required to achieve this target.

Average cost estimates in 1998/1999 values for public works are summarised below. The 1998/1999 values have been applied to past and future works to simplify the economic evaluation.

- Pumpsite establishment $157,000
- O&M (inc renewals) $35/ML
- Pumpsite & basin establishment $157,000 + $225,000 = $382,000
- Additional basin O&M $1000/basin
- Additional Annual $730/site

Public pumpsite establishment costs are as reported in the 1998/1999 annual report for the Plan. The costs include investigation, capital, administration, and the costs of unsuccessful investigations. The average success rate for investigations to 1998/1999 has been approximately 60%. The basin cost is based on an average size of 15 ha and an investigation, design and construction cost of $15,000/ha.

The annual O&M of $35/ML is based on the actual recorded direct and indirect cost of $31/ML incurred by Central Goulburn in 1996/1997. That year is considered to reflect an average level of pumping. An amount of $1000/yr has been allowed to cover basin maintenance activities. An additional annual cost of $730/site has been allowed to cover increased channel and drain maintenance due to groundwater disposal. The $730 is based on an exercise undertaken in 1997 to assess groundwater disposal impacts on channel and drain maintenance.

The average area served by public pumps is currently based on the original Plan assumption of 200 ha/site. It should be noted that the average net area within the 0.1 m drawdown contour and subject to local beneficiary rates for the 17 pumps installed to 1998/1999 was approximately 145 ha. However, the area served by a pump extends beyond the 0.1 m drawdown contour and the 200 ha/pump has been retained to estimate Regional benefits.

A.3 Low Volume Pumps and Tile Drains

The original Plan has provision for the installation of tile drainage or low capacity pumps to protect the productive capacity of areas where aquifers are limited or non-existent. Works to date and the future works program have largely been restricted to perennial horticultural plantings in Shepparton East pending development of a cost-effective strategy for pasture areas.

The Shepparton East program developed during the 1993/1994 review estimated that up to 1300 ha of orchard may require groundwater control by the year 2020. The program comprised 40 new groundwater pumps serving an average of 25 ha/pump and 300 ha of new tile drainage.

To the end of June 2000, 21 pumps and approximately 16 ha of tiles had been installed to serve approximately 540 ha (based on 25 ha/pump). The future works program assumes the groundwater pump component of Shepparton East is largely implemented by 2010. The tile drainage component has been assumed to be largely completed by 2015. Adopted average costs in 1998/1999 values are given below.

- Pumpsite establishment $42,500/site
- Tile drain installation $7,150/ha
- Pumpsite O&M $20/ML
- Tile Drain O&M $25/ML
- Whole Farm Plans $150/ha
- GMP volumetric charge not applicable to de-watering sites
- GMP fixed charge $200/site
- License review costs not applicable to new private works

Pumpsite and tile drain establishment costs include investigation, capital contribution by the Plan and the landholder, administration costs, and the costs of unsuccessful investigations.

The annual operation and maintenance cost, including renewals, has been assumed to be $20/ML for pumpsites and $25/ML for tile drains. An average annual extraction rate of 2 ML/ha has been assumed for full groundwater control. No allowance has been made for any potential increase in drain maintenance costs due to groundwater disposal.

The 1993/1994 review included an allowance for Whole Farm Plan costs as they were required under the policies for horticultural works. A Plan target of 100 farms averaging 15 ha at a cost of $150/ha has been assumed. Non salinity benefits resulting from the Whole Farm Plan have not been included.

It should be noted that there may be a requirement to meter approximately 53 existing bores in Shepparton East that are used for horticultural protection. These works and disposal practices were established prior to 1 January 1988 however, their operation needs to be monitored for salt disposal accounting purposes. The issue of whether these works need to be metered is yet to be resolved and the potential cost or benefits of this work has not been included in the future works program.

A.4 Salt Disposal Requirements

Salt disposal requirement estimates are summarised below and notes on the assumptions are given following the table.

- **Table A4-1 SDE Estimates**

Activity	Cumulative SDE Estimates by Year End					Original Estimate	Revised Estimate
	99/00	04/05	09/10	14/15	22/23		
Private Pumps	1.26	2.43	2.7	2.7	2.7	3.7	2.7
Private Horti	0.16	0.26	0.36	0.39	0.4	0	0.4
Private C Type	Nil	0.07	0.37	1.85	3.7	4.1	3.7
Public Pumps	0.80	2.32	3.69	5.57	8.9	8.9	8.9
Total	2.22	5.09	7.12	10.51	15.7	16.7	15.7

Notes: Private pasture revised SDE requirement is based on the Plan (1989) estimate less a nominal 1 EC due to a reduced requirement resulting from the 1993/1994 review which resolved that disposal from existing private pumps would be voluntary and only encouraged where the groundwater salinity was > 1000 EC. 1999/2000 estimate taken from the 1998/1999 salt disposal report for the Region and subject to review under the GMP.

Private horticulture SDE is based on 21 pumps x 25 ha + 15 ha of tiles = 540 ha served to 1999/2000 at an average SDE requirement of 0.163/540 EC/ha.

Private C Type pasture activities are assumed to commence late in the 5 year period ending 2004/2005 following the development of a cost effective strategy. Overall original Plan SDE allowance for C Types has been retained at this stage and works have been assumed to proceed at a rate of 0.02, 0.08, 0.4 and 0.5 of 3.7 EC to 2023.

The public pump SDE for 1999/2000 is based on 0.8 EC for the 21 pumps commissioned to end June 2000. The 2004/2005 estimate is based on an additional 40 sites at 0.8/21 EC/pumpsite. The original overall estimate of 8.9 EC for the public program has been retained at this stage.

An estimated 10000 ha B1 Type Areas (>11700 EC) will need to be served by pumps disposing to basins. If these pumps were to disposal to channels and drains, more than 4 EC of additional SDE would be required for the public pumping program.

A.5 Sub-Regional Targets

The estimated number of B3 and B2 Type pumps by sub-region is summarised in **Table A5-1**. The original Plan estimates for B1 Types allowed for 25 pumps and basins in both the Rochester and Rodney/Tongala sub-regions resulting in 50 basins to serve 10000 ha.

■ Table A5-2 Pump Distribution by Sub-Region

Sub-Region	Private Pumps								Public Pumps			
	Exist Low B3		New Low B3		Exist High B3		New High B3		High B3		B2 Type	
	No	Area	No	Area	No	Area	No	Area	No	Area	No	Area
Murray Valley	200	25000	128	16000	20	2500	20	2500	20	4000	2.5	500
Shepparton	0	0	0	0	5	500	5	500	5	1000	10	2000
Rod/Tongala	100	10000	160	16000	20	2000	20	2000	160	32000	52.5	10500
Rochester	40	4000	20	2000	10	1000	10	1000	100	20000	25	5000
Total	340	39000	308	34000	55	6000	55	6000	285	57000	90	18000
NCentral CMA	31	3060	15	1530	8	760	8	760	76	15280	11	2200

Note: NC CMA component of Rochester sub-region works are those west of the Campaspe River.

■ Table A-3 Regional Private Pumping Program

YEAR		Private B Type Works Program										Private Cumulative Annual $ x 1000				
		Targets				Establishment Costs $ x 1000										
		New	Existing (Upgrades)	Existing (sal bores)	Area (total)	New	Upgrades	GM Plan (Metering)	GM Plan (Lic Review)	Total	SDA (cum)	O&M Su	O&M Wi	GMP (vol)	GMP (fix)	Total
1 - 9	1998 / 1999	171	55	55	25006	12628	476	143	0	13247	1.223	500	125	0	0	625
10	1999 / 2000	23	4	108	39830	1699	35	118	0	1851	1.256	797	199	60	71	1127
11	2000 / 2001	21	8	47	47486	1551	69	115	6	1741	1.500	950	237	71	85	1343
12	2001 / 2002	20	7	47	55032	1477	61	48	6	1592	1.740	1101	275	83	98	1557
13	2002 / 2003	19	7	46	62355	1403	61	0	6	1470	1.973	1247	312	94	111	1764
14	2003 / 2004	18	7	46	69568	1329	61	0	6	1396	2.202	1391	348	104	124	1968
15	2004 / 2005	17	7	46	76671	1255	61	0	6	1322	2.428	1533	383	115	137	2169
16	2005 / 2006	16	7		78425	1182	61	0		1242	2.485	1568	392	118	140	2218
17	2006 / 2007	15	7		80068	1108	61	0		1168	2.539	1601	400	120	143	2265
18	2007 / 2008	15	7		81712	1108	61	0		1168	2.593	1634	409	123	146	2311
19	2008 / 2009	15	7		83356	1108	61	0		1168	2.646	1667	417	125	149	2358
20	2009 / 2010	15	7		85000	1108	61	0		1168	2.700	1700	425	128	152	2405
21	2010 / 2011				85000						2.700	1700	425	128	152	2405
22	2011 / 2012				85000						2.700	1700	425	128	152	2405
23	2012 / 2013				85000						2.700	1700	425	128	152	2405
24	2013 / 2014				85000						2.700	1700	425	128	152	2405
25	2014 / 2015				85000						2.700	1700	425	128	152	2405
26	2015 / 2016				85000						2.700	1700	425	128	152	2405
27	2016 / 2017				85000						2.700	1700	425	128	152	2405
28	2017 / 2018				85000						2.700	1700	425	128	152	2405
29	2018 / 2019				85000						2.700	1700	425	128	152	2405
30	2019 / 2020				85000						2.700	1700	425	128	152	2405
31	2020 / 2021				85000						2.700	1700	425	128	152	2405
32	2021 / 2022				85000						2.700	1700	425	128	152	2405
33	2022 / 2023				85000						2.700	1700	425	128	152	2405
	Total	365		395	85000	26955	1125	424	30	28533	2.7	1700	425	128	152	2405

Note: SDA is the cumulative annual EC allocation to works.

■ Table A-4 Regional Public Pumping Program

Year		Public B Type Works Program							Public Annual $x1000
		Targets			Establishment Costs $ x 1000				
		Reuse	Basin	Area (cum)	Reuse	Basin	Total	SDA (cum)	
1 – 9	1998 / 1999	17		3400	2669	0	2669	0.686	72
10	1999 / 2000	4		4200	628	0	628	0.800	89
11	2000 / 2001	6		5400	942	0	942	1.029	114
12	2001 / 2002	7		6800	1099	0	1099	1.295	144
13	2002 / 2003	8		8400	1256	0	1256	1.600	178
14	2003 / 2004	9		10200	1413	0	1413	1.943	216
15	2004 / 2005	10		12200	1570	0	1570	2.324	258
16	2005 / 2006	11	1	14600	1727	382	2109	2.554	309
17	2006 / 2007	12	1	17200	1884	382	2266	2.805	364
18	2007 / 2008	13	2	20200	2041	764	2805	3.078	428
19	2008 / 2009	14	2	23400	2198	764	2962	3.371	497
20	2009 / 2010	15	2	26800	2355	764	3119	3.685	569
21	2010 / 2011	16	2	30400	2512	764	3276	4.020	646
22	2011 / 2012	18	2	34400	2826	764	3590	4.397	731
23	2012 / 2013	18	2	38400	2826	764	3590	4.774	816
24	2013 / 2014	19	3	42800	2983	1146	4129	5.172	910
25	2014 / 2015	19	3	47200	2983	1146	4129	5.570	1004
26	2015 / 2016	19	3	51600	2983	1146	4129	5.968	1098
27	2016 / 2017	20	3	56200	3140	1146	4286	6.387	1196
28	2017 / 2018	20	4	61000	3140	1528	4668	6.806	1298
29	2018 / 2019	20	4	65800	3140	1528	4668	7.224	1401
30	2019 / 2020	20	4	70600	3140	1528	4668	7.643	1503
31	2020 / 2021	20	4	75400	3140	1528	4668	8.062	1606
32	2021 / 2022	20	4	80200	3140	1528	4668	8.481	1709
33	2022 / 2023	20	4	85000	3140	1528	4668	8.900	1811
	Total	375	50	85000	58875	19100	77975	8.9	1811

Note: SDA is the cumulative annual EC allocation to works.

■ Table A-3 Private Horticultural Program

Year		Private Horticultural Works Program									Private Cumulative Annual $ x 1000				
		Targets			Establishment Costs $ x 1000										
		New	Tile Drain	Area	New	Tile Drain	WFP	GM Plan	Total	SDA (cum)	O&M Pump	O&M Tile	GMP (vol)	GMP (fix)	Total
1 –9	1998 / 1999	19	15.9	491	807	114	50	na	971	0.155	19	1	na	0	20
10	1999 / 2000	2		541	85	0	5	na	89	0.163	21	1	na	5	27
11	2000 / 2001	2	10	601	85	72	9	na	165	0.181	23	1	na	6	30
12	2001 / 2002	2	15	666	85	107	11	na	203	0.201	25	2	na	7	34
13	2002 / 2003	2	15	731	85	107	11	na	203	0.221	27	3	na	8	37
14	2003 / 2004	2	15	796	85	107	11	na	203	0.240	29	4	na	9	41
15	2004 / 2005	2	15	861	85	107	11	na	203	0.260	31	4	na	10	45
16	2005 / 2006	2	15	926	85	107	11	na	203	0.279	33	5	na	11	49
17	2006 / 2007	2	15	991	85	107	11	na	203	0.299	35	6	na	12	52
18	2007 / 2008	2	20	1061	85	143	14	na	241	0.320	37	7	na	13	57
19	2008 / 2009	2	20	1131	85	143	14	na	241	0.341	39	8	na	14	61
20	2009 / 2010	1	20	1176	42	143	11	na	197	0.355	40	9	na	15	64
21	2010 / 2011		20	1196		143	9		152	0.361	40	10	na	16	66
22	2011 / 2012		25	1221		179	11		190	0.369	40	11	na	17	68
23	2012 / 2013		25	1246		179	11		190	0.376	40	12	na	18	70
24	2013 / 2014		25	1271		179	11		190	0.384	40	14	na	19	72
25	2014 / 2015		29.1	1300		208	13		221	0.392	40	15	na	20	75
26	2015 / 2016			1300						0.392	40	15	na	20	75
27	2016 / 2017			1300						0.392	40	15	na	20	75
28	2017 / 2018			1300						0.392	40	15	na	20	75
29	2018 / 2019			1300						0.392	40	15	na	20	75
30	2019 / 2020			1300						0.392	40	15	na	20	75
31	2020 / 2021			1300						0.392	40	15	na	20	75
32	2021 / 2022			1300						0.392	40	15	na	20	75
33	2022 / 2023			1300						0.392	40	15	na	20	75
Total		40	300	1300	1700	2145	225	0	4070	0.4	40	15	0	20	75

Note: SDA is the cumulative annual EC allocation to works.

Appendix B Economic Evaluation

B.1 Introduction

The MDBC Drainage Evaluation Spreadsheet Model (DESM) Version 3 has been applied to the future works program given in **Appendix A**

In applying the DESM model, it was necessary to quantify a range of input parameters relating to the project. This appendix details the assumptions that were made during the application of the model.

B.2 Model Structure

There are a number of modules in the DESM model, each of which represents a key feature of the project evaluation:

- Agricultural production – with project
- Agricultural production – without the project
- Agricultural production losses due to salinity
- Agricultural production losses due to waterlogging and flooding
- Drainage and on farm works – with project
- Drainage and on farm works – without project
- Effectiveness of drainage and on farm works
- Drainage Capital and O & M costs
- Reuse Benefits
- Downstream Impacts
- Road Benefits

B.3 Agricultural Production

Model inputs and enterprise types were assumed to be the same both with and without the project.

B.3.1 Land Use Areas

Dairying was assumed to be the dominant agricultural enterprise for the private and public pasture pumping programs. The gross areas served were converted to effective ha of perennial pasture using a factor of 0.8. This was based on an average mix of 70% perennial pasture, 20% of annual pasture and 10% of dryland within the gross areas served. Two ha of annual pasture or 10 ha of dryland was assumed to equivalent to 1 ha of perennial pasture.

The 0.8 is consistent with the results of G-MW's Irrigated Farm Census 1987 (approximately 0.75 to 0.85 depending on farm size). However, it is slightly less than that observed for the Girgarre Project (0.82) and that for public pumps installed to date (approximately 0.85).

For the private horticultural program, all of the areas served by low capacity pumps and tile drainage systems were assumed to be planted to perennial horticulture.

B.3.2 Achievable Gross Margin

It was assumed that the achievable dairy gross margin in the absence of salinity and waterlogging was $1,512 per effective hectare (ref: North East Gross Margins, 1997-1998, DNRE). This figure is based on an income of $2,061, less costs of $549 per effective hectare and was considered reasonable for use in 1998/99 (O Gyles, DNRE, pers comm December 2000).

The achievable horticulture gross margin in the absence salinity and waterlogging was assumed to be $3,578 per effective hectare (O Montecillo, DNRE, pers comm December 2000). This figure, calculated in 1998, was based on a regional survey, conducted in 1991 that concluded a regional horticultural composition of 3% apricots, 22% apples, 55% pears, and 20% peaches.

B.3.3 Gross Water Use Intensity

The gross water use intensity was assumed to be at least 5 ML/effective ha for both the dairying and horticultural enterprises.

B.4 Agricultural Production Losses Due to Salinity

The MDBC salinity loss function method was used in this module. For the private pumping program, public reuse program, and horticultural works program, the low groundwater salinity (<10,000 EC) loss function and an irrigation intensity of 5 ML/ha was used. For areas assessed using the low salinity function it was assumed that 5% of the effective area was affected by salinity at the beginning of the assessment period.

The 1993/94 review assumed that there would be a proportion of existing private pumps that operated reasonably consistently prior to the Plan to serve a proportion of the Region. The number of pumps is unknown however, a nominal allowance of 20,000 ML serving 20,000 ha was used and has been retained for this exercise. The salinity benefits associated with the 20,000 ha has not been attributed to the Plan.

For public pumps disposing to basins, the high groundwater salinity (>10,000 EC) loss function and an irrigation intensity of 5 ML/ha was adopted. It was assumed the 10% of the effective area served by public pumps disposing to basins was affected by salinity at the beginning of the assessment period.

B.5 Waterlogging and Flooding

Agricultural production losses due to waterlogging and flooding were ignored.

B.6 Drainage And Landforming

All of the net areas served were provided with sub-surface drainage. Without the project it was assumed that no area had sub-subsurface drainage. The gross area served by existing private pumps due to the Plan was reduced to 25,000 ha to account for the private pump operation prior to the Plan.

Surface drainage and landforming were ignored and set to zero. It was assumed that no area would be drainage and landformed without the project.

The effectiveness of sub-surface drainage alone for the pasture pumping program in reducing salinity losses was assumed to be 80%. This was derived by assuming 70% of the effective area served would be fully protected and one-third of the remaining area be protected. This is consistent with the current assumptions used in the feasibility level investigations for new public pumps.

The DESM default value of 90% was retained for the effectiveness of sub-surface drainage alone for the private horticultural in reducing salinity losses.

B.7 Capital and O&M Costs

Works establishment and annual costs (including renewals) are detailed in **Appendix A – Future Works Program**. The costs in **Appendix A** do not include salt disposal costs as the DESM calculates downstream impacts (refer **Section B.9**).

The aggregated cost for years 1 to 9 in **Appendix A** was assumed to be equally distributed over that period. The DESM was modified to accommodate works program of greater than 20 years and a varying annual costs.

It should be noted that the DESM calculates a residual asset value at the end of the evaluation period and includes this in the net present value calculations. This results in a slight reduction in the net present value of the works program establishment costs.

B.8 Reuse Benefits

The DESM default of $50/ML was used as the reuse value of groundwater used on farm or via the channel and surface drainage system. Any potential reuse benefits of drainage water reaching the River Murray have been excluded from this analysis.

B.9 Downstream Impacts

DESM Method 1 was used to estimate the downstream impacts. The calculation is based on:

- The average salinity of shallow groundwater;
- The rate of groundwater extraction; and,
- The proportion of sub-surface drainage water reused.

The adopted parameters for the DESM models are presented below.

Table B9-1 Parameters for Determining Downstream Impact

Program Component	Regional Private Pumping		Regional Public Pumping		Private Horticulture Program	
	New Pumps	Existing Pumps[1]	Reuse Pumps	Basin Pumps	Tile Drainage	Pumps
Gross Area (ha)	40000	45000	75000	No Disposal	300	1000
Effective Area	32000	20000	60000	No Disposal	300	1000
Annual Vol (ML)	50000	56250	37500	No Disposal	600	2000
ML/Eff ha/year	1.563	2.813	0.625	No Disposal	2	2
Average EC	1500	1500	4330	No Disposal	833	833
Reuse %	80	80	37.5	No Disposal	0	0

B.10 Road Benefits

Any potential benefits of the project to rural sealed and unsealed roads or farm tracks were ignored.

B.11 DESM Results

The DESM was run for each component of the works program. The analysis period was 50 years using a discount rate of 5%. The results are tabulated below.

- **Table B11-1 DESM Discounted Cash Flow Results ($ x 1000)**

	Private Pasture Pumps		Public Pasture Pumps		Total Pasture Program	Horticultural Program
	Existing	New	Reuse	Basin		
Benefits						
Salinity	38,961	65,228	56,232	6,979	167,313	8,077
Reuse	23,831	22,730	4,018	0	50,580	0
Total Benefits	62,793	87,959	60,250	6,979	217,893	8,077
Costs						
Establishment	955	16,632	18,196	4,666	40,449	1,991
Annual	13,473	12,890	8,862	952	36,176	732
Downstream	2,587	2,434	8,911	0	13,932	324
Total Costs	17,015	31,955	35,969	5,618	90,557	3,048
NPV	45,778	56,003	24,282	1,361	127,336	5,029
Benefit/Cost	3.69	2.75	1.68	1.24	2.41	2.65

The DESM returned a favourable benefit cost ratio for all of the programs. The input assumptions are based on the Plan's experience to date and are considered to be reasonable. No attempt has been made to sensitivity test the assumptions and results.

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