Developing Commercial Inland Saline Aquaculture in Australia: Part 2. Resource Inventory and Assessment

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2. ACKNOWLEDGMENTS

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3. NON-TECHNICAL SUMMARY

98/335	Developing Commercial Inland Saline Aquaculture in Australia. Part 2. Resource Inventory and Assessment

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OBJECTIVES:

1. Review the developmental status of inland saline aquaculture in Australia.

2. Evaluate likely obstacles and limitations to the commercial expansion of inland saline aquaculture and the ability for R & D to address these limitations.

3. Develop an R & D plan to address these obstacles and limitations in consultation with the aquaculture industry and related disciplinary experts (Developing Commercial Inland Saline Aquaculture in Australia: Part 1. R & D Plan).

4. Document the distribution and characteristics of inland saline groundwaters and their potential use for the farming of aquatic organisms (Developing Commercial Inland Saline Aquaculture in Australia. Part 2. Resource Inventory and Assessment).

NON TECHNICAL SUMMARY:

The National R&D Plan for Inland Saline Aquaculture arose following a workshop on inland saline aquaculture run by ACIAR. Two of the main outcomes of the Workshop were identification of the need for a national, strategic R&D Plan for inland saline aquaculture (Part 1) and identification of the need for an inventory of inland saline resources and assessment of the potential of these for aquaculture (Part 2).

Existing Inland Saline Aquaculture in Australia

There are small-scale research and development or commercial inland saline aquaculture projects in all states except Queensland, Tasmania and the ACT. Current activities include:

- NSW - NSW Fisheries investigating snapper culture, with funding from the CRC for Aquaculture; one commercial barramundi farm; CSIRO (L & W) Project on serial biological concentration to combine irrigation and saline aquaculture.
- Victoria - Inland Mariculture Scoping Study was undertaken on a range of sub-tropical and temperate species; funding from the State Government and Murray-Darling Basin Commission. Rural Industries Research & Development Corporation (RIRDC), ACIAR, and the State Government are funding other smaller-scale saline water studies with silver perch and rainbow trout. One commercial operation producing Artemia (brine shrimp) and salt.

- ❖ SA - investigating production of Artemia, Dunaliella and finfish in poly-tunnels as part of salt-water management procedures; RIRDC funding. Commercial farms for barramundi and other finfish being developed.
- ❖ WA - extensive interest in inland saline aquaculture - Outback Ocean project by WA Fisheries to trial black bream and winter trout production in saline ponds and dams. A detailed resource inventory is also being compiled.
- ❖ NT - has undertaken successful pilot-scale Dunaliella (micro-algae) production near Alice Springs; commercial venture currently being established. Experimental production of the tiger prawn *Penaeus monodon* using saline bore water is underway at the University of NT.
- ❖ Qld - presently no inland saline aquaculture.
- ❖ Tas – presently no inland saline aquaculture.

Resource Inventory and Assessment

The contract to help prepare the Resource Inventory and Assessment was won by the consultants Atech Pty Ltd on the basis of price and documented experience preparing similar inventories and with accessing and cataloguing hydrological data from government agencies throughout Australia. The objectives of the inventory project were:

1. To undertake an inventory of key saline surface and groundwater resources that may be suitable for inland saline aquaculture.
2. To undertake a preliminary assessment of the suitability of identified resources for the establishment of hatchery or adult fish production aquaculture.

Information was identified and collated from a wide range of sources, including the Internet, abstracting and subject-specific databases, agency libraries, unpublished reports, the scientific literature, as well as discussions with agency staff. Broad screening criteria were used to avoid collecting detailed information and assessing resources that are clearly unsuitable for the establishment of a saline aquaculture industry.

A diverse range of saline water resources was identified as having potential for inland saline aquaculture. These resources included:

1. Existing large-scale groundwater interception schemes and associated disposal basins located in three main areas of the southern Murray-Darling Basin. These were:
- ❖ the Riverland Region of SA;
- ❖ the Sunraysia Region of Victoria and NSW; and
- ❖ the Riverine Plains west of Shepparton in northern Victoria.

   In total, the pond area in existing groundwater interception schemes and associated disposal basins, identified as having aquaculture potential, exceeds 6 250 ha in 11 schemes. These schemes were constructed at a total cost of more than $108 million and cost more than $3 million per year to operate. They are used to dispose of more than 50 000 ML/yr.

2. A number of new proposed and planned saline groundwater interception schemes in these same regions.

   There are another 8 schemes being constructed or planned which could also have aquaculture potential. These new schemes will cost more than $50 million to build and more than $2 million per year to operate. They will dispose of a further more than 13 100 ML/yr.

3. Permanent natural saline lakes in Victoria, these were:

- the Kerang Lakes on the Riverine Plains near Kerang; and
- the Western District Volcanic Lakes near Colac.

4. Saline and brackish groundwaters from sedimentary basins and fractured rock aquifers around Australia. These were found in all states except Tasmania. A number of brackish geothermal groundwaters were also identified.

5. Urban groundwater pumping to protect urban infrastructure and property in areas affected by dryland or irrigation-derived salinity. These opportunities for cost-sharing were located in:

- the Murray-Darling Basin; and
- the wheat belt area of southwest Western Australia.

ome 74 rural towns (24 in Victoria, 21 in NSW, 1 in South Australia and 28 in Western Australia) which are experiencing or threatened by rising saline groundwater tables.

6. Proposed shallow groundwater pumping in the Ord River Irrigation Area around Kununurra in northern WA.
7. Two other unusual saline water resources with exceptional aquaculture potential were also identified. These were:

- The proposed Esperance-Kalgoorlie seawater pipeline.
- Saline drainage water associated with coal mines in NSW and Queensland.

Thirteen criteria were developed for a preliminary assessment of the potential of these identified saline water resources for the establishment of hatchery or adult fish production aquaculture. These criteria dealt with the following areas:

- The availability and nature of the resource.
- The availability of land and freshwater.
- The nature of the surrounding environment.
- Existing infrastructure and services.
- Opportunities for cost-sharing.

Specific criteria and tentative weightings were developed which addressed different saline aquaculture requirements of different industry types. The aquaculture types used were:

- marine hatcheries;
- grow-out of stenohaline fish using recirculating facilities;
- grow-out of stenohaline fish using ponds;
- grow-out of diadromous fish using recirculating facilities;
- grow-out of diadromous fish using ponds;
- grow-out of freshwater native fish using recirculating facilities; and
- grow-out of freshwater native fish using ponds.

The application of the developed criteria to potentially suitable saline water resources provided an indicative assessment of the suitability in relation to the various aquaculture types.

A number of saline resources were identified as being attractive for a range of aquaculture types. (On the basis of a preliminary and indicative assessment using tentative scoring criteria, and often with limited resource information.) These were in particular:

- The Esperance-Kalgoorlie seawater pipeline.
- Most groundwater interception schemes.
- Most of the Kerang Lakes.
- Urban groundwater pumping.
- The aquifers of the Murray Hydrogeological Basin.
- Coal mine drainage water.

4. BACKGROUND

This project arose from a national workshop on Inland Saline Aquaculture held in Perth on 6-7 August 1997. The Workshop was funded primarily by ACIAR, with co-funding support provided by FRDC and RIRDC. It was convened because of the high level of interest in inland saline aquaculture in Australia, and the need to coordinate R&D activities from a national perspective. The Workshop brought together selected aquaculture and land/water specialists from Australian States and Territories, along with representatives from ACIAR, FRDC and the CRC for Aquaculture. Workshop sessions addressed current activities in the country, key technical and environmental issues, and major opportunities and constraints to the development of inland saline aquaculture ventures. A comprehensive report of the proceedings and outcomes was published by ACIAR in 1999.

The main outcome of the Workshop was identification of the need for development of a strategic plan to provide a national framework for R&D on inland saline aquaculture. The plan was needed to help guide and facilitate the integration of R&D across geographical areas, land/water disciplines, taxa, industry sectors and potential investment groups and between funding, research and management agencies. In addition, the need for an inventory of inland saline groundwater resources and an assessment of their aquaculture potential was also recognised.

4.1. Inland Saline Aquaculture - Resource and Potential

Farming of marine species in Australia's coastal zone is increasingly limited by high land prices, shortage of suitable sites, environmental constraints (land and water alienation and effluent disposal) and conflict with other land and water users. As highlighted in the National Strategy on Aquaculture (1994) it is clear that a shortage of suitable coastal sites is a major constraint to the expansion of the mariculture industry in Australia.

Away from the coastal zone, Australia has large inland saline water resources. These water resources can be grouped into the following categories:

1. Natural saline lakes: common in south-eastern Australia, can be large in area and highly seasonal.
2. Shallow aquifers and salt affected farm land: saline water tables at or near the surface, often caused by changes in land management practices that have altered natural water tables.
3. Deep aquifers: generally at depths greater than 30 metres, formed from ancient water; chemically stable; can be artesian (some suitable, others not).

The availability of inland saline waters opens up the potential for development of a saline aquaculture industry remote from the sea. Commercial incentives that would encourage the development of inland mariculture include comparatively cheap land, enhanced quarantine capability and limited conflict over the same resource. The opportunity for integrating these activities with land salinisation remedial operations is particularly attractive. Such development would provide an additional incentive for a systems approach to remediation projects, help offset costs of such projects and provide important additional benefits of job creation and diversification for the farming industry in remote rural areas.

4.2. Current Activities in Inland Saline Aquaculture

Research activities in inland saline aquaculture are comparatively recent, but are being undertaken in several States.

- NSW - NSW Fisheries investigating snapper culture, with funding from the CRC for Aquaculture; one commercial barramundi farm; CSIRO (L & W) Project on serial biological concentration to combine irrigation and saline aquaculture.
- Victoria - Inland Mariculture Scoping Study was undertaken on a range of sub-tropical and temperate species; funding from the State Government and Murray-Darling Basin Commission. RIRDC, ACIAR, and the State Government are funding other smaller-scale saline water studies with silver perch and rainbow trout. One commercial operation producing Artemia and salt.
- SA - investigating production of Artemia, Dunaliella and finfish in poly-tunnels as part of salt-water management procedures; RIRDC funding. Commercial farms for barramundi and other finfish being developed.
- WA - extensive interest in inland saline aquaculture, “Outback Ocean” project by WA Fisheries to trial winter salmon production in saline ponds and dams.
- NT - has undertaken successful pilot-scale Dunaliella production near Alice Springs; commercial venture currently being established. Experimental production of *P.monodon* using saline bore water is underway at the University of NT.
- Qld - presently no inland saline aquaculture.
- Tas – presently no inland saline aquaculture.

5. NEED

There is considerable interest in the potential for inland saline aquaculture in Australia. Several developmental projects are currently underway. While these are appropriate regionally, they are being undertaken in the absence of planning and review at the national level. There is an urgent need for national planning to ensure that current and future R&D is coordinated, focused, avoids duplication, and is targeted at realistic and meaningful commercial outcomes. The mapping and classification of inland saline groundwater resources will provide a valuable information bank for both researchers and investors. Successful development of inland saline aquaculture will generate employment opportunities in rural areas, and may defray costs associated with management of shallow saline aquifers.

ATTRACTIVENESS:
The development of a national plan for coordinating R&D on inland saline will have benefits for all stakeholders. The industry will benefit from streamlined research aimed at commercial outcomes. Funding agencies and research providers will have guidelines indicating priorities, and a plan for where particular projects fit into the bigger scheme of R&D in inland saline aquaculture.

FEASIBILITY:
The recent workshop on Inland Saline Aquaculture in Perth has laid much of the groundwork for the present project. The Aquaculture Committee, on which all State fisheries management agencies are represented, committed its support for the project. There are no technical constraints to satisfactory completion of the project.

RISKS:
The major risk is that a consultant sufficiently knowledgeable and experienced to prepare the R&D plan is not available for the consultancy. However, the steering group for the project will actively solicit appropriate people if necessary.

6. OBJECTIVES

1. Review the developmental status of inland saline aquaculture in Australia.

2. Evaluate likely obstacles and limitations to the commercial expansion of inland saline aquaculture and the ability for R&D to address these limitations.

3. Develop an R&D plan to address these obstacles and limitations in consultation with the aquaculture industry and related disciplinary experts (Part 1).

4. Document the distribution and characteristics of inland saline groundwaters and their potential use for the farming of aquatic organisms (Part 2).

7. METHODS

7.1. Steering Group Formation

- A small interdisciplinary steering group (representatives from industry [such as NAC and other relevant groups], research and management) was formed to provide expert input into the development of the R&D Plan (Part 1). Members of the Steering Committee met with the Consultant appointed to help prepare the R&D Plan individually and then collectively in a workshop to review and prioritise R&D activities.
- The type of inland saline water resources identified by the Steering Committee to have the highest priority for commercial aquaculture developments were identified. These were then nominated as key types of resources to help focus the Resource Inventory and Assessment component of the project (Part 2).

7.2. Preparation of the Resource Inventory and Assessment

A decision was made not to employ someone directly to undertake this aspect of the project (as was originally proposed) but to contract out the task to a consultant. This decision was taken because of the importance of knowing where the relevant information was located and the obvious experience some of the consultants had with this compiling similar types of inventories. A second "Expression of Interest" was drafted and sent to all respondents from the first advertisement. There were four excellent applications. The successful applicant, Atech Group, was selected on the basis of price and demonstrated experience with water resource inventories.

8. INLAND SALINE AQUACULTURE: A RESOURCE INVENTORY AND ASSESSMENT

8.1. Executive Summary

The objectives of this inventory project were:

1. To undertake an inventory of key saline surface and groundwater resources that may be suitable for inland saline aquaculture.
2. To undertake a preliminary assessment of the suitability of identified resources for the establishment of hatchery or adult fish production aquaculture.

Information was identified and collated from a wide range of sources, including the Internet, abstracting and subject-specific databases, agency libraries, unpublished reports, the scientific literature, as well as discussions with agency staff. Broad screening criteria were used to avoid collecting detailed information and assessing resources that are clearly unsuitable for the establishment of a saline aquaculture industry.

A diverse range of saline water resources was identified as having potential for inland saline aquaculture. These resources included:

- ❖ Existing large-scale groundwater interception schemes and associated disposal basins located in three main areas of the southern Murray-Darling Basin (see Figure 1). These were:
  - the Riverland Region of SA;
  - the Sunraysia Region of Victoria and NSW; and
  - the Riverine Plains west of Shepparton in northern Victoria.
- ❖ A number of new proposed and planned saline groundwater interception schemes in these same regions.
- ❖ Permanent natural saline lakes in Victoria, specifically:
  - the Kerang Lakes on the Riverine Plains near Kerang; and
  - the Western District Volcanic Lakes near Colac.
- ❖ Saline and brackish groundwaters from sedimentary basins and fractured rock aquifers around Australia. These were found in all states except Tasmania (see Figure 2). A number of brackish geothermal groundwaters were also identified.
- ❖ Urban groundwater pumping to protect urban infrastructure and property in areas affected by dryland or irrigation-derived salinity (see Figure 3). These opportunities for cost-sharing were located in:
  - the Murray-Darling Basin; and
  - the wheat belt area of southwest Western Australia.
- ❖ Proposed shallow groundwater pumping in the Ord River Irrigation Area around Kununurra in northern WA.

Two other unusual saline water resources with exceptional aquaculture potential were also identified. These were:

- ❖ The proposed Esperance-Kalgoorlie seawater pipeline.
- ❖ Saline drainage water associated with coal mines in NSW and Queensland.

Thirteen criteria were developed for a preliminary assessment of the potential of these identified saline water resources for the establishment of hatchery or adult fish production aquaculture. These criteria dealt with the following areas:

- The availability and nature of the resource.
- The availability of land and freshwater.
- The nature of the surrounding environment.
- Existing infrastructure and services.
- Opportunities for cost-sharing.

Specific criteria and tentative weightings were developed which addressed different saline aquaculture requirements of different industry types (see Table 9.9). The aquaculture types used were:

- marine hatcheries;
- grow-out of stenohaline fish using recirculating facilities;
- grow-out of stenohaline fish using ponds;
- grow-out of diadromous fish using recirculating facilities;
- grow-out of diadromous fish using ponds;
- grow-out of freshwater native fish using recirculating facilities; and
- grow-out of freshwater native fish using ponds.

The application of the developed criteria to potentially suitable saline water resources provided an indicative assessment of the suitability in relation to the various aquaculture types.
A number of saline resources were identified as being attractive for a range of aquaculture types. These were in particular:

- The Esperance-Kalgoorlie seawater pipeline.
- Most groundwater interception schemes.
- Most of the Kerang Lakes.
- Urban groundwater pumping.
- The aquifers of the Murray Hydrogeological Basin.
- Coal mine drainage water.

The results are, however, a preliminary and indicative assessment using tentative scoring criteria, and often with limited resource information. Other potential saline water resources, such as the Western District Volcanic Lakes, could well score better under different criteria or weightings, or have other qualities that may make them more attractive to the establishment of saline aquaculture.

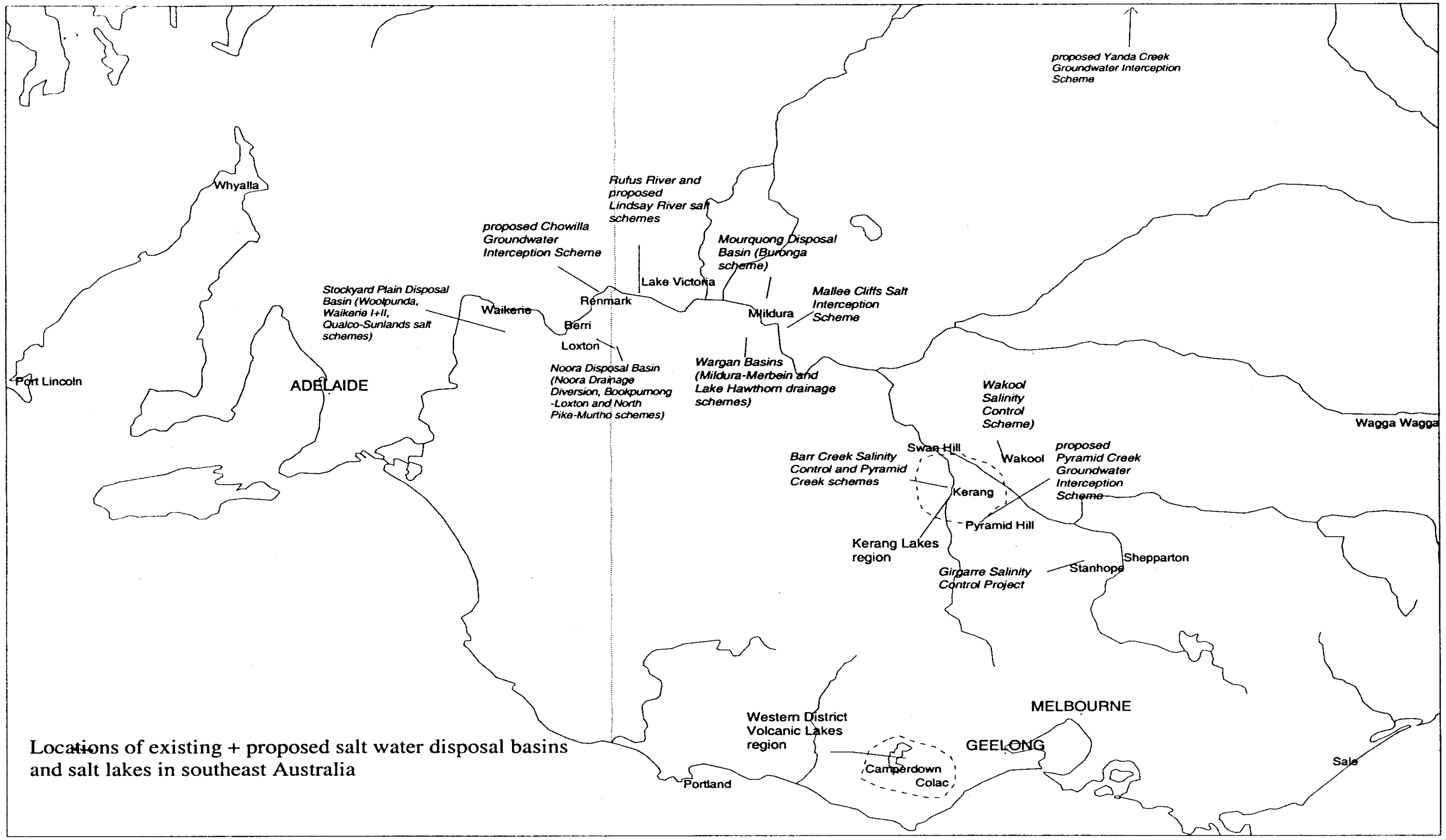

Figure 1: Locations of existing and proposed salt water disposal basins and salt lakes in southeast Australia

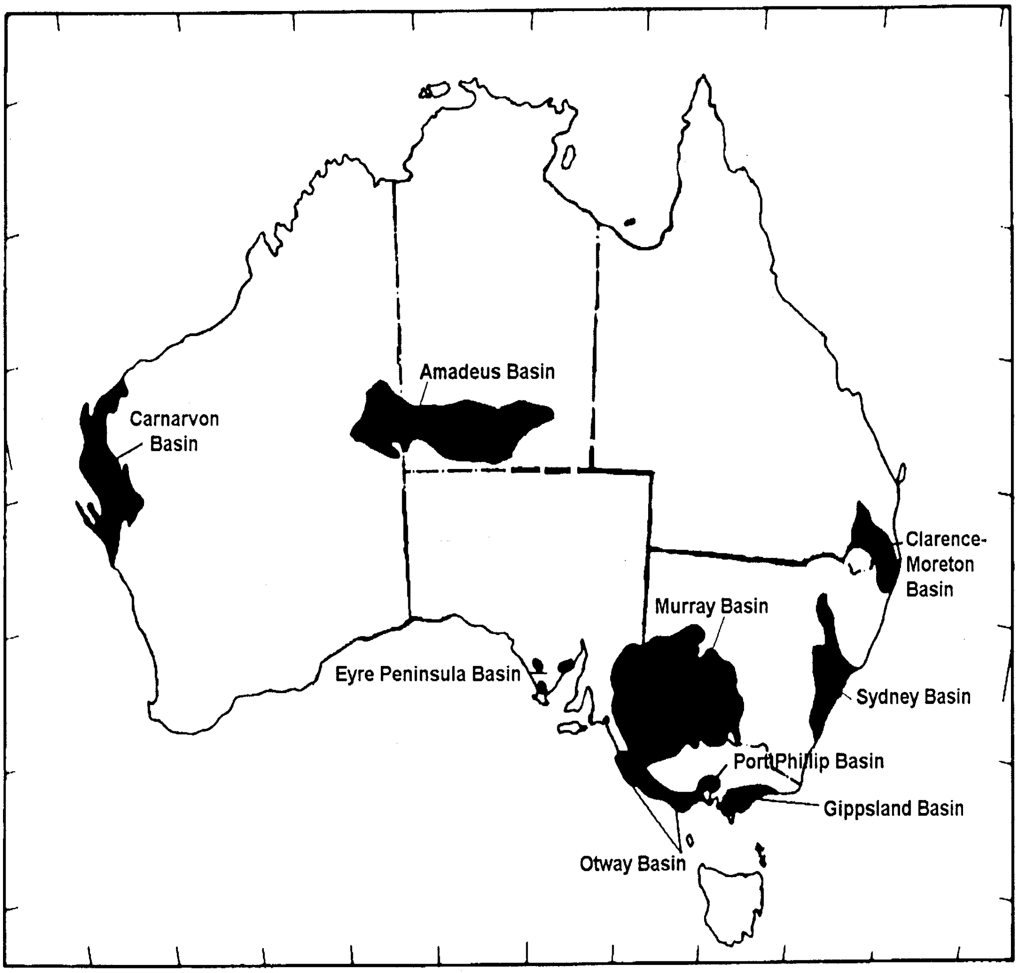

Figure 2: Locations of the major basins with the greatest potential for inland saline aquaculture

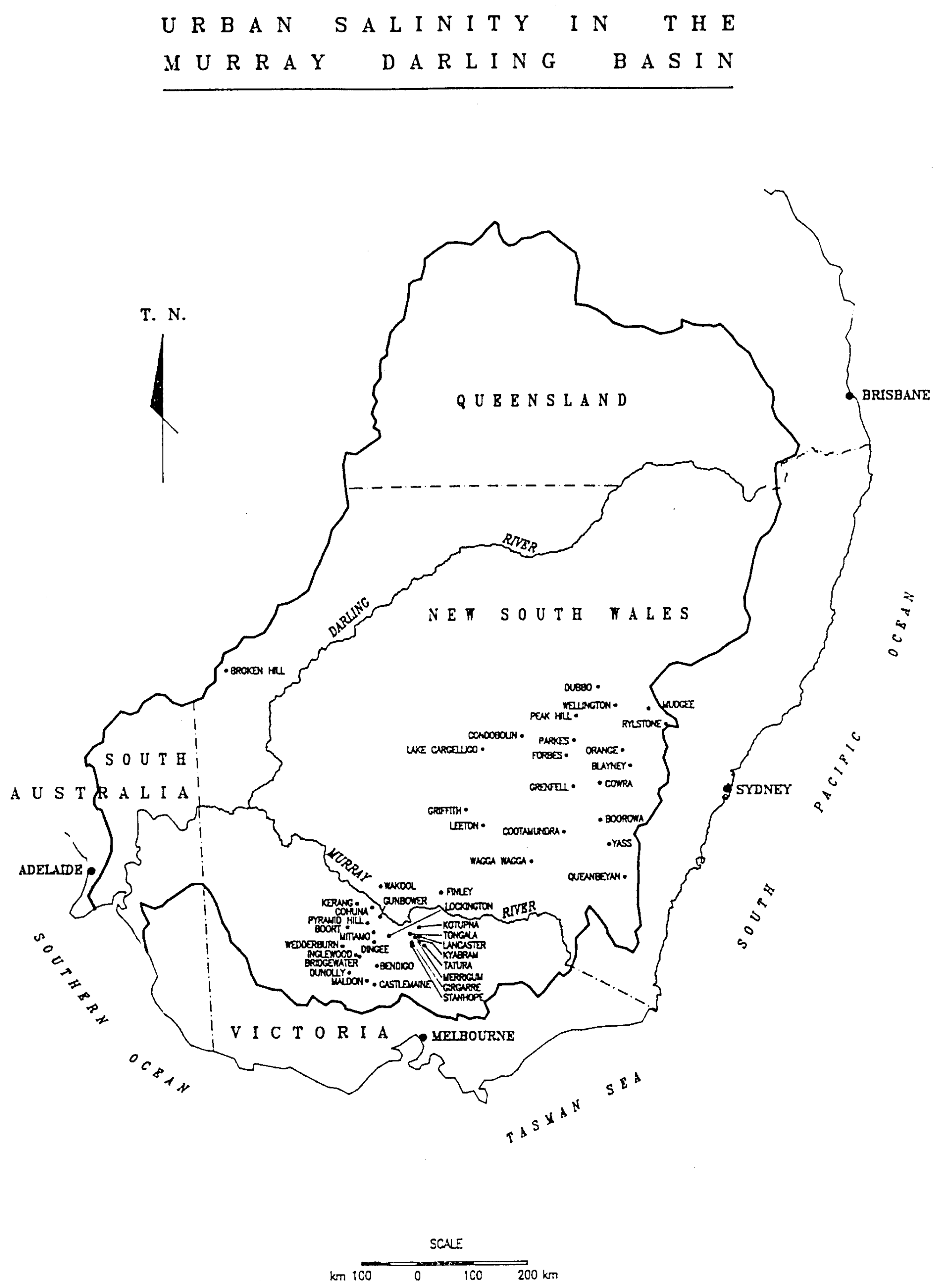

Figure 3: Urban salinity in the Murray Darling Basin

8.2. Context

Inland saline aquaculture has the potential to become an important emerging industry for Australia, and a number of research, scoping and pilot studies, based on finfish, crustaceans and algae, are already being undertaken in a number of states. This high level of interest was reflected at a national workshop on the subject in Perth in 1997, which explored the opportunities and constraints facing the development of inland saline aquaculture in Australia (Smith and Barlow 1999). The workshop identified as one of its priorities, the need for the development of a strategic plan to coordinate and provide a national framework for research and development on inland saline aquaculture. Another important identified issue was the development of an inventory of inland saline water resources for potential use by aquaculturists.

NSW Fisheries at the Port Stephens Research Centre has received funding from FRDC, to support the development of an inland saline aquaculture industry. One of the key activities was to undertake an inventory and resource assessment of suitable inland saline water resources for aquaculture. These resources of interest are broadly of three principal types:

1. Saline water resources in irrigation areas, particularly where drainage water or groundwater is disposed of into evaporation basins - particularly in the Murray-Darling Basin, and southeastern Western Australia.
2. Other saline groundwaters.
3. Saline water in permanent or ephemeral lakes.

The development of a saline resource inventory would include general information on the location, size, ownership and surrounding infrastructure, so as to enable a general assessment of suitability of the resource for the establishment of an aquaculture industry. It would also include more specific information on the water quality characteristics of the resource to enable a general assessment of its potential suitability for saline aquaculture.
More specifically the inventory was to include the following information where this is available:

1. location and type of saline water;
2. ownership;
3. contact details;
4. brief description of the scheme or water system;
5. water supply volume and seasonal changes or flows;
6. estimation of availability of adjacent land for aquaculture;
7. nearby infrastructure;
8. opportunity for waste-water disposal;
9. water quality (salinity range; ionic composition, pH, nutrients etc.); and
10. ambient air temperatures.

8.3. Objectives and Scope of the Project

The specific objectives of the project are:

1. To undertake an inventory of key saline surface and groundwater resources on the Australian mainland that are potentially suitable for saline aquaculture.
2. To undertake an assessment of the suitability of identified saline resources, their location and surrounding infrastructure for the establishment of various types of aquaculture industries. This may be hatcheries or adult fish production.

The following points have been agreed upon to assist in defining the scope and limitations of the project:

- ❖ The primary focus of the study will be on evaporation or disposal basins associated with groundwater pumping schemes in the irrigation areas, particularly those in the Murray-Darling Basin, and where they exist in southeastern Western Australia. This follows identification of these areas in the national R&D plan as having the highest potential for aquaculture.
- ❖ The project will also examine other significant saline groundwater resources in shallower aquifers, especially from the prospective use of these resources for marine hatcheries.
- ❖ The project will also evaluate the resource potential of significant permanent saline lakes. Opportunities are more limited for use of ephemeral saline resources. It is noted nevertheless that an assessment of the aquaculture resource potential of ephemeral Western Australian lakes is currently being undertaken.
- ❖ Estuarine lakes will not be considered in this inventory
- ❖ It was agreed that the emphasis of the study would be on New South Wales, Victoria, South Australia, southeast Queensland, particularly in the Murray-Darling Basin, and the southwest of Western Australia. Given the limited resources it was decided that the Northern Territory and Tasmania would not be included in this scoping review.
- ❖ The waters of interest to saline aquaculture range from virtual freshwater to seawater and beyond. The wide salinity range reflects the fact that many marine and freshwater fish can be acclimatized to brackish water. Practically this study has largely limited itself to consideration of waters in the range of 3,000 to 75,000 mg/L of salt.
- ❖ Dual fresh and saline water supplies are of particular interest to saline aquaculture, because of the potential for blending of water to achieve or maintain salinities as well as other production aspects.
- ❖ The ionic composition of water resources can be important in regard to saline aquaculture and should be characterised where possible. Deficiencies in composition in comparison with seawater should not however, preclude consideration of their potential use for aquaculture, as these may be able to be overcome by inexpensive remediation.
- ❖ The size of evaporation basins or ponds for potential use in aquaculture is variable, and can range from several tens to hundreds of hectares. Similarly the minimum volume of water resource required varies depending on the nature of the aquaculture industry, but has been taken as 50,000 L/day (~18 ML/yr).
- ❖ The potential capacity to dispose of saline wastewater from aquaculture - which can be in the order of 10% of total water use per day – has to be considered as an important issue.
- ❖ The broad focus of this study is saline aquaculture associated with hatcheries, finfish, crustaceans and shellfish production – it will not deal with issues associated with saline algal aquaculture.
- ❖ There are different resource and infrastructure requirements for hatcheries, intensive recirculation grow-out facilities and intensive grow-out ponds for stenohaline, diadromous and freshwater fish. Details of the requirements for these various types of aquaculture have been developed in consultation with Geoff Allan and Stuart Fielder from NSW Fisheries.

8.4. Approach and Methodology

The following approach was adopted for this study:

1. Define criteria for an initial screening of inland saline water resources.
2. Identify potentially suitable saline water resources.
3. Collate information on identified saline water resources.
4. Develop criteria to assess the suitability of inland saline water resources for various types of aquaculture.
5. Assess and categorise the suitability of inland saline water resources for various types of aquaculture.

Each of these steps is briefly elaborated below.

8.4.1. Define Criteria for Screening Inland Saline Water Resources

This is the initial screening process for selecting inland saline water resources or areas for more detailed assessment for potential aquaculture use. An initial set of screening criteria required for this task, was broadly defined at the first project meeting. However, it was soon recognized that in many cases at a broad national scale it would not be possible to apply quantitative criteria. Consequently, some subjective and qualitative criteria - based nevertheless on common sense – were developed and used. The application of these criteria – as indicated below – was to help focus on saline water resources that had most potential for the establishment of an aquaculture industry. The nature of the screening criteria used were:

- ❖ Broad geographic regions or areas of interest.
  - Southeast Australia.
  - The Murray-Darling Basin.
  - Southwest Western Australia.
  - Other locations around Australia on an *ad hoc* basis.
- ❖ Saline water resources of interest.
  - Evaporation basins and saline groundwater disposal schemes (including potential schemes) in the Murray-Darling Basin and southeast WA.
  - Saline water from shallow and deep aquifers.
  - Saline water in permanent saline lakes in Victoria.
  - Other potential saline water resources.
- ❖ Magnitude and reliability of the saline water resource - volume, area or flow.
  - Groundwater or drainage water disposal basins - a minimum pumped volume of ~50 x 10^3 L/day (~18 ML/yr) or a minimum volume of 2 ML. Continuity of supply was considered an important consideration for this type of resource.
  - Natural saline lakes - a minimum volume of 900 ML; a minimum lake area of 10 hectares (ha), and a minimum mean lake depth of 1.9 m. These criteria recognise that lake volumes are largely a function of rainfall and run-off, and that the lakes serve important nature conservation functions.
  - Groundwater aquifers - indicative bore yields of at least 2 L/sec (~17 x 10^4 L/day) and salinity levels above 2,000 mg/L.
- ❖ Degree of proximity to communities, infrastructure, power and transport.
  - Within 50 km of basic infrastructure and community services - in exceptional cases some infrastructure or service elements could be up to 100 km away.
- ❖ Availability of freshwater.
  - The initial assessment was based on the likely availability of freshwater, such as from an irrigation system or a nearby river such as the River Murray. The actual availability of

water was not considered as this might need to be bought at commercial rates or otherwise obtained.

- ❖ Compatibility and/or environmental sensitivity of the saline water resource and surrounding land uses with a saline aquaculture industry.
  - Incompatible land uses include National Parks or reserves, native title land or urban areas. However saline wetlands listed in Ramsar or Important Wetlands in Australia directories were not excluded from consideration, as such listing does not preclude other uses such as aquaculture.

The objective of this task is to avoid collecting detailed information on and assessing those resources which are clearly unsuitable for the establishment of a saline aquaculture industry. In undertaking this screening task Atech Group noted the stated preference of the Project Manager for fewer but potentially more suitable resources to be evaluated in greater detail, rather than more resources assessed in lesser detail.

Another important criterion in addition to the above relates to the issue of continuity of resource supply. This is particularly important in regard to saline disposal basins, which had been identified as potentially attractive for inland saline aquaculture. In many cases these only receive saline drainage or groundwater during certain times of the year, and even then intermittently.

8.4.2. Identify and Collate Saline Water Resource Information

Library searches were undertaken at a number of State and Commonwealth agencies and departments to obtain information on inland saline water resources. These included:

- ❖ Murray-Darling Basin Commission (MDBC);
- ❖ Australian Geological Survey Organisation (AGSO);
- ❖ CSIRO Land &Water (CSIRO L&W);
- ❖ NSW Department of Land and Water Conservation (DLWC); and
- ❖ Victorian Department of Natural Resources and Environment (DNRE).

The internet and electronic abstracting databases such as Streamline were searched, as were a number of subject-specific databases and inventories dealing with surface and groundwater resources. One of the more important of these was the database inventory of saline disposal basins in the Murray Basin developed by AGSO. Information was also obtained from the ‘grey literature’ - unpublished internal agency reports, for example, salt disposal basins inventory assessment reports. Documents produced for the review of the MDBC’s Salinity and Drainage Strategy also provided information on salt disposal schemes in the Murray Basin. In many cases specific detailed information on salt interception schemes was obtained through personal discussions with the relevant individuals. The scientific literature also provided useful information particularly in relation to natural salt lakes.

Selected saline water resources were additionally screened in relation to the quality and completeness of the available information, to ascertain whether they warranted further and more detailed examination and evaluation.

8.4.3. Develop Criteria to Assess Suitability of Saline Water Resources for Aquaculture

This task involved the identification and development of criteria for use in undertaking a more detailed assessment of the suitability of selected saline water resources for seven broad aquaculture types as follows:

- hatcheries;
- intensive recirculation grow-out facilities for each of stenohaline, diadromous and freshwater fish; and
- intensive grow-out ponds for each of stenohaline, diadromous and freshwater fish.

A matrix relating each of these seven broad types of saline aquaculture to a range of resource, infrastructure, environmental and other criteria was developed by Bob Banens (Atech Pty Ltd), Geoff Allan and Stewart Fielder (NSW Fisheries) (see Table 9.11).

These criteria involved:

- Aquaculture-specific criteria such as saline volume, salinity range, chemical composition.
- More generic criteria relating to land use and availability, soils, power and freshwater supply, community infrastructure and transport services.
- Other criteria such as environmental sensitivity and cost sharing opportunity.

Each assessment criterion was divided into three or four assessment levels that related to its suitability for the various saline aquaculture categories. Each of these assessment levels was allocated a numerical value relating to its degree of suitability, and in relation to the criterion's importance vis-à-vis other criteria. Consequently, the summing of points for all of the assessment criteria enables an overall characterization of a saline resource with respect to its suitability for each of the seven broad saline aquaculture types.

8.4.4. Assess and Categorise the Suitability of Saline Water Resources

Whilst most of the assessment criteria are quantitative, it needs to be recognised that in many instances incomplete information necessitated a subjective judgement, based on the available information. The individual criterion scores for each water resource for each aquaculture type would be provided in a series of tables, so as to enable updating with additional or better information. An overall score and ranking of saline water resource according to their suitability for the various saline aquaculture types will also be provided.

8.4.5. Structure of the Rest of the Report

The remainder of the report will consist of a series of chapters describing various types of saline water resources potentially suitable for aquaculture, a chapter on resource assessment and a reference and resource list. The structure and content of the following chapters is provided below:

- **Salt Disposal Basin Database**: this chapter will discuss the MDBC disposal basins database, issues associated with disposal basins and the results of its interrogation.
- **Salt Interception & Disposal Schemes**: this chapter provides details of large groundwater interception schemes currently in operation in the Murray-Darling Basin.
- **Proposed Salt Interception Schemes**: this chapter provides details on new, proposed or planned groundwater interception schemes for the Murray-Darling Basin.
- **Permanent Victorian Saline lakes**: this chapter will discuss the possibilities of the saline Kerang and Western District volcanic lakes for aquaculture.
- **Saline Groundwater Resources**: this chapter provides an overview of potentially suitable saline groundwater resources.
- **Other Saline Water Resource Opportunities**: this chapter explores various saline water resources - largely shallow groundwater and water-table related - that may provide other opportunities for aquaculture.
- **Resource Assessment Criteria**: this chapter discusses the resource assessment categories and criteria, and provides a table that summarises the specific requirements and weighting in relation to the various types of saline aquaculture.

- **Saline Water Resource Assessment**: this chapter briefly discusses, and then presents the result of the assessment of each identified resource in relation to the various saline aquaculture types in a series of tables.
- **References and Source Materials**: this chapter lists the references and other relevant resource materials.

8.5. Salt Disposal Basins

8.5.1. Overview

The Murray-Darling Basin, the southeast of Western Australia and many other arid areas of Australia contain vast stores of salt in the soil and shallow groundwater. The origin of this salt is mainly the small quantity of sea-salt present in rainfall, that has become accumulated in the soil over millions of years (cyclic salt) as a result of high evaporation and low run-off in an arid climate (e.g. Gunn and Richardson, 1979). In some regions, the release of sea-salt trapped in marine sediments (connate salt) may also be important (e.g. Johnson, 1980). Salts derived from the weathering of minerals, such as from igneous rocks, are generally of minor importance except in certain circumstances (e.g. Banens, 1987).

In undisturbed environments such salt is largely locked low in the soil profile out of harms way. However, intensive irrigation and extensive land clearing have resulted in rising water tables that have mobilised such salt and brought it to the land surface. This has resulted in the degradation and salinisation of agricultural and natural land, reduced the quality of water resources, and resulted in a loss of agricultural productivity. The collection and diversion of irrigation drainage water, and the pumping of saline groundwater to salt disposal basins has been used to reduce regional water tables, as well as salt accession to the River Murray. This use of evaporation basins for the disposal of saline water was first used in 1917. Their use is now commonplace in land and water management strategies in irrigation areas along the River Murray and elsewhere, and now number around 190. Typically such disposal basins are topographic depressions in the landscape, salt lakes, shallow freshwater lakes, clay pans and small-scale constructed basins.

There has been an increasing shift in recent years from local disposal basins located within or adjacent to irrigation areas – often on the flood plain - to large actively-managed disposal complexes - located off the flood plain - for major irrigation regions. At the same time there has also been an exploration of the effectiveness of managing salt on the farm through the use of small on-farm disposal basins.

8.5.2. The MDBC Salinity & Drainage Strategy

For many years prior to 1988 there had been considerable debate between South Australia, Victoria and New South Wales about the causes, responsibilities and costs of salinity problems in the River Murray. By and large the costs from river salinity were incurred in South Australia, which considered that the problems had been caused to a significant extent by the actions of the upper States. In 1988, the newly formed Murray-Darling Basin Commission developed the Salinity and Drainage (S&D) Strategy as a framework for joint government action to manage the salinity problems in the Basin. Its objectives were to improve water quality in the River Murray for all beneficial uses. These included the environment, the arresting of land degradation and undertaking of rehabilitation to enable sustainable resource use, and the protection of natural environments and ecosystems from salinity impacts. The primary focus of the S&D Strategy was on irrigation-related salinity.

The initial activity undertaken through the S&D Strategy was a program of salinity mitigation works to reduce river salinity at Morgan in South Australia by some 80 EC from the existing 600 EC average. This involved the construction of a number of new groundwater interception schemes such at Woolpunda, Waikerie and Mallee Cliffs, as well as improvements to the existing Buronga and Mildura-Merbein groundwater interception schemes. Such schemes would be funded equally by the three States and the Commonwealth. A ‘salinity credits’ system was also introduced, with each State, following the construction of these interception schemes, initially entitled a credit of 15 EC (at Morgan). State Governments were also responsible for any future development within their State that had a salinity impact. They had to ensure that any such development was either covered by their available salinity credits, or linked to new salinity mitigation works which generated additional credits.

Dramatic increases in the levels of saline shallow groundwater as a result of vegetation clearance – dryland salinity – has been demonstrated over extensive areas of the Murray-Darling Basin. This major and widespread problem is not only increasing the salinisation of land, but also increasing the salt levels of streams and rivers including ultimately the River Murray at Morgan. This emerging issue and other factors have prompted a review of the Commission’s S&D strategy to focus it more broadly at general groundwater salinity rather than just salinity and drainage associated with irrigation. The outcomes of this review are not clear at this point in time, but may well involve large-scale salinity mitigation measures including in all probability additional groundwater interception schemes.

8.5.3. Sources of information on salt disposal basins

Within the Murray-Darling Basin information on saline disposal basins has been systematically collated into a number of reports and an electronic database. The focus of these reports has been on the disposal basins per se rather than any drainage, salt or groundwater interception schemes that they are part of. Information on the latter is much more fragmented and dispersed, and has consequently not only proved more difficult to obtain, but also difficult to get a clear picture of the current status of these schemes.

The key information source for saline disposal basins is a 3-volume report Inventory of saline disposal basins, Murray Basin (Hostetler & Radke, 1995 (vols 1 & 2) and Sedgmen, 1999 (vol 3)). The information of these reports is also available in a relational database that consists of a number of components (Brodie *et al.,* 1995):

- ❖ a GIS coverage storing the disposal basin outlines (documentation provided in Hostetler *et al.,* 1997);
- ❖ GIS coverage of representative cross-sections showing borehole lithologies and stratigraphy in the vicinity of disposal basins;
- ❖ scanned images of aerial photography;
- ❖ rectified, digital aerial photography (River Murray Mapping);
- ❖ an ArcView interface; and
- ❖ internet accessible documentation and software downloads.

Additional information on disposal basins was also obtained from saline disposal basin evaluation reports (Simmons *et al.*, 1999; DENR, 1995; Sinclair Knight Merz, 1996).

For salt interception schemes and associated disposal basins, various reports and publications dealing with aspects of construction, operation and performance assessment have, where they were available, been an incomplete source of information. This was supplemented by discussions with key individuals in organisations involved in the planning, design, operation or management of groundwater interception schemes. These include:

- Pradeep Sharma and Bob Newman of the Murray-Darling Basin Commission;
- Mike Ernie and Mike Williams from NSW Department of Land and Water Conservation;
- Ray Evans from the groundwater group of the Bureau of Resource Sciences (formerly part of AGSO);
- Keith Collett, Rob O'Brien and Danielle Heffer from the Victorian Department of Natural Resources and the Environment;
- Peter Forward from SA Water;
- John Ginnivan and Peter Dickinson from Goulburn-Murray Water;
- Carl Mathers from Murray Irrigation Ltd;
- Matt Kendall from Sinclair Knight Merz; and
- Gavin Privett from Pyramid Salt Pty Ltd.

8.5.4. Issues Relating to Salt Interception Schemes and Disposal Basins

This review of saline disposal basins and saline groundwater interception schemes and discussion with key individuals has highlighted a number of issues that have important implications for any potential saline aquaculture industry. These are listed below in dot point form:

- Many disposal schemes, based on tile drainage, groundwater seepage or even comprehensive district drainage systems, only pump saline effluent on a periodic basis - consequently some of these disposal basins may well dry out during summer or extended dry periods. Notwithstanding this, the volumes associated with larger disposal basins could nevertheless provide opportunities for an aquaculture industry to conserve water to cover such periods. Furthermore, pumping of local saline groundwater might also enable supplementation of water resources at such times.
- Only groundwater interception schemes pump water more or less continuously to disposal basins - even these often cease pumping during high flow periods in the river. There are only a limited number of such schemes in the Murray-Darling Basin, although the review of the MDBC's S&D Strategy is likely to see an expansion of their number.
- Many saline disposal basins are located on the River Murray flood plain, and are subject to periodic flooding either by design or otherwise. Consequently the salinities of such basins can vary dramatically according to prevailing hydrological conditions.
- The salinity levels of source water derived from tile drainage and shallow groundwater seepage schemes can also vary dramatically as a result of prevailing rainfall conditions. High rainfall can result in comparatively fresh water while extended dry periods can result in more saline effluent.
- Irrigation drainage water may from time to time be contaminated with chemicals used in irrigated agriculture – pesticides, herbicides or nutrients. The significance of such contamination, if any, and its potential impact on aquaculture is not clear at this stage (see e.g. Bowmer *et al.,* 1995). The impact of highly toxic pesticide endosulfan in cotton farm effluent on fish and other aquatic organisms is well known (Bowmer *et al.,* 1996).
- Shallow groundwater, such as that associated with irrigation drainage systems tends to have somewhat higher nutrient levels, whereas deeper groundwater, such as associated with larger groundwater interception schemes, tends to low in nutrients.
- Regional groundwater-interception schemes, on the other hand, not only provide unadulterated saline groundwater, but also water of a relatively constant salinity.
- The greater proportion of horticultural crops in the Riverland Region of South Australia, and the Sunraysia Region of Victoria and NSW is provided with tile drainage, which was linked to local evaporation basins constructed nearby on the flood plain. These basins were not only often located in environmentally sensitive areas, but were of inadequate capacity, and generally increased the rate of saline groundwater inflow into the River Murray.
- Many of the disposal basins located on the environmentally sensitive area flood plain, rely on the effect of periodic flood flushing to scour away the accumulated salt. This is no longer a favoured approach to the saline water disposal, and coupled with other problems, has resulted

in an increasing tendency to pump drainage effluent to disposal basins located out of the flood plain.

- At the same time there has also a move away from smaller local schemes into larger regional complexes. Noora Evaporation basins in the Riverland has since 1983 taken drainage water from the Berri and Renmark irrigation districts, and is likely to take additional irrigation drainage and intercepted groundwater from the Loxton and Bookpurnong irrigation areas. Stockyard Plain near Waikerie is another example of a disposal basin which takes effluent from a number of schemes. It currently takes groundwater from the Woolpunda and Waikerie interception schemes, and likely, in the near future to take saline water from the Qualco-Sunland drainage and groundwater scheme.
- A number of new groundwater interception schemes are likely to be developed, and existing interception or drainage schemes expanded as a result of funding arising out of the new MDBC Salinity Strategy currently being developed for the Murray-Darling Basin.
- Saline water from groundwater interception schemes often contains high levels of iron bacteria that can result in biofouling of pipes and pumps which greatly impacts long-term pump performance. In-situ chlorination of groundwater by electrolysis is commonly undertaken to prevent the formation of such deposits of iron in pipe mains and pumps.
- In a few cases water from groundwater interception schemes is extremely corrosive or ‘aggressive’. Epoxy protective coating of pump components has had to be undertaken to minimise the impact of such corrosive saline water.

8.5.5. Specific disposal basin database search criteria

The general criteria developed to identify saline water resources potentially suitable for inland saline aquaculture required some modification to be usefully applied to the Disposal Basin Database. In particular a number of additional criteria were required, as follows:

1. The disposal basin must be in active use.
2. The disposal basins must be associated with larger or comprehensive drainage systems, or groundwater interception schemes. Local or isolated tile drainage and/or groundwater seepage disposal systems were not considered to supply an adequate or continuous water supply.
3. The disposal basin must be located off the River Murray flood plain. This is to ensure or avoid:
   - requirements in relation to environmental sensitivity;
   - isolation from native fish stock;
   - large and rapid fluctuations in salinity levels; and
   - problems associated with flooding.

8.5.6. Database Search Results

The application of the defined general criteria to the Murray Evaporation Disposal Basins Database yielded some 18 disposal basins that could potentially be suitable for saline aquaculture. Of these, a number were part of the same disposal complex, several were either too small and/or *ad hoc* in operation, or about to be decommissioned. This left 11 separate potentially suitable locations.

In the subsequent discussion it was generally considered to be more appropriate to focus on the salt interception schemes rather than their associated disposal basins. An outline of each scheme is provided in Table 1, with a technical summary for each scheme provided in Table 2.

Table 1: Outline of Salt Interception Schemes and Related Disposal Basins

Scheme/ Basin	Location	Nature	Managing agency
Woolpunda Groundwater Interception Scheme	Waikerie in the Riverland Region of SA	Saline groundwater from aquifers along the River Murray is pumped into Stockyard Plain Disposal Basin	SA Water
Waikerie in the Riverland Region of SA	Waikerie in the Riverland Region of SA	Saline groundwater along the River Murray is pumped into Stockyard Plain Disposal Basin	SA Water
Stockyard Plain Disposal Basin	Waikerie in the Riverland Region of SA	Currently serves the Woolpunda and Waikerie groundwater interception schemes. Will receive additional groundwater and irrigation drainage water from the Qualco-Sunland and Waikerie II schemes in the near future.	SA Water
Noora Disposal Basin	Near Berri and Loxton in the Riverland Region of SA	Receives irrigation drainage from Dishers Creek and Berri disposal basins that are part of a comprehensive drainage scheme for the area. Will take irrigation drainage and intercepted groundwater from the Bookpurnong-Loxton area in the future	SA Water
Rufus River Groundwater Interception Scheme	Near Lake Victoria in NSW ~80 km west of Wentworth	Groundwater seepage and pumped groundwater disposed of to a specially constructed basin nearby. Although located in NSW about 100 km east of Renmark in SA, it is managed by SA Water	SA Water
Mildura-Merbein Groundwater Interception Scheme	Mildura in the Sunraysia District of Victoria	Intercepted groundwater is concentrated in Lake Ranfurly on the flood plain and then disposed of to the Wargan Basins in the Mallee. Adjacent to the Lake Hawthorn Comprehensive Drainage Scheme	Goulburn-Murray Water
Buronga Salt Interception Scheme	In NSW near Mildura in the Sunraysia District	Intercepted groundwater is pumped to the Mourquong Groundwater Discharge Complex	Dept. Land and Water Conservation
Mallee Cliffs Salt Interception Scheme	In NSW near Mildura in the Sunraysia District	Intercepted groundwater is pumped to the Mallee Cliffs Disposal Basin	Dept. Land and Water Conservation
Wakool Evaporation Basins	Near Wakool in NSW	Large disposal basin complex serving shallow groundwater interception and comprehensive drainage systems	Murray Irrigation Ltd
Barr Creek Salinity Control Scheme	Near Kerang in Victoria	Saline surface and drainage water interception with disposal to lakes Tutchewop, Kelly and William	Goulburn-Murray Water
Pyramid Hill	Near Kerang in Victoria	Private local shallow groundwater interception scheme for land reclamation, salt production and aquaculture	Pyramid Salt Ltd
Girgarre Basin	Near Stanhope in the Shepparton irrigation area of Victoria	Shallow groundwater pumping scheme to reduce regional water tables with disposal into a specially constructed disposal basins	Goulburn-Murray Water

Most of these salt disposal schemes are based on groundwater interception, with a couple involving saline water-table pumping and/or comprehensive drainage schemes. They can be grouped into three main geographic regions corresponding to major irrigation regions and known areas of highly saline groundwater, namely:

1. the Riverland Region of SA;
2. the Sunraysia Region of northwestern Victoria and southwestern NSW; and
3. the Riverine Plains of northern Victoria and southern NSW.

8.5.7. The Riverland Region

The Riverland Region in South Australia is a major and relatively prosperous irrigation region on the River Murray near the NSW-Victoria border. The irrigation industry is based on horticulture, principally fruit and grapes for wine production, with various horticulture-related secondary industries such as wineries, fruit juice and fruit canning factories also found in the region. Grazing and cereal growing are other key land uses beyond the irrigated corridor either side of the River Murray. The Riverland Region has population of about 35,000, with major towns being Renmark (8,000), Berri (7,000), Loxton (7,000), Waikerie (5,000) and Barmera (4,500). Berri is located about 2.5 hours or 235 km by Sturt Highway east from Adelaide and 100 km west of Mildura. There is an airport in Renmark although there are currently no regular air services. There is also a railway near Loxton however this is only used for grain transport at certain times of the year.

The climate of the Riverland is characterised by long hot and dry summers, with mild winters and occasional frosts. Mean annual rainfall is very low at around 220 mm. Annual evaporation is 2,300 mm, and is high throughout the year exceeding precipitation in every month. The sandy soils of the Mallee High Plains of the region typically support mallee scrub vegetation. On the other hand, the River Murray flood plain is typically characterised by heavy gray plastic, often saline, clay soils, with river redgum and black box gums being the dominant vegetation type in the riverine corridor.

8.5.8. The Sunraysia Region

The Sunraysia Region extends on both sides of the River Murray from Nyah, just north of Swan Hill, to Lock 9, 60 km downstream of the Murray and Darling River junction. In this region the River Murray passes into the semi-arid mallee zone, with its wind-formed landscape, sandy soils and mallee scrub, much of which has now been cleared for agriculture. The River Murray flood plain corridor with its red gum forests, wetlands and rich habitat for aquatic and riparian fauna and flora provides a stark contrast to the semi-arid surroundings. The largest centre in the region is Mildura with a population of 21,000. The Sunraysia District in Victoria-New South Wales is centred on Mildura, Dareton and Red Cliffs. It is similar in character to the Riverland Region.

The average rainfall of the region ranges from 355 mm in the east to 280 mm in the west, most of which falls in autumn and spring. The average pan evaporation rate is about 2,200 mm - about 6 times higher than the average rainfall. Summers are long and hot, with temperatures often reaching more than 40^{o}C.

8.5.9. The Riverine Plains Region

The Riverine Plains of southern NSW and northern Victoria, stretching for some 250 km between Yarrawonga and Swan Hill, are the most extensive areas of irrigated land in the Murray-Darling Basin. The approximately 750,000 ha of land devoted to irrigation in this region can be broadly divided into four general areas - that centred on the Victorian towns of Kerang and Shepparton, and that centred on the New South Wales towns of Wakool and Deniliquin. Nearly half of the land in this region is under irrigated pasture or fodder crops, principally for dairying, fat lambs and beef cattle. The main crops are rice produced in the Deniliquin and Wakool areas of NSW, and fruit, grapes and vegetables in the Shepparton and Cobram districts. The latter produces some 80% of Australia's canned peaches, apricots and pears. Other crops include oil seed and grain legumes.

While large parts of the Riverine Plains are ideal for irrigation because of the generally flat terrain and appropriate soils, large areas of clay soils with low permeability and poor structure, such as the Kerang irrigation area, are not suitable for irrigated crops.

8.6. Salt Interception & Disposal Schemes

(See Table 2 for a summary of existing salinity control schemes and Appendices 2 & 3 for details on ambient air temperatures in representative irrigation areas and representative water chemistry in selected salt interception schemes respectively).

8.6.1. Woolpunda Groundwater Interception Scheme

The Woolpunda Groundwater Interception Scheme is designed to minimise saline groundwater inflows into the River Murray in a critical stretch of river between Overland Corner and Waikerie in South Australia. In this stretch some 200 tonnes of salt per day entered the river, and had a major impact on domestic, industrial and agricultural users downstream. It is a MDBC funded scheme that cost some $20.9 million to construct in 1992. It involved drilling about 50 extraction wells on both sides of the river to pump saline groundwater from the Murray Group aquifer, and dispose of it in the Stockyard Plain Disposal Basin located some 15 km west-southwest of Waikerie outside of the flood plain. The scheme prevents large volumes of high salinity groundwater entering the river system, and has effectively reduced river salinity at Morgan by 35.4 EC on average. It saves downstream users millions of dollars of salinity-related costs associated with loss of agricultural productivity, corrosion, and water treatment. The Woolpunda Scheme pumps about 7,000 ML of groundwater with a salinity of 20,000 mg/L (62,100 tonnes of salt) annually to the Stockyard Plains Disposal Basin (see below) located about 20 km to the southwest.

The Woolpunda Scheme has an annual operating and maintenance cost of $0.85 million, and is managed by SA Water. The relevant contact is Peter Forward from SA Water in Berri on 08-8595 2200 (or via-mail: peter.forward@sawater.sa.gov.au).

8.6.2. Waikerie Salt Interception Scheme

The Waikerie Salt Interception Scheme is a MDBC funded scheme completed in 1993 at a capital cost $7.6 million. It consists of some 17 bores and pumps along the river either side of Waikerie to intercept the saline groundwater mound that has developed under the Waikerie irrigation area. Besides reducing the water-table, its purpose is also to relieve pressure on the underlying Renmark aquifer which has resulted in significantly increased inflows of highly saline groundwater into the River Murray. The bores are connected through a single disposal main to the existing Woolpunda disposal main to the Stockyard Plain Disposal Basin. The annual disposal volume of the scheme is about 4,000 ML, at an average salinity of 15,000 mg/L - equivalent to an annual disposal of 23,700 tonnes of salt. The annual operation and maintenance cost of the scheme is in the order of $0.33 million.

The Waikerie Salt Interception Scheme has resulted in a benefit of 13.6 EC in the average salinity at Morgan. It operates continuously except for maintenance and breakdown purposes, and is operated by SA Water. The contact is Peter Forward from SA Water. (See Woolpunda above).

8.6.3. Stockyard Plain Disposal Basin

The Stockyard Plain Disposal Basin currently serves both the Woolpunda and Waikerie Schemes. The basin's use will be increased with further expansion of the Qualco-Sunlands and Waikerie stage II drainage and interception schemes. It is located about 15 km west-southwest of Waikerie in a low point in the mallee landscape. It lies within the Stockyard Plain Disposal Basin Reserve, a 1,870 ha parcel of land purchased by SA Water specifically for this purpose. The total depression area available for disposal is about 680 ha, of which the current lake water area is around 350 ha. At present there are 4 ponding areas and a 35 ha salina mainly managed for waterbirds. The typical depth of the ponds is 1-2 metres, although one small area has a maximum depth of about 6 metres. At the current supply level the ponds have a capacity of 5,300 ML, which can increase to 11,100 ML at full supply level - 1 m higher than at present.

A buffer zone of up to 800 m surrounds the Basin. The surrounding land is generally of low value with grazing to the north, and some dryland cereal cropping to the south. The soils are a mixture of wind-blown mallee sand and calcrete, with swales, a little more clayey. The disposal basin was designed to take into account the leaky nature of the soils. Freshwater is available at the basin site through an existing supply main that is now only used for domestic and stock water supply to a few farms in the surrounding area. Electricity is not currently available at the basin itself, although it is available about 5 km away. Consideration is being given to bringing power to the site to re-lift disposal water to sub-basins higher and further away in the complex. This would be in conjunction with the development of Qualco-Sunlands and Waikerie stage II drainage and interception schemes (see Sections 9.7.2 and 9.7.3). It has been suggested that land closer to Waikerie, with water and electrical services could be available at reasonable cost. Furthermore, access to saline water from the disposal main and the return of used water containing added nutrients from aquaculture was not considered to be a problem. Additional nutrients in the effluent could well be a plus stimulating biological activity for the large number of waterbirds that the basin currently hosts. The relevant contact is Peter Forward from SA Water.

8.6.4. Noora Drainage Diversion Scheme

The Noora Drainage Diversion Scheme is part of a comprehensive drainage system serving the Berri and Renmark irrigation areas in South Australia's Riverland. The tile drainage flows collected from these irrigation areas as well as some pumped shallow groundwater are first diverted to the existing Disher Creek and Berri evaporation basins. Following some accumulation and concentration in these basins, the water is then pumped to the Noora Disposal Basin. The Noora Disposal Basin was constructed to relieve small existing and inappropriately located disposal basins in the area, and is located in mallee country some 20 km east-southeast of Berri above and away from the River Murray flood plain. Saline effluent from the Disher Creek and Berri basins is pumped via a rising main to Bookpurnong, from which it gravitates to the Noora Disposal Basin. The Noora Basin is quite large, with up to 1,000 ha being available for disposal, although only 200 ha has ever been inundated. The existing Berri-Noora disposal main is significantly under-utilised, as in recent years the need for disposal from these basins has declined, in part because of improved irrigation practices. Inflow has been intermittent in recent years such that Noora Basin has become ephemeral, and has on occasions dried up. Consequently, its aquatic habitat that has previously attracted large numbers of waterbirds is under threat. Some 44,000 tonnes of salt annually are diverted from the river by the scheme, equating approximately to an annual disposal volume of 2,500 ML at a typical salinity of around 18,000 mg/L.

There is currently a proposal to significantly expand the use of the Noora Disposal Basin, by disposing of intercepted saline groundwater from the nearby Bookpurnong area, and drainage effluent from the Loxton Comprehensive Drainage Scheme. These additional flows could be directed to the Noora Basin through a new pipeline, or disposed of via the existing Berri-Noora disposal main. Given the Basin's available capacity, the additional flows from the combined Bookpurnong-Loxton scheme are more than capable of being accommodated. It would at the same time assure the Basin's future as an attractive aquatic habitat. Consideration is also being given to its use in conjunction with a possible North Pike-Murtho salt interception scheme located near Paringa.

Construction of stage 1 of the Noora Disposal Basin Scheme commenced in 1980, with stage 3 completed in 1984 at a total cost of approximately $12 million. Its annual operation and maintenance costs are around $80,000.

Noora Basin is a natural depression in good dryland cropping country devoted mainly to cereals. The soils of the area are coarse sandy soils, which are largely reworked Loxton-Parilla Sands, with the disposal basin designed to take advantage of the leaky nature of the soil. Electricity and freshwater are not directly available at Noora Basin, but are available nearby – local farms have a 'poly water network' from the river, and 'single wire earth return' (SWER) power lines. There is a railway line adjacent to Noora Basin that passes through Loxton to Adelaide, however it is only used at selected times of the year for grain transport.

8.6.5. Rufus River Groundwater Interception Scheme

Rufus River is located in NSW just north of the River Murray some 20 km from the South Australian Border. It is a short river joining Lake Victoria, a large natural depression of some 11,000 ha, to the River Murray. The Rufus River Groundwater Interception Scheme lies between the Riverland and Sunraysia regions, but will be considered as part of the Sunraysia region for the purposes of this review. Inflows of highly saline groundwater from the extensive Parilla Sands aquifer in the region to the Rufus River and nearby creeks, and ultimately to the River Murray have significantly increased as a result of the operation of Lake Victoria as a regulating storage. This at times results in water levels in Lake Victoria being up to 7 metres above that in the Rufus River and River Murray. It has been estimated, that under average conditions, this results in some 130 tonnes of salt per day entering the Rufus River, and ultimately the River Murray.

The Rufus River Groundwater Interception Scheme was commissioned in 1984 under the MDBC's S&D Strategy at a capital cost of $3.2 million to reduce saline groundwater inflow in the Lake Victoria area. The scheme annually diverts, on the average, around 1,400 ML of groundwater at a salinity of 30,000 mg/L from the Rufus River. This is equivalent to an improvement of 18 EC in median salinity at Morgan. The Scheme essentially involves the installation of 178 well-points in four lines, two east and two west of the Rufus River, each line with a well point pumping station and rising main. It also includes an additional pumping station to take saline groundwater seepage from the adjacent Brilka, Little Brilka and Mungo Creek system, and a small balancing storage created from a meander loop of the Rufus River. A major pumping station and rising main transfers water from the interception scheme to an evaporation basin some 5 km to the northwest. The scheme does not operate during high river flows, and on average pumps around 275 days per year. It has an annual operating and maintenance cost of around $200,000.

The specially constructed evaporation basin is located in saltbush country, and consists of a series of 5 or so depressions linked by excavated channels, with water retained by 2 embankments 1.3 and 0.5 km long. The maximum depth of these bays is less than 1 m. The land tenure around the disposal basin is a mixture of state forest, land owned by SA Water and leasehold. The leasehold land is used for grazing on the saltbush and dispersed mallee country. The soils around the disposal basin site are the typical sandy-calcrete soils associated with mallee country. There is no power or freshwater in the immediate vicinity of the disposal basin, although these are available at the interception site about 5 km away or from surrounding properties. Wentworth, 80 km to the east via the Sturt Highway, is the nearest town, while Renmark is 100 km to the west. The basin has negligible environmental value. Peter Forward from SA Water in Berri is the relevant contact.

8.6.6. Mildura-Merbein Groundwater Interception Scheme

A significant increase in River Murray salinity of up to 170 EC at regulated flows was measured between Mildura and Merbein, as a result of significant inflows of highly saline groundwater in this area. The volume of this inflow was estimated to be around 10 ML/day just from the Victorian side of the reach. In the late 1970s work was undertaken in both NSW - the Buronga/Mourquong Scheme - and Victoria - the Mildura-Merbein Interception Scheme - to intercept and divert this saline groundwater to evaporation basins. An upgrade to the Mildura-Merbein Scheme as part of the MDBC's S&D Strategy was undertaken in 1991. The salinity reduction in the River Murray, as a result of this Scheme are around 19 EC on average, and up to 70 EC during low flows.

The Mildura-Merbein Groundwater Interception Scheme consists of 17 groundwater interception bores with pumps located about 600 m apart and about 150 m south of the River between Mildura weir and the Merbein township. Disposal of the intercepted water from these bores is initially to Lake Ranfurly, a natural shallow depression located on the flood plain 1 km south of the Murray. The effluent from the groundwater interception scheme is first concentrated in Lake Ranfurly. It is then pumped via an existing Lake Hawthorn-Wargan basins reinforced cement (RC) pipeline to the Wargan evaporation basins located further away off the flood plain. Lake Hawthorn, immediately adjacent to Lake Ranfurly, has been used as an irrigation tile-drainage disposal site since 1968, with saline effluent, concentrated in Lake Hawthorn, disposed of to the Wargan basins via a 13 km long RC pipeline. The Wargan basins are 5 interconnected basins with a total capacity of 10,700 ML and a maximum surface area of 690 ha, and a net evaporative capacity of 10,200 ML/year.

Because some of the intercepted groundwater was found to be potentially aggressive, Lake Ranfurly has been operated as 2 separate basins through the use of a dividing bank. The east Lake Ranfurly basin (933 ML, 138 ha) is used to concentrate the aggressive water which is pumped separately to the Wargan basins via a PVC pipeline. The west Lake Ranfurly basin (482 ML, 81 ha) is used for the non-aggressive water.

The operation of the Mildura-Merbein Groundwater Interception Scheme is dependent on River Murray salinities and flow levels. The groundwater pumps operate when the flow in the Murray is less than 10,000 ML/day or when the flow at Merbein is between 10,000 and 20,000 ML/day and the river salinity at Merbein is above 420 EC. In reality however, the Scheme operates in all river flows up to 15,000 ML/day regardless of salinity. This means that the pumps only operate for 8 months or about 245 days per year, although this can vary significantly from one year to the next. Annual intercepted groundwater discharge to Lake Ranfurly is estimated to be 3,500 ML at a salinity of around 35,000 mg/L. About 61% of the salt inflow to Lake Ranfurly is pumped on to the Wargan basins - the remaining 39% is lost by seepage ultimately back to the interception pumps and the River Murray. Pumping from Lake Ranfurly to the Wargan basins is automatic and simply operates on the water level in the former. Annual disposal from both lakes Ranfurly and Hawthorn (the Lake Hawthorn Drainage Diversion Scheme) to the Wargan basins over the past 7 years has been around 6,000 ML at a salinity of 62,000 mg/L, totalling some 37,000 tonnes of salt.

The adjacent Lake Hawthorn Drainage Diversion Scheme receives irrigation drainage from the Mildura-Merbein area, stormwater from the city of Mildura as well as natural saline groundwater inflows. It is operated conjunction with the Mildura-Merbein Groundwater Interception Scheme by Goulburn-Murray Water. Lake Hawthorn has a volume of 4,400 ML, a surface area of 214 ha, and an average salinity of 3,000-3,500 mg/L. It has not been considered further in this report because of its location on the flood plain.

Lakes Ranfurly and Hawthorn are largely located within residential areas, although there is also some horticulture around Lake Hawthorn. Although electricity and freshwater are readily available at these sites their residential status makes them less suitable for aquaculture. Land use around the Wargan basins is private dryland cropping and grazing, although the Wargan basins site itself is Crown land. Power is available nearby, and while no freshwater is available at the site, it is likely to be available within 1-2 km. It has been suggested that one of the two disposal pipelines might be able to be used to provide freshwater when it is not being used for disposal. None of the basins has a high environmental value or status. Soils around the Wargan basins are the typical sandy soils found throughout the Sunraysia Region.

The relevant management contact is John Ginnivan from Goulburn-Murray Water at Tatura on 03-5451 0140.

8.6.7. Buronga Salt Interception Scheme

The Buronga Salt Interception Scheme in NSW 2-3 km north of Mildura, is designed to intercept highly saline groundwater entering this stretch of the River Murray, with the object of reducing average salinity levels at Morgan by about 11 EC. It was a NSW State scheme constructed in 1979 that was subsequently upgraded by the MDBC in 1991. The total capital investment in the Scheme is in the order of $3-4 million.

The Buronga Scheme consists of a line of 6 interception bores pumping highly saline groundwater from the Parilla Sands aquifer to the Mourquong Groundwater Discharge Complex about 4 km to the north. The Mourquong Complex is a large, natural, semi-circular topographic depression some 10 km in diameter located in mallee country outside of the River Murray flood plain. The disposal basin only covers a small area of about 320 ha in the southwest end of the complex, in what was formerly a partly vegetated playa containing a number of worked-out gypsum pits. The groundwater interception system pumps continuously when the flow in the River Murray is less than 10 ML/day, but is usually switched off during floods when dilution flows make salt interception unnecessary. On the average it operates for 270 days per year, with an annual running cost of around $160,000.

Since the Buronga Salt Interception Scheme commenced operation in 1979, some 2,200 ML waste water with an average salinity of 34,000 mg/L has been disposed of annually to the Mourquong site. Saline groundwater is disposed of at the southern end of the disposal basin, from where the water flows westward and northward to form a large shallow pond about 5 km^2 in area. Evaporation along this flow path has produced a brine whose salinity varies between 91,000 and 350,000 mg/L, depending on the season and rate of discharge of the disposal water. There is some experimental food-grade salt harvesting being undertaken at Mourquong and an application for a full mining licence is currently being processed.

Mourquong Groundwater Discharge Complex is adjacent and directly north of Stanley Wines vineyards on the Sturt Highway between Buronga and Dareton about 8 km from Mildura. It is opposite the vineyards on the other side of the highway. The immediate area around the disposal complex is Crown land vested in the DLWC. Besides the Stanley Wines, Simeon Wines, and a few other vineyards, the surrounding land is Western Leasehold land used for dryland grazing and occasional cropping. Small parcels of land should not be too difficult to acquire in the region. Power and freshwater supplies are not available on-site but are available nearby. The soils of the region are sandy loams with occasional calcrete and gypsum, which are underlain by Blanchtown clays. There is no environmental value or status associated with the Mourquong disposal basin. As a site for possible aquaculture development it is considered superior to the nearby Mallee Cliffs Scheme by DLWC's contact at Dareton, Mike Ernie (phone: 03-5027 4303).

8.6.8. Mallee Cliffs Salt Interception Scheme

The Mallee Cliffs reach of the River Murray around Lambert Island (about 25 km southeast of Mildura on the NSW side of the river) has long been known to receive significant volumes of highly saline groundwater from an underlying aquifer system. This 4 km stretch of the river can add over 30 EC at low flows, equating to an input of about 105 tonnes of salt per day. At times of high river-level, salt intrusion is prevented because water flows from the River into the Parilla Sands aquifer.

The Mallee Cliffs Salt Interception Scheme was developed and funded under the MDBC's S&D Strategy to reduce salinity levels in the lower River Murray. The Scheme was designed to reduce river salinity levels locally by about 18 EC, and by about 8.8 EC at Morgan in South Australia. It was completed in 1995 at a total project cost of $12.2 million, and has an annual operating and maintenance cost of $0.47 million.

The Mallee Cliffs Scheme involves a series of seven interception bores up to 45 m deep and spaced over 4 km adjacent to the river where large inflows to the river had been detected. Submersible pumps located at the bottom of these bores pump between 1.2-5 ML groundwater each day from the Parilla Sands aquifer. This water is disposed of via a 500 mm diameter polyethylene pipeline to a disposal basin located 14 km northeast of the river. This specially constructed 110 ha disposal basin is divided into four cells for management flexibility and to reduce wind-driven waves and associated bank erosion. Windbreaks have also been established at key locations around the basin. Water depth in the basin varies between 1 and 4 metres, and the basin has the capacity to contain water from 12 months of continuous pumping.

The system is operated continuously, but is shut down during high river flows, during which major maintenance is performed on the system. Typically pumping occurs on about 270 days per year. System operation is automatic, with system status information and alarms displayed at DLWC's Dareton office. The average annual pumped volume is in the order of 2,000 ML, with typical groundwater salinity levels of around 35,000 mg/L

An 80 mm diameter, 14 km long freshwater supply line and associated pump station provides freshwater at the rate of 2 L/sec at the basin site. It was installed to provide water for construction activities, the establishment of tree windbreaks, and to supply landholders affected by the construction of the disposal basin. Electricity is not available on site, but is available in the vicinity.

Most of the land surrounding the disposal complex is natural bush. The disposal basin is located adjacent to the Mallee Cliffs National Park on the north. Protection measures for the park and surrounding land have included the construction of clay cores in the embankment walls to restrict leakage to local shallow water-table aquifers. The bottom of the basin is located in Blanchtown clay. The disposal basin is located on land owned by the DLWC. The remaining land use around the basin is Western Leasehold land used for grazing. Soils are sandy loams with calcrete, but without gypsum. There is no environmental value or status associated with the basin. The relevant contact is Mike Ernie from DLWC at Dareton on 03-5027 4303.

8.6.9. Barr Creek Salinity Control Scheme

The Barr Creek drains a large part of the Kerang irrigation district. It intercepts shallow groundwater and also collects large salt loads from surface wash-off during heavy rain. Although its flow is quite small, Barr Creek is the largest point source discharge of salt (160,000-250,000 tonnes annually) to the River Murray. The Barr Creek Salinity Control Project was installed in 1968 and has the capacity to intercept about 20% of the average flow from this stream and pump it into evaporation basins. The remainder drains into the Lodden River and thence into the River Murray. Water from Barr Creek is pumped via a number of constructed channels into lakes Tutchewop, William, Little and Kelly that are located between Kerang and Swan Hill in north-central Victoria. The lakes form part of the Kerang Lakes system of natural depressions and associated lunettes - small crescent-shaped dunes on eastern lake margins - on the flood plain of the Avoca and Lodden rivers.

Until 1968 Lake Tutchewop was a predominantly freshwater terminal lake of the Avoca River system, and was subjected to annual flooding. With the construction of the Barr Creek-Tutchewop drainage channel, the lake was isolated to become the largest of the disposal basins for the Barr Creek groundwater-pumping scheme. The other disposal basins, lakes Little, Kelly and William, are also linked to the saline-water drainage channel. Formerly these were isolated salt lakes fed by saline springs, and were regularly harvested for salt. A MDBC project to trial harvesting of high-value salt is about to be undertaken in Lake Tutchewop by Geo-Processors. The objective of this production trial would be the separation of low-concentration (rare) salts from the dominant ordinary sodium chloride.

The annual volume of saline water diverted under the Barr Creek Salinity Control Scheme is in the order of 11,000 ML, with typical effluent salinity levels around 5,000 mg/L. The salinity range of the diverted water is from 3,500 to 8,500 mg/L, depending on the year and the time of the year. Capital cost for the whole scheme is in the order of $6 million, with maintenance and operating costs of less than $0.1 million.

Freshwater and power are available at Lake Tutchewop, but not directly available at the lakes William and Kelly sites, although they should be available within 1-2 km. Further detail on the lakes Tutchewop, Kelly and William are provided in Sections 7.3.1, 7.3.4 and 7.3.6. The principal contact for the scheme is John Ginnivan from Goulburn-Murray Water at Tatura on 03-5451 0140.

8.6.10. Wakool Salinity Control Scheme

The Wakool Salinity Control Scheme is a large regional groundwater interception scheme designed to reduce the extensive and severe waterlogging and salinity problems affecting properties in the Wakool area of southern NSW. The scheme was constructed in two stages in 1982 and 1988 from four farms totally degraded by the surface expression of saline groundwater. It consists of some 54 shallow groundwater pumps typically located at depths of 10-12 metres, and spread over an area of some 15-20 km. These pump around 13,000 ML per year through two main pipelines into two major disposal basins comprising around 1,600 ha in total. Each basin is divided into a series of holding and crystallisation ponds that are designed to hold water to a depth of 1 m. The salinity of the pumped groundwater is relatively constant at around 15,500 mg/L.

The scheme has been particularly successful at shallow groundwater control, with a greater than 2 m reduction in water-table depth over an area of around 25,000 ha. Lesser but still significant reductions in water-tables have occurred over a further 50,000 ha. This has resulted in a reclamation of formerly salinised farmland, and has also arrested and reversed the decline in agricultural productivity of the region. There have also been significant environmental, social and community benefits from the scheme. For example, the Wakool Shire Council has substantially benefited from the greatly reduced damage to roads and sewerage systems caused by shallow saline groundwater. Within the Wakool village (population 200) the water table reduction has enabled septic tanks to function properly again. Although not designed to reduce salinity in the River Murray, the Wakool Scheme now also results in a reduction in EC at Morgan.

Soils in the area of the disposal complex are generally medium clays to sandy loams. Three-phase power is available at the site, and while freshwater is not currently available on-site, it is available within a few kilometres. Murray Irrigation Ltd, the operator, is currently in the process of negotiating the construction of a freshwater dam and supply pipeline adjacent to the complex. The land surrounding the disposal complex is private freehold land and largely devoted to irrigated pasture and irrigated cereal production. Availability of land is not considered to be a problem – indeed it is suggested that surrounding landowners as well as Murray Irrigation would be particularly interested in the establishment of a new industry such as aquaculture. Two companies are presently considering or in the process of establishing a salt harvesting industry at the Wakool disposal complex. NSW Fisheries is currently trialing saline aquaculture in some of the Wakool ponds using snapper.

Originally built by the NSW government at a cost of $28 million, the Wakool Salinity Control Scheme is now owned and operated by Murray Irrigation. Annual operation and maintenance costs of the scheme are around $0.35 million. The relevant management contact is Carl Mathers from Murray Irrigation Ltd at Wakool on 03-5887 0400.

8.6.11. Girgarre Salinity Control Project

Girgarre Salinity Control Project is a small, sub-regional groundwater interception scheme. It was designed to reduce the widespread and severe waterlogging and salinity problems affecting properties in the Stanhope/Girgarre area of northern Victoria. The scheme consists of three shallow groundwater extraction pumps several kilometres apart and a 30 ha groundwater disposal basin. Two of the groundwater pumps discharge moderately saline water (about 2,500 and 5,200 mg/L) into the Deakin Main Drain, which discharges to the River Murray upstream of Echuca. The third pump discharges its high salinity groundwater (11,500 mg/L) to the Girgarre basin located about 5-6 km north of Stanhope, although at times of high flow this is sometimes also discharged to the Deakin Main Drain. The Girgarre evaporation basin is divided into three main bays, which are operated to progressively concentrate the salinity of the effluent. The disposal basin configuration also includes eight small bays that were initially used to trial various floor treatments. The Girgarre system is operated continuously during summer and automatically during winter, depending on groundwater and evaporation basin levels. It became fully operational in September 1987.

Capital cost of the scheme was around $1.3 million in 1986-1987, which equates to about $1.9 million in present day terms. Annual operating cost is about $0.03 million.

The annual disposal volume to the basin is around 410 ML/yr at a salinity of about 10,700 mg/L. Similar volumes are discharged to the Deakin Main Drain by the other two lower-salinity pumps. The salinity of bay A of the Girgarre basin is relatively constant at around 12,000 mg/L, while that of bay B fluctuates between 15,000 and 33,500 mg/L, but appears to be gradually increasing. The salinity of bay C has progressively increased from 33,000 to around 91,000 mg/L since operation of the scheme. There is some seepage beneath the basin. This is, however, being recycled by the high salinity pump, and should extend the life of the basin indefinitely.

Extensive monitoring has shown that the operation of the Girgarre Salinity Control system has effectively reduced groundwater levels over an area of 1,000 ha by at least 0.3 m. This has enabled not only reclamation of salt affected pastures, but also a significant increase in agricultural productivity. The relevant contact is Peter Dickinson from Goulburn-Murray Water at Tatura on 03- 5833 5681.

8.6.12. Pyramid Hill Groundwater Interception & Salt Harvesting Scheme

Decades of irrigation in northern Victoria have left farmland in the Loddon Plains degraded, saline, and with high water tables. Pyramid Salt Pty Ltd established a private groundwater interception scheme, initially for the purpose of land reclamation and salt harvesting, but which now also includes aquaculture. The scheme involves pumping saline groundwater from shallow,

low-yield, 'shoestring' 1-2 m thick sand (silt) aquifers located at a depth of about 10-12 m through a series of small pumps spaced about 400 m apart. These 15 pumps dispose of 100,000-150,000 litres of saline groundwater daily into a series of thirteen 0.3-1.0 m deep evaporation ponds covering an area of some 15 ha. Water travels through these ponds becoming progressively more salty until it crystallises out in the final ponds. Pyramid Salt produces salt with a range of purity for a variety of purposes, and is also looking at developing new value-added markets for salt, such as the use of sodium hydroxide in aluminium smelting. When in full production it is expected that the company will produce 5,000 tonnes of salt per year. Currently bagged salt for the market is trucked to Melbourne.

The salinity of the groundwater is relatively constant around 30,000 mg/L and, despite its shallow origin, is relatively nutrient free. Nevertheless, brine shrimp (Artemia) production is used to 'clean up' nutrients from the final brines. The brine shrimp are grown in heated tanks and harvested for sale to the aquarium industry. Brine shrimp production has to some extent been limited by the low nutrient-status saline groundwater, and ways of enhancing production and culture are currently being explored. The company is experimenting with nutrient-rich cheese factory effluent to enable more intensive brine shrimp production and harvesting. This is with the view of expanding beyond just supplying the aquarium industry to supplying the emerging fish farm industry. Although not the primary focus of the company, brine shrimp aquaculture has nevertheless become a profitable sideline.

The private groundwater interception scheme and its associated complex of evaporation ponds has achieved its goal of reclaiming degraded land. Pyramid Salt has improved the agricultural productivity and quality of some 750 ha of surrounding farmland that was previously degraded and unproductive. It is investigating the possibilities for expansion and for placing bores for salt production in other parts of the district. Pyramid Salt is one of the few permanent inland commercial salt producers in the Murray-Darling Basin, although a number of other companies do engage in opportunistic salt harvesting in the area. Since 1993 Pyramid Salt has invested about $12 million in the scheme, with a significant expense involved in lining the evaporation ponds with plastic. The need to line the ponds arose when the clayey soils of the area were found to consist of dispensable clays which proved unable to adequately hold salt water. (This was not a problem with freshwater). Annual operating and maintenance costs for the scheme are about $0.2-0.3 million. The contact person is Gavin Privett from Pyramid Salt on 03-5455 1299.

Table 2: Summary Information on Existing Salinity Control Schemes (see also Figure 1)

Scheme	Type of Scheme	Nearest Major Town	Capital Cost $million	Operation/ Maint Cost $million/ year	Year Developed	Pumped Volume ML/yr	Typical Salinity mg/L	No. of Bores or Wells	Surface Water Interception	Associated Disposal Basins	Number of Ponds or Bays	Surface Area ha	Max depth m
Woolpunda, SA	Groundwater interception	Waikerie, SA	20.9	0.85	1992	7,000	20,000	50 bores	no	Stockyard Plain Disposal Basin	4+	350-680	1-2 (max-6)
Waikerie, SA	Groundwater interception	Waikerie, SA	7.6	0.33	1993	4,000	15,000	17 bores	no	Stockyard Plain Disposal Basin	4+	350-680	1-2 (max-6)
Noora, SA	Drainage diversion	Berri / Loxton, SA	12.0	0.08	1984	2,500	18,000	not yet*	irrigation drainage	Noora Disposal Basin	na	200-1,000	na
Rufus River, NSW	Groundwater interception	Wentworth, NSW	3.2	0.20	1984	1,400	30,000	178 well points	some	Rufus River disposal basin	5	n.a.	<1
Mildura-Merbein, Vic	Groundwater interception	Mildura, Vic	#0.86	0.18	1980 & 1991	3,500 (LR) 6,000 (Wb)	35000 (LR) 60000 (Wb)	17 bores	Irrig drainage & stormwater	Lake Ranfurly & Wargan basins	2 (LR) 5 (Wb)	219 (LR) 690 (Wb)	na
Buronga, NSW	Groundwater interception	Mildura, Vic	3-4	0.16	1979 & 1991	2,200	34,000	6 bores	no	Mourquong Discharge Complex	1	320<	na
Mallee Cliffs, NSW	Groundwater interception	Mildura, Vic	12.2	0.47	1995	2,000	36,000	7 bores	no	Mallee Cliffs basin	4	110	1-4
Barr Creek, Vic	Surface runoff & groundwater interception	Kerang, Vic	6	0.10	1968	11,000	5,000	-	yes	Lakes Tutchewop, Little, Kelly & William	na	1,139 (total)	-
Pyramid Hill, Vic	Shallow groundwater interception	Kerang, Vic	~12	0.25	1993	37-55	30,000	15 wells	no	Relatively small constructed salt-harvesting ponds	13	15	0.3-1.0
Wakool, NSW	Shallow groundwater interception	Deniliquin, NSW	28.0	0.35	1982 & 1988	13,000	15,500	54 wells	no	2 large basins divided into crystallisation and holding ponds	na	1,600	1
Girgarre, Vic	Shallow groundwater interception	Stanhope near Shepparton, Vic	1.3	0.03	1987	410	10,700	3	no	Girgarre basin & Deakin Main Drain	3	30	0.4

Stage 2 cost only; na not available; LR Lake Ranfurly; Wb Wargan basins; * will have with new schemes

8.7. Proposed Salt Interception Schemes

8.7.1. Background

The increasing problems of salt accession to the River Murray, ongoing salinisation of productive land, and the review of the MDBC's S&D Strategy have led to a number of proposed or potential saline groundwater interception schemes. (See Table 3 for a summary of information and Figure 1 for locations). Most of these salinity schemes have a positive cost-benefit ratio based on the economic issues; however, environmental and local benefits often make such schemes very attractive. The major salt interception schemes proposed for the Murray-Darling Basin are listed below. Each of these schemes - which are in various stages of conception, planning, design and evaluation - is described in detail later.

Table 3: New Proposed or Planned Groundwater Interception Schemes

Scheme	Location	Status	Capital Cost $million	Operating Cost $million	Disposal Volume ML	Typical Salinity mg/L
Qualco-Sunlands Groundwater and Salinity Control Scheme	Waikerie, SA Riverland	under construction	7.2	0.26	3,200	25,000
Waikerie (Phase IIA & IIB) Salt Interception Scheme	Waikerie, SA Riverland	will proceed in near future	5	0.4	1,600	20,000
Lindsay River Groundwater Interception Scheme	Mildura, Sunraysia Vic.	will proceed in near future	4	0.25		<36,000
Pyramid Creek Groundwater Interception Scheme	Kerang, Victoria	will proceed in near future	10.1	0.15	2,200	30,000
Bookpurnong-Loxton Groundwater Interception Scheme	Loxton/Berri, SA Riverland	likely to proceed	11	0.45	4,500	11,000
Chowilla Groundwater Interception Scheme	Renmark, SA Riverland	likely to proceed	9.8	0.5		24,000-36,000
North Pike-Murtho Groundwater Interception Scheme	Renmark, SA Riverland	early stage of consideration	2-3		1,600	10,000
Yanda Creek Groundwater Interception Scheme	Louth, (Darling River) NSW	early stage of consideration				

8.7.2. Qualco-Sunlands Groundwater & Salinity Control Scheme

The Qualco-Sunlands Groundwater & Salinity Control Scheme is currently being constructed about 10-15 km northwest of Waikerie in SA's Riverland. Its purpose is to lower a rising groundwater mound underneath this expanding horticultural irrigation area, and reduce the consequent highly saline groundwater inflow into the River Murray. It is also intended to reduce crop losses, land degradation, enable future irrigation development in the district as well as reduce local flood plain degradation and cliff slippage. The Qualco-Sunlands Scheme would involve around 15 bores with a pumped groundwater volume of 3,200 ML annually at a salinity of 25,000 mg/L. This would result in an improvement in the River Murray salinity at Morgan of some 3.5 EC. The intercepted groundwater and drainage water would be disposed of to the existing Stockyard Plain Disposal Basin (see Section 9.6.3).

The capital cost of the Qualco-Sunlands Scheme of $7.2 million will be shared by state and federal governments and the community, with growers responsible for the operating and maintenance cost of around $0.30 million. The contact for the Scheme is Jim Zissopoulos, Project Manager, Qualco-Sunlands Drainage District Inc. on 08-8541 2165 (or via e-mail: qsddpm@riverland.net.au).

8.7.3. Waikerie Phase II Salt Interception Scheme

The Waikerie Phase II Salt Interception Scheme is an expansion of the existing Waikerie Groundwater Interception Scheme. It deals with the lateral flow of diluted groundwater through the Upper Murray Group aquifer into the River Murray and flood plain from the Little Toolunka reach immediately downstream of the existing interception scheme. This salt inflow was noted in the original scheme, but it was not considered cost-effective to intercept that at the time. Increasing irrigation in the Toolunka irrigation area and the Qualco-Sunlands Drainage District, and a build up of a groundwater mound under this area have steadily increased salt input to the river. The MDBC is keen to utilise the spare capacity of the existing Waikerie scheme to help reduce salinity at Morgan. The Phase II proposal would include the interception of saline groundwater at Ramco Bend and the Little Toolunk reach, and an extension of the groundwater-pumping scheme being constructed for the Qualco-Sunlands Drainage District (see above). Saline water from both schemes would be pumped to the existing Stockyard Plain Disposal Basin.

The Waikerie Phase II Scheme would involve some 15-18 bores pumping an indicative volume of 1,600 ML annually at a salinity of 20,000 mg/L. Capital cost of the scheme is estimated at $5 million with an annual operating and maintenance cost of $0.4 million. The management contact for this proposed scheme is Peter Forward of SA Water in Berri on 08-8595 2200, (or via e-mail: peter.forward@sawater.sa.gov.au).

8.7.4. Pyramid Creek Groundwater Interception Scheme

The proposed Pyramid Creek Groundwater Interception Scheme is located immediately downstream of Kow Swamp in the Kerang region of northern Victoria. The objective of this scheme is to prevent salt inflow to Pyramid Creek by intercepting saline groundwater over a 12.5 km reach of the creek. It would involve some 120 airlift pumps spaced 100 m apart on one side of the creek, intercepting 2,200 ML/yr of highly saline (~30,000 mg/L) groundwater. This would be pumped to a nearby 265 ha constructed and lined evaporation basin with salt harvesting capabilities.

Construction costs are estimated at $10.13 million, with annual operating and maintenance costs of around $0.15 million. Investigations are at an advanced stage and are being considered by the MDBC and Victorian Government. The Pyramid Creek Groundwater Interception Scheme is a public scheme that should not be confused with the private Pyramid Salt salt-harvesting and aquaculture scheme at Pyramid Hill nearby.

Contacts for further details on this proposal are Stuart Critchell from DNRE on 03-9637 8371, or Matt Kendall from Sinclair Knight Merz on 03-9248 3353.

8.7.5. Lindsay River Groundwater Interception Scheme

The Lindsay River is a 52 km long anabranch of the River Murray located approximately 100 km west of Mildura near Lake Victoria. The area between the Lindsay River and the River Murray is called Lindsay Island. Mullaroo Creek is another anabranch starting just upstream of Lock 7, which flows into Lindsay River, dividing it into the upper and lower Lindsay River, upstream and downstream of the junction. Collectively this is known as the Lindsay River Anabranch System.

The salt load into the Lindsay River is derived entirely from saline groundwater discharge from the Channel Sands and Parilla Sands aquifers. The salinities of these groundwater inflows range between 6,000 and 36,000 mg/L. Although this discharge is in part natural, the regulation of the River Murray, and the operation of Lock 7 have greatly exacerbated it. On average now, 60 tonnes of salt per day enters the Lindsay River - 50% from groundwater discharge into upper Lindsay River, and 50% into Mullaroo Creek and the lower Lindsay River. During flood recession 40% of this salt input is discharged into the Murray River, resulting in a 3.8 EC effect at Morgan. The remaining salt is stored in saline pools that form in the upper Lindsay River.

The primary objectives of the proposed Lindsay River Groundwater Interception Scheme are as follows:

- ❖ To reduce River Murray salinity at Morgan.
- ❖ To redistribute salinity dilution-flows for Mullaroo Creek that will no longer be required.
- ❖ To improve the upper Lindsay River habitat by lowering salinity and removing saline pools.
- ❖ To improve the flood plain forest environment on Lindsay Island by enabling artificial flooding and preventing rising saline groundwater tables.

The proposal is to construct between 10 and 20 tubewells at groundwater interception sites near the upper Lindsay River and Mullaroo Creek. The intercepted groundwater would be pumped either under the River Murray to the existing Rufus River disposal basin in NSW, or to a location near Lake Wallawalla in Victoria. The capital cost of the scheme is estimated to be about $4 million, with a recurrent operating and maintenance cost of $0.25 million. Contacts for this proposal are Mike Dudding, project design engineer with SKM, on 03-9248 3100, or David Lewis, DNRE on 03-9412 4352.

8.7.6. Chowilla Groundwater Interception Scheme

The construction of Lock 6 on the River Murray has been the primary factor raising groundwater levels over the Chowilla region, levels that have resulted in significant environmental degradation in the creeks and downstream river system. The region is a natural zone of groundwater discharge that has been greatly exacerbated by the operation of Lake Victoria as a regulating storage. The high salinity - 24,000-36,000 mg/L – and shallow groundwater are significant factors causing the environmental degradation.

The objectives of the proposed Chowilla Groundwater Interception Scheme are twofold:

- ❖ To reduce EC in the River Murray at Morgan.
- ❖ To protect the Ramsar listed wetlands of the Chowilla flood plain that are currently under severe threat. Ramsar listing means the wetlands are recognised as being of international importance and some 7,000-10,000 ha of high conservation-value flood plain will be protected under the proposal.

The Scheme would involve pumping saline groundwater from the Parilla Sands through 18 tubewells. This groundwater would then be disposed of to one of three possible disposal sites some 10 km north of the interception site, including the originally proposed Tilmy Dams site. The proposal has demonstrated a significant positive cost-benefit, and is now undergoing more detailed environmental and engineering studies and assessment. The indicative capital cost for the scheme is about $9.8 million, with an annual operation and maintenance cost of around $0.5 million. Natural Heritage Trust funding has been obtained to fully develop the proposal for funding consideration by the Murray-Darling Basin Commission. The area involved in the proposal is managed by the Bookmark Biosphere Reserve1 but is owned by SA National Parks. Although located in Mallee country, the soils at the disposal sites being considered are derived from Blanchtown clay. The surrounding land use is principally grazing, with a network of 'poly pipe' providing river water to stock troughs. SWER power may be available locally within 5-6 km from these sites. The contacts for this proposal are Leon Broster from the Murray-Darling Association on 08-8226 5995, or Peter Forward from SA Water in Berri on 08-8595 2200, (or via e-mail: peter.forward@sawater.sa.gov.au).

8.7.7. Bookpurnong-Loxton Groundwater Interception & Drainage Scheme

The Loxton and Bookpurnong irrigation areas are located on the River Murray in South Australia between the towns of Loxton and Berri. Recent surveys have shown that salt loads to the River Murray between Bookpurnong and Loxton are in the order of 160 tonnes/day, equating to a salinity of 36 EC at Morgan.

The Loxton Irrigation area was established in 1948 and now diverts more than 35 GL annually for irrigation of over 3,000 ha of grapes, citrus and other fruit. An extensive groundwater mound has formed under the Loxton irrigation area, which at its maximum height is 15 m above river level. A comprehensive drainage scheme for the area, begun in 1964, currently disposes about 5,500 ML of drainage water annually to the Katarapko Evaporation Basin located on the environmentally sensitive flood plain north of the River. This disposal volume represents only a third of the total drainage from the area - the remaining two-thirds going to the ever-increasing groundwater mound. The volume of drainage water intercepted by the system is increasing as the growth of the mound increasingly intersects subsurface farm drains. This has placed greater pressure on the Katarapko Evaporation Basin with resultant greater leakage into the River, and increased environmental impact on the surrounding wetlands. Salt load to the River Murray from Loxton and the Katarapko Evaporation Basin is in the order of 110 tonnes/day. The salinity of groundwater in the Loxton area is around 35,000 mg/L.

There has also been rapid and continuing expansion of irrigation at the nearby Bookpurnong area. It currently consists of 1,100 ha of irrigated crops, mostly grapes, citrus and almonds. The elevated character of the Bookpurnong area means that, with current irrigation practices, the irrigation area is unlikely to be threatened by water logging from the underlying groundwater mound. However the impact of irrigation at Bookpurnong on the river is high, resulting in an increased salt load to the River Murray of some 47 tonnes/day.

1 The Bookmark Biosphere Reserve is located on the River Murray at the state boundary with NSW and Victoria, and covers more than 600,000 ha, including 21 parcels of land ranging from national park to privately owned grazing land. It is part of a world-wide network of 330 Biosphere reserves in 83 countries under the *UNESCO Man and the Biosphere Program*. The functions of a Biosphere Reserve include conservation of species diversity, research, environmental monitoring, education, and the development and promotion of ecologically sustainable development.

The proposed scheme is as follows:

- Interception of saline groundwater from the Bookpurnong area.
- The diversion of Loxton Comprehensive Drainage Scheme effluent away from the Katarapko Evaporation Basin.
- The disposal of both groundwater and drainage water to the Noora Disposal Basin.

The two options being considered for water disposal are, either through the existing under-utilised Berri-Noora disposal main, or pumping directly to the Noora Basin through a new pipeline. The Noora Basin is located approximately 20 km east-northeast of Loxton, and receives drainage flows from Disher Creek and Berri Evaporation basins, which respectively serve Renmark and Berri irrigation areas (see Section 9.6.4). In recent years the need for disposal from these basins to the Noora Basin has declined, in part because of improved irrigation practices, with inflow becoming so intermittent that Noora is now ephemeral. It is suggested that flows from the combined Loxton-Bookpurnong scheme would assure the Basin's future as an attractive aquatic habitat, which was being threatened by the current low flows.

The indicative capital cost for the proposed scheme is $11 million, with a likely operating and maintenance cost of around $0.45 million. The estimated disposal volume from both schemes is around 4,500 ML annually, at an average salinity of around 11,000 mg/L. Peter Forward from SA Water in Berri is the relevant contact.

8.7.8. North Pike-Murtho Salt Interception Scheme

Recent 'run of the river' studies have shown that the North Pike-Murtho area - 10 km east of Paringa and south of the River Murray in SA's Riverland - has contributed significant quantities of salt to the River. As has occurred around Waikerie and Loxton, this is as a result of a groundwater mound forming under irrigation areas along the river which is forcing highly saline groundwater into the river. The principal land use of the area is irrigated horticulture, with grazing further away from the River. The North Pike-Murtho Groundwater Interception Scheme is currently at the concept stage and probably still 5 years away from construction. It is envisaged that the proposed Scheme would intercept and dispose of about 1,600 ML of groundwater annually with a salinity of around 10,000 mg/L. The Noora Disposal Basin some 15 km away is currently seen as the most attractive disposal site. The scheme is likely to be state owned, and involve capital costs in the order of $2-3 million. The contact for this proposed scheme is Peter Forward from SA Water in Berri.

8.7.9. Yanda Creek Groundwater Interception Scheme

Yanda Creek located on the Darling River near Louth in New South Wales has for some time been known to be the location of a major saline groundwater inflow to the Darling River. The Yanda Creek Groundwater Interception Scheme proposal is currently at a preliminary stage. It has been given a fairly low priority on the basis of its initial economic cost-benefits and its limited ability to generate EC reduction at Morgan in SA. Mike Williams from the DLWC on 02-9895 7706 is one of the proponents of this scheme.

8.8. Permanent Victorian Saline Lakes

8.8.1 Background

Australia, given its general aridity and temperature range, is renowned for its numerous and very large salt lakes. Most of these salt lakes, however, are shallow ephemeral lakes or playas (dry salt pans) that may contain water only very infrequently. The most famous of these is Lake Eyre in SA, which fills only once or twice every 100 years, but when filled constitutes a massive body of saline water, which may exist for several years. The ephemeral nature of such lakes, their generally highly variable salinity, isolated location, as well as the lack of freshwater, means that these are generally unsuitable for the development of a saline aquaculture industry. There are nevertheless a number of permanent saline lakes, particularly in Victoria that have the potential to be suitable for aquaculture. These are the Kerang Lakes around Kerang in northern Victoria and the Western District volcanic lakes around Colac in south-central Victoria. (See Table 4 for a summary of information on permanent Kerang Lakes and Figure 1 for locations).

8.8.2. The Kerang Lakes System

The Kerang Lakes are a system of some 57 lakes and swamps of widely differing permanence, depth, salinity and degree of aquatic vegetation and which provide important waterbird habitat for large numbers of endemic and migratory species. They are located on the northern Lodden Plain near the western arm of the Riverine Plains of the Murray Basin, some 330 km northwest of Melbourne. Most of the Kerang Lakes lie within a radius of about 25 km of each other. Table 8.4 summarizes information on selected saline Kerang lakes.

Origins:
The Kerang Lakes are a series of deflation basins - created by wind excavation in an arid climate - in a zone of natural regional groundwater discharge. Most of the 40 plus lakes are lake-lunette complexes, with small crescent-shaped dunes or lunettes composed of clay-gypsum on the eastern or lee side of the lakes, suggesting historical wetting and drying cycles. Many of the larger Kerang lakes are round, oval or kidney shaped. Prior to European settlement most of these lakes were ephemeral. However, extensive flood irrigation since the late 19^{th} century has greatly enhanced recharge to regional groundwater so that now all lakes are maintained at relatively constant water levels. Salinity in the lakes ranges widely from fresh to salt levels several times that of seawater. A number of the lakes are used for irrigation supply, whilst others are used for saline drainage and groundwater disposal.

Regional land use, infrastructure and climate:
The central town of the Kerang lakes region is Kerang with a population of around 4,500. The lakes region around Kerang is part of the Torrumbarry irrigation area, and largely consists of irrigated pastures mainly for fat lamb and beef cattle production, based on broad-scale flood irrigation. Some cereal, fodder, lucerne, sunflower and citrus crops are also produced in the area. Mixed farming based on irrigation in the region is now only marginally profitable, and faces major environmental problems and constraints principally associated with rising water-tables and salinisation (Wasson *et al.,* 1996). The proximity to the River Murray, and the extensive series of lakes and waterways in the Kerang area, have also resulted in a significant tourist industry. Many of these lakes are used for water sports such as boating, skiing, fishing and swimming, and are popular picnic and camping areas. Numerous waterbirds are found in the area and Middle Reedy Lake just north of Kerang is believed to have the world's largest ibis rookery. Some of the lakes, for example Lake Kangaroo, are used for water supply, while others such as Lake Tutchewop are used for the disposal of saline irrigation

drainage water. Salt production is currently undertaken at Pyramid Hill some 40 km southeast of Kerang by Pyramid Salt Pty Ltd.

Swan Hill, population around 10,000, is located at the northern boundary of the Kerang lakes region. It is a regional service centre principally for the irrigation-based horticulture - vineyards, stonefruit and market gardening – as well as dairying and livestock industries. First settled around the middle of the 19^{th} century, Swan Hill became a major inland port of the inland river trade. The clearing and development of the mallee for agricultural purposes and irrigation development rejuvenated Swan Hill, and it became a city in 1965. Local industry includes wine production and farm machinery manufacture.

Kerang and Swan Hill are located on the Murray Valley Highway with various other minor roads traversing the Kerang Lakes region, which also includes a number of minor communities such as Lake Boga. A railway line linking Swan Hill to Melbourne roughly parallel to the Murray Valley Highway used to run through the region, however the line now only extends as far as Bendigo about 100 km to the south.

The climate of the region is semi-arid with typically hot summers and mild winters. The average daily maximum temperature is 22°C, while the average daily minimum temperature is 9.6°C. Rainfall mainly occurs as low intensity winter falls, supplemented by irregular summer storms, and averages around 360 mm per year. Average annual evaporation is 1,350 mm, and exceeds rainfall in all months other than June and July.

General Environmental Issues:
A significant portion of the Kerang Lakes region was designated as an Australian Ramsar site (Site 17) in 1982 - i.e. a wetland site of international importance. Most of these lakes have also been listed in the *Directory of Important Wetlands in Australia* (DIWA). Nomination of these lakes as part of a Ramsar site does not and has not precluded alternative use of such resources, provided such use is consistent with the Ramsar management objectives developed for these sites. Similarly listing in the Directory places no specific restrictions on the use of these lake/wetland resources. It merely indicates that they are considered to be significant, and suggests that any proposed use should consider and be sympathetic to their wetland status.

Not withstanding their Ramsar listing in 1982, no Ramsar Plan of Management has so far been prepared for the Kerang Lakes, and there has in fact been a considerable degradation of many of the Kerang wetlands since then. Those saline lakes that have been used for the disposal of saline drainage water have particularly experienced significant changes and loss of environmental value. Changed hydrology, such as isolation from natural flood flows, has also resulted in increased salinity and modified biota in some wetlands. A number of freshwater lakes in the area are managed as holding storages for irrigation water supply, and consequently have lost some environmental value. Efforts are nevertheless being made to improve the environmental management of a few individual lakes.

8.8.3. Details of Permanent Saline Kerang Lakes

Discussion will generally be restricted to those lakes meeting the primary criteria for consideration. Information has mostly been obtained from:

- Discussions with and information supplied by individuals at Goulburn-Murray Water and the Department of Natural Resources and Environment at Tatura.
- The draft Kerang-Swan Hill Lakes Salinity Management Plan.
- The Directory of Important Wetlands in Australia (ANCA 1996).
- Environment Australia's report to the 6^{th} Ramsar Convention in Brisbane in 1996.

- Various scientific and other publications.

Lake Tutchewop:
Lake Tutchewop is a Ramsar and DIWA listed wetland largely because of its aquatic bird habitat. However, its environmental value has rapidly declined to a moderate level as result of its use as the main saline disposal basin for the Barr Creek Salt Interception Scheme. Its salinity has gradually increased from about 13,500 mg/L in 1975 to around 75,000 mg/L at present, a trend, which if continued would result in salinity levels that would be unable to support much animal or plant life. Studies are being undertaken into the long-term management of Lake Tutchewop to maximise the quality of its wetland habitat and to protect its Ramsar values, whilst retaining its use as an evaporation basin. It has been proposed to lower its salinity levels to 15,000 mg/L by making use of other lakes (William and Kelly) as final effluent disposal sites, as well through commercial salt harvesting. A commercial trial, financially supported by the MDBC, of harvesting high-value rare-salts is about to be undertaken at the edge of Lake Tutchewop. This could lead to the establishment of a large-scale salt harvesting industry at the lake. The lake foreshore of about 75 m is Crown land with grazing licences now discontinued. Land use surrounding the lake is mainly mixed dryland cropping of oats and barley and grazing, with a few small areas devoted to irrigated pasture.

Lake Cullen:
Lake Cullen is one of the larger moderately-saline Kerang lakes. It has been Ramsar and DIWA listed, but in contrast to Lake Tutchewop, has still retained much of its environmental value. The lake was previously linked into the Torrumbarry Irrigation System and used as an irrigation water storage. It has now, however, been isolated from the system – presumably because of increasing salinity - and is no longer used for water supply. There is no grazing on most of the lake frontage, although there are still a few patches that are in the process of being phased out. There is some irrigated pasture and a small pocket of irrigated lucerne on the western side of the lake. On the eastern side mixed dryland farming, cropping and grazing is the predominant land use, although there is also a single large centre-pivot irrigation system growing lucerne in this area. Fresh water in the form of adjacent lakes – e.g. Kangaroo - and irrigation channels is relatively close by. Groundwater in the vicinity of Lake Cullen is shallow, and has a salinity level approaching that of seawater.

Lake Elizabeth:
Lake Elizabeth, although not Ramsar or DIWA listed, has a moderate environmental value, with work currently underway to improve its environmental amenity. It is not used for saline water disposal or water supply. As with Lake Cullen most of the foreshore frontage is no longer used for grazing. Surrounding land use is mainly mixed grazing and cropping with the occasional pockets of low intensity irrigation to the east.

Lakes Kelly and Little:
Lake Kelly and Little Lake (also known as Little Lake Kelly) are linked adjacent saline lakes that are part of the Barr Creek Salinity Control Scheme. As a consequence, the lakes have been considerably degraded such that they now only have low to moderate environmental value, notwithstanding the fact that Lake Kelly has been Ramsar and DIWA listed. The land surrounding the lakes is also very degraded and consists solely of light grazing. Irrigation is undertaken further away from the lake.

Lake Wandella:
Lake Wandella - locally known as Brandy's Lake - has a moderate environmental value. Although it has experienced an increase in salinity in recent times, this has not significantly changed its environmental status. The lake is not used for saline water disposal or irrigation water supply. The 80-100 m frontage to Lake Wandella is not grazed. The surrounding land to the west is used for intensive irrigated dairy farming, whereas to the north, east and south the land is mainly devoted to mixed dryland farming consisting of cropping oats and barley and grazing.

Lake William:
Lake William is also part of the Barr Creek Salinity Control Scheme. This has caused severe degradation of the lake such that it only has a low environmental value – despite its Ramsar and DIWA listing. This degradation has extended to the lake frontage and the surrounding land, and only light dryland grazing occurs around the lake.

Lake Charm:
Lake Charm is one of the large freshwater lakes of the Kerang area. Since the 1880s Lake Charm and a number of other lakes and streams have been used for irrigation water carriers and storage. The operation of the lake has resulted in it becoming slightly brackish over time so that it now has salinity of around 3,000 mg/L. New engineering works to improve the flushing of the lake should gradually reduce its salinity to 1,500 mg/L.

Table 4: Specific Information on Permanent Saline or brackish Kerang Lakes (see Figure 1 for locations)

Lake	Volume (FSL) ML	Surface area (FSL) ha	Max. depth m	Mean depth m	Salinity* mg/L	Wetland listing	Principal use or status	Environmental value & trend
Tutchewop	13,200	775		1.7	50,000+	Ramsar DIWA	saline water disposal	Moderate ↓
Kelly	2,260	201		1.1	45,000	Ramsar DIWA	saline water disposal	Low-moderate ↓
Little Kelly	460	44		1.0	45,000		saline water disposal	low-moderate ↓
William	2,700	108		2.5	61,000	Ramsar DIWA	saline water disposal	Low ↓
Elizabeth		94			30,000 ->20,000		public land	Moderate ↑
Wandella		44			30,000		public land	Moderate ↔
Cullen	13,400	632	4	2.1	12,000	Ramsar DIWA	previously a water supply	High ↔
Charm	22,000	486		4.5	3000 ->1,500	Ramsar DIWA	irrigation water supply	moderate-high ↑
Lookout	1,230	61	4	2.0	~3,000			

*Converted from average EC x 0.6 as reported in the Kerang-Swan Hill Salinity Management Plan (1993).

8.8.4. The Western District Volcanic Lakes

(See Table 5 for a summary of information on Western District Volcanic lakes and Appendix 4 for details of representative water chemistry in selected permanent saline lakes)

The volcanic plains of the Western District of Victoria, some 160 km west-southwest of Melbourne contain a significant number of permanent saline lakes, including Australia's largest permanent saline lake, Lake Corangamite. While some of these salt lakes are shallow and subject to substantial salinity variation in association with flooding or heavy rain, a number of them are quite large and moderately deep. The salinity of the western district lakes ranges from hypersaline - Lake Gnotuk ~58,000 mg/L - through to virtual freshwater - Lake Purrumbete ~400 mg/L. Most of the lakes lie within a 25 km radius of each other. Information on these lakes for this report has mostly been obtained from De Deckker & Williams (1988); Williams (1981); Williams (1978); Timms (1976, 1983) and ANCA (1996). Discussion will generally be restricted to those lakes meeting the primary criteria for consideration.

Origins:
The origins of the lakes in the Western District are diverse, but are generally the result of former volcanic activity which occurred between the Pleistocene and about ~5-7,000 BP. The oldest carbon-dated age is of Lake Keilambete at around 30,000 BP, however most lakes are considerably younger. Some are maar lakes, for example lakes Gnotuk, Bullenmerri, Purrumbete, Keilambete, Elingamite, Red Rock and Basin. Others are volcano crater lakes – lakes Mumblin and Surprise. Lake Corangamite arose either by a volcano-tectonic process involving subsidence above a large magma

chamber, or possibly by the blockage of a river by a lava-flow. Some of the smaller lakes have been formed by the collapse of lava tunnels, while some shallow eastern lakes that lie on wind- or lake-derived sediments could well be deflation basins. The region is an undulating plain with an altitude of between 150 and 300 m. The endorheic drainage of the region means these lakes are the termini of inland drainage basins, which coupled with large evaporation rates largely accounts for their elevated salinity.

Regional land use, infrastructure and climate:
The Western District was originally a grassy but largely treeless undulating plain. Since settlement in 1840, the fertile but shallow stony basaltic soils of the area have largely been given over to agriculture, principally sheep and cattle grazing on improved pastures, dairying and cropping. The two major towns in the region are Colac with a population of 6,500 (has been over 10,000) and Camperdown about 50 km away with a population of 3,200 - both on the Princess Highway between Geelong and Warrnambool. Cobden 15 km south-southwest of Camperdown has a population of 1,500 and has several industries, including the large Bonlac Foods Ltd milk drying plant, and the Ausfeed stockfeed mill. A number of other small communities and roads dot and traverse the region. There was a rail link between Colac and Geelong.

The climate of the region is temperate, typically with warm dry summers and cool wet winters. Average annual rainfall varies between 500 mm in the north of the region to around 800 mm in the south. Average maximum air temperature varies from 27^oC in summer to 10^oC in winter. Average annual evaporation is between 1000-1500 mm with a minimum of 50 mm during June and July, and a maximum in January of 125< mm. Evaporation usually exceeds precipitation during the ‘summer’ months of October to April. Williams (1981) and references therein provide more detail.

General environmental issues:
A number of the Western District lakes have been nominated as an Australian Ramsar site (Site 20) - i.e. wetland sites of international importance. Nomination of these lakes as part of a Ramsar site does not preclude alternative uses of these resources, provided such use is consistent with the Ramsar management objectives developed for these sites. Three of the lakes listed in Table 9.5 below are Ramsar listed. Most of the other lakes have been listed in the DIWA (ANCA 1996). Again the listing of these lakes in the Directory places no specific restrictions on the use of these lake/wetland resources. It does indicate that they are considered to be significant, and that any proposed use would have to be sympathetic to their wetland status. A number of the fresher lakes in the region are used for irrigation while others are used for industrial process water and disposal.

Table 5: Specific Information on Selected Permanent Saline Western District Lakes (see Figure 1 for locations)

Lake	**Volume ML x 10^3**	**Surface area ha**	**Max depth m**	**Mean depth m**	**Salinity range mg/L**	**Wetland listing**
Corangamite	1,510 - 456	25,200 - 32,300	~6.0 4.9	6.0 2.9	22,400 – 36,300	Ramsar/ DIWA
Bullen Merri	192	488	66	39.3	5,000 – 9,100	?
Purrumbete	157	552	45	28.5	300 - 430	
Martin	79	4,020	<3	2	2,900 – 8,400	DIWA
Gnarpurt	70.3 - 26.5	2,730 - 2,580	<3 2.4	2.57 1.9	7,200 – 13,700	Ramsar/ DIWA
Colac	52 - 71.3	2,420 - 2,970		2.2 2.4	1,890 - 2,500	
Gnotuk	32	208	18.5	15.3	51,800 – 59,800	DIWA
Colongulac	32	1,460	3.9	2.2	8,300 – 12,100	Ramsar/ DIWA
East Basin	1.24	27.4	12	7.3		DIWA
West Basin	0.92	15.8	13.5	5.8		DIWA

8.9. Saline Groundwater Resources

(See Table 6 for a summary and Figure 2 for the location of the major basins with the greatest potential for inland saline aquaculture).

8.9.1. Background

Groundwater can be found virtually anywhere in Australia, although the quantity and quality in terms of salinity and other characteristics can vary widely from place to place. Groundwater resources are usually classified into three broad types:

- **Surficial aquifers**: These are comparatively shallow water-table aquifers - generally comprising unconsolidated sediment - that may constitute a variable resource and provide variable yield. Such unconsolidated sediments form a veneer over much of Australia. In areas affected by dryland salinity or under irrigation regions where groundwater accession occurs, such aquifers can be a significant saline water resource.
- **Sedimentary basins:** These are generally deeper aquifers consisting of layers of porous sandstone or limestone rock. They are often significant water resources with high yields, however the salinity of these sedimentary aquifers is highly variable. Because of the different sedimentary layers in such basins, they often contain a number of superimposed aquifers at different depths.
- **Fractured rock aquifers:** These are essentially non-porous rocks such as igneous or metamorphic rocks that have been fractured by geologic activity. Such groundwater resources are usually limited and are associated with low yields.

A hydrogeological map of Australia (Lau *et al.,* 1987), shows where the major aquifers, in terms of volume and/or yield, occur around Australia. It should be remembered that groundwater resources are

3-dimensional, and superimposed multi-aquifer systems can not be represented easily on single-sheet hydrogeologic maps. As the map indicates, groundwater can be found virtually anywhere in Australia. However, there are several major groundwater regions in Australia where salinities of the principal aquifer are typically of the same order as seawater. These are:

1. The lower Murray Hydrogeological Basin extending to the Western Districts of Victoria.
2. Eyre Peninsula in South Australia.
3. Central Australia; principally the Northern Territory.
4. The wheatbelt zone of southwest Western Australia.

Areas of brackish groundwater (indicated as 1,500-5,000 mg/L) tend to more or less surround these higher salinity regions, and include most South Australia, virtually all of Western Australia and large areas of NSW, Victoria and the Northern Territory. Areas of brackish groundwater also occur in the southwest and eastern areas of Queensland. Only Tasmania appears to have negligible brackish or saline groundwater.

From an inland saline aquaculture perspective, surficial aquifers and sedimentary basin aquifers are likely to be of principal interest. Nevertheless fractured rock aquifers could also, in places, provide sufficient saline groundwater for the establishment of an aquaculture industry.

Information for this report was initially accessed from agency reports and maps, via the Internet, and through personal discussion with agency hydrogeologists. Saline groundwater is dealt with by state. Sedimentary basins which span more than one state are only addressed under the first state for which they are reported. Table 6 provides a summary of the most important saline groundwater resources.

8.9.2. Victoria

Background:
The Victorian government provides a useful overview of the state's hydrogeology and groundwater in its Internet site (http://www.nre.vic.gov.au/dnre/grndwtr/grndwtr.htm). Information can also be accessed from various agency publications, such as *Water Victoria: A Resource Handbook* (DWRV 1989), and *Groundwater Quality and the Potential Impact of Contaminants* (SKM 1999). More specific and detailed information on local groundwater or bore characteristics can be obtained from the State's groundwater database, which is managed by Sinclair Knight Merz (phone 03-9248 3100)

Hydrogeology overview:
Victoria consists of an old central backbone of fractured rock called the Highland Province and a number of younger, principally Tertiary, sedimentary basins. These are in order of size:

- ❖ The Murray Basin.
- ❖ The Otway Basin.
- ❖ The Gippsland Basin.
- ❖ The Port Phillip Basin (comparatively minor.
- ❖ The Western Port Basin (comparatively minor).

Only the Murray Basin, and to a lesser extent the Otway Basin, have significant saline groundwater resources. A few individual aquifers in the other basins and isolated pockets of the Highlands Province also contain some brackish groundwater. Shallow water-table aquifers may comprise any number of geological units across the region. They are most directly affected by land use activities at the surface, and in many areas have significant impacts on the land use as well as wetlands, streams and other water bodies. In Victoria brackish or saline groundwater associated with water-table aquifers is mainly found in the western two-thirds of the State. The more saline water-table groundwater is found in the northwestern corner, corresponding largely to the Murray Hydrogeological Basin. A descriptive summary of each relevant groundwater region is provided below.

Murray Hydrogeological Basin:
The Murray Hydrogeological Basin is a large, shallow closed groundwater basin that consists of a 200-600 m thick veneer of sedimentary rocks containing a number of aquifer systems. It extends across Victoria, NSW and SA, and corresponds approximately to the lower part of the Murray-Darling hydrological catchment, with which there is significant interaction.

Groundwater salinities in the Basin are highly variable, ranging from freshwater up to 300,000 mg/L. Most of the higher salinity (>7,000 mg/L) groundwater occurs west and north of a line through Torrumbarry and Balranald, which corresponds approximately to the eastern extent of a palaeo-inland-sea, with salinity generally increasing to the north and west along the groundwater flow-path.

The most significant geological aquifer forming units in the Basin are the Pliocene Loxton-Parilla Sands, and the Calivil Formation and the Middle-Tertiary Renmark Group, which lie at depths of 15-20 m and 25-130 m respectively. The salinities in these aquifers vary, but are typically well over 13,000 mg/L. Several zones of very high salinity (35,000 mg/L) groundwater occur around the Sunraysia and Riverland regions of Victoria, NSW and South Australia. Bore yields for these aquifers vary widely - between 2-125 L/sec - but are typically high. These are the aquifers from which groundwater interception schemes in the Murray Basin generally pump.

The Lower Renmark Group - a basal Tertiary aquifer occurring throughout the Basin - also contains substantial saline groundwater resources at depths of between 50-420 m.
The shallow nature of several saline aquifers in the Basin has resulted in the inflow of highly saline groundwater into the River Murray. Regulation of the River and adjacent irrigation activities has significantly increased this salt inflow and its impact.

A substantial number of significant urban communities in the Murray Basin are underlain by significant saline groundwater resources. Several are discussed in relation to salt interception schemes, or the Kerang salt lakes. In Victoria these urban centres include Mildura, Red Cliffs, Ouyen, Robinvale, Swan Hill, Kerang and Horsham, with Shepparton, Echuca and Charlton having access to brackish groundwater with salinities between 3,500-13,000 mg/L. Other major communities underlain by saline groundwater include Balranald, Euston, Dareton, Deniliquin and Wentworth in NSW; and Renmark, Berri, Loxton, Barmera, Waikerie, and Morgan in SA. Smaller communities with access to saline or brackish groundwater resources are not listed.

Otway Basin:
The main geological aquifer-forming units in the Otway Basin associated with brackish groundwater are the Newer Volcanics. These stretch in a broad zone west from Geelong to near Hamilton. These groundwaters typically have salinity levels between 2,000-8,000 mg/L. Bore yields are mostly less than 1.5 L/sec (0.13 ML/day), but in places can be as high as 60 L/sec (5.2 ML/day). There are several pockets south of Ballarat, and west of Geelong, where groundwater salinities in the Newer Volcanics get above 13,500 mg/L. The somewhat deeper Dilwyn Formation of the lower Tertiary is also associated with brackish groundwater. It stretches in a V from near Hamilton down to Warrnambool, and then back up through Camperdown to Geelong. Salinities in this aquifer unit are generally above 3,500 mg/L, although in the Warrnambool area its salinity is over 5,000 mg/L. Bore yields are as high as 115 L/sec (9.9 ML/day). Around Portland in western Victoria this aquifer yields only slightly brackish groundwater, with salinities between 1,000-3,500 mg/L. The interesting quality of this groundwater is that it is geothermal and has a temperature of about 50^{o}C.

Water-table aquifers, mainly in the northern half of the Otway Basin, provide brackish groundwater with salinities between 3,500 and 13,000 mg/L. Surficial groundwater with higher salinities above 13,000 mg/L is found in a few isolated pockets.

Gippsland Basin:
There are no saline and very limited brackish groundwater resources in the Gippsland Basin, with most groundwater resources having a salinity of less than 1,500 mg/L. There is one small area just to the east of Sale where brackish groundwater with salinity over 3,500 mg/L occurs in the upper Tertiary Gippsland Limestone as well as shallow water-table aquifers. The yield for this upper Tertiary Gippsland Limestone is generally less than 2 L/sec but can be as high as 10 L/sec.

Port Phillip and Westernport basins:
Both the Port Phillip and Westernport basins are small sedimentary basins with negligible brackish or saline groundwater resources. There is a limited region of brackish groundwater west of Melbourne from Werribee to the Geelong region. The geological aquifer forming units in this region are the Werribee Delta, the Newer Volcanics, the Moorabool Viaduct Formation and the Werribee Formation. The salinity of these aquifers is variable but nearly always less than 6,000 mg/L. Bore yields range from <1.5-50 L/sec. Water-table aquifer salinities in these basins largely mirror those of the underlying sedimentary aquifers.

The Highlands fractured rock province:
The Highlands Province consisting of fractured rock aquifers has negligible saline or brackish groundwater resources. Most groundwater salinity in the province is substantially less than 3,000 mg/L, coupled with highly variable, though usually low, bore yields. Only the Palaeozoic sedimentary and igneous rocks of the West Victorian Highlands around the Hepburn Springs and Daylesford area yield higher salinity groundwaters. These, however, tend to be mineral waters with a substantially different ionic chemistry composition to the typical sodium-chloride dominated groundwaters of other areas. The mineral groundwater from this area is bottled and sold commercially. There are negligible saline or brackish water resources associated with water-table aquifers.

8.9.3. New South Wales

Hydrogeology overview:
New South Wales consists of five sedimentary basins, several of which are shared with adjacent states, and four geographic fractured rock provinces. These basins and fractured rock provinces are in large part overlain by a thin layer of unconsolidated sediments that constitute groundwater systems more or less independent of the underlying aquifers.

- The Great Artesian Basin (shared with Qld, NT & SA).
- The Murray Basin (shared with Vic & SA).
- The Sydney Basin.
- The Clarence-Morton Basin (shared with Qld).
- The Oxley Basin.
- The Western Slopes and Plains fractured rock province.
- West Darling fractured rock province.
- Central and Southern Tablelands fractured rock province.
- New England fractured rock province.

Of the geological groundwater units listed above, only the Murray Basin provides a significant and suitable saline groundwater resource for aquaculture. Saline or brackish groundwater is also found in the Great Artesian, Sydney and Clarence-Morton basins, and also to a lesser extent in the Western

Slopes and Plains, and West Darling fractured rock provinces. However, isolation, inappropriate chemistry and lack of freshwater rule out the Great Artesian Basin and the West Darling fractured rock province. This leaves the Sydney and Clarence-Morton basins, and the Western Slopes and Plains fractured rock province as other locations where saline groundwater may be available and suitable for aquaculture.

Shallow water-table aquifers in unconsolidated surficial sediments also exist across most geological units. The most saline water-table groundwater is found in the southwestern corner of the State, corresponding approximately to the boundary of the Murray Hydrogeological Basin. Brackish shallow groundwater is also found in the western two thirds of the State. Dryland salinity and rising saline water-tables as a result of clearing of native vegetation have dramatically increased in extent in recent years. They now constitute a significant saline problem as well as a significant potential saline water resource over large areas of the State west of the divide.

A summary of relevant saline groundwater regions is provided below.

The Great Artesian Basin:
The Great Artesian Basin is Australia's largest sedimentary basin, and comprises a number of sub-basins, and consists mainly of Triassic, Jurassic, Cretaceous and Tertiary sediments. It extends from source areas in northern and eastern Queensland and northern NSW into discharge zones in inland Queensland, NSW and northwest SA. It constitutes an important groundwater resource for the grazing industry over much of arid inland Australia, as well as a number of mining projects. The groundwater from the deeper aquifer is artesian, with very high flow rates, generally fresh, and often geothermal with temperatures as high as 120°C. A significant portion of flow from uncapped bores is wasted through evaporation from open bore drains – however, a program of bore capping is now underway to conserve the resource. Water quality in terms of total dissolved solids generally decreases along the flow path from the northeast to the southwest and with increased residence time. Some groundwater has been dated as being 2 million years old. Salinity in this deeper aquifer is generally dominated by sodium bicarbonate. The shallower Tertiary sediments (<200 m thick) generally contain poorer quality and more saline groundwater and also have lower yields.

Overall the Great Artesian Basin despite its extent and the magnitude of its groundwater resource does not appear to be suitable for inland saline aquaculture. Its groundwater in the more populated areas is generally fresh, with increased salinity levels generally being found in the more isolated areas. Furthermore salinity from the principal aquifer is more mineral in character, and dominated by sodium bicarbonate. Only the shallower Tertiary aquifers, which contain higher salinity groundwater, may provide some aquaculture potential. Flows are non-artesian and yields substantially lower, but still likely to be adequate for aquaculture. Isolation is nevertheless the main problem.

Sydney Basin:
The Sydney Basin extends from Batemans Bay on the NSW south coast to Swansea in the north and inland almost as far as Dubbo and Narrabri, and includes Sydney at its centre. It consists of Permian and Triassic marine, estuarine and riverine sediments, and contains a mixture of saline and fresh groundwater resources. The basal marine sediments/coal measures, and the Wianamatta Group provide the principal saline or brackish groundwater resources.

The basal Permian sediments comprise marine and coal measure sequences including some volcanic sediments, and tend to outcrop around the margins of the Basin. This sedimentary layer outcrops south of Wollongong, inland to Tallong, and north through Lithgow to the Goulburn and Hunter river valleys, and provides groundwater that is typically brackish. It exhibits low yields of between 0.25-2 L/sec. from bores located at depths of between 30-100 m.

The Wianamatta Group consisting mainly of marine shales is one of three main groups of the younger Triassic sediments in the Basin. It occurs mainly on the Cumberland Plain west and southwest of Sydney. The groundwater associated with these sediments is generally saline and occasionally brackish, but generally provides only low yields of 0.1-2 L/sec.

The Narrabeen Group is another of the three groups of Triassic sediments, and is mainly found in the northern part of the Basin. It is generally associated with brackish groundwater and low (0.2-2 L/sec) yields.

Clarence-Moreton Basin:
The Clarence-Morton Basin, which extends from 50 km south of Grafton north into Queensland, consists of Triassic and Jurassic sediments that include a number of coal measures. It contains a range of fresh, brackish and saline low-yield groundwater resources. The basal Triassic coal sequence in the south and southeast of the Basin is associated with high salinity groundwater. The Jurassic Walloon Coal Measures, located near the centre of the Basin are similarly associated with brackish or salty groundwater - often within 30 m of the surface. Fresh groundwater can often be obtained from the overlying Kangaroo Creek Sandstone, although yields are typically low (<1 L/sec).

Western Slopes and Plains fractured rock province:
There are limited saline groundwater resources in the Western Slopes and Plains fractured rock province, which consist of extensive areas of granite, and metamorphic rocks. Groundwater is often difficult to find, and where it does occur, yields – as with all fractured rocks - tend to be low (<0.4 L/sec). North of the Murrumbidgee River groundwater tends to become brackish and progressively more saline to the north and west. North of the Lachlan River and northwest of the town of Forbes, groundwater salinity is usually above 10,000 mg/L.

West Darling fractured rock province:
The West Darling fractured rock province is located in the Barrier Range and northwards from Broken Hill, and consists of Precambrian and Palaeozoic rocks. The very limited groundwater resources of this province are invariably brackish or saline, and in large part reflect the arid nature of the country. Yields rarely exceed 0.3 L/sec.

8.9.4. South Australia

Hydrogeology overview:
The two main saline groundwater resources in South Australia are the Murray Basin, and the southwestern two-thirds of the State, which include the Eyre Peninsula region. Brackish groundwater resources are also found in the arid and largely unpopulated northwest of the State. Given that the groundwater resources of the Murray Basin have previously been discussed in this report under a number of headings, this discussion will now focus on the Eyre Peninsula Region.

Eyre Peninsula region:
The groundwater resource in the Eyre Peninsula Region of SA consists mainly of fractured rock, which is overlain by shallow Quaternary sediments. The latter aquifer provides fresh groundwater (<1,500 mg/L) for most communities in this region. The underlying fractured rock aquifer contains saline groundwater, and while bore yields are generally on the low side they are likely to be adequate for saline aquaculture. Further detail was unable to be obtained in time for this report. Additional information may be obtained from Cobb *et al.,* (1982). The Groundwater Division of the Department of Primary Industries and Resources SA (phone 08 8463 3147) can also provide additional information for a fee.

The combination of fresh and saline water resources and significant urban communities already involved in fisheries and/or aquaculture make this region potentially attractive for inland saline aquaculture. Cities such as Port Lincoln, Whyalla and Port Pirie, all provide significant infrastructure and labour. Port Lincoln also has major fishing and offshore aquaculture industries as well as fish processing plants that may enable synergies with any inland saline aquaculture. Fisheries market pathways are already established. Because of the saline aquaculture potential of the region, a brief overview of Port Lincoln and Whyalla is presented below.

Port Lincoln:
Port Lincoln - population 14,000 - is located on the southern tip of Eyre Peninsula. It is situated on Boston Bay, a large natural deepwater harbour which is the home of Australia's largest commercial tuna fleet. A significant number of lobster fishing vessels also operate out of the port, which is also the centre for major bulk grain exports for much of Eyre Peninsula. Port Lincoln is 680 km from Adelaide by road or about 280 km and 45 minutes west of Adelaide by air.

It has a moderate Mediterranean climate, which is tempered by the surrounding sea. The annual rainfall of 550 mm falls mainly in the winter months from April to September when maximum temperatures average between 16 and 22^{o}C. Average maximum summer temperatures range between 22-27^{o}C, with the maximum temperature rarely climbing over 35^{o}C.

Whyalla:
Whyalla is South Australia's second largest city with a population of 24,000. It is located on the northwestern coast of Spencer Gulf and is a centre for the northern Eyre Peninsula and Upper Spencer Gulf regions. Whyalla is a 390 km drive from Adelaide, and 290 km from Port Lincoln to the south. It also has rail and port facilities. Kendell Airlines provides daily air services to Adelaide 240 km away.

Whyalla was a traditional steel city, with ore from nearby Iron Knob and Iron Duke used to produce steel for both domestic and export markets. Whyalla also hosts a number of other major industries, including the $4 billion SANTOS oil and gas fractionation plant at Port Bonython. The city additionally has a number of other smaller industries, some of which relate to aquaculture. These include commercial salt production by Pacific Salt, beta-carotene production by Betatene, and more recently the development of an aquaculture industry in nearby Fitzgerald Bay.

There is little natural freshwater available in the Whyalla district, and water is supplied by pipeline from the River Murray.

Whyalla is located in a semi-arid zone, and experiences clear skies for much of the year. Mean maximum temperature range for summer months is 24-29^{o}C, while for the winter months it is 17-23^{o}C. The average annual rainfall of around 270 mm is distributed throughout the year, but is less reliable in summer. Average relative humidity ranges from about 50-55% in winter to about 35-38% in summer.

8.9.5. Western Australia

Hydrogeology overview:
Large areas of groundwater resources in Western Australia are either brackish or saline. However many of these areas are either too isolated or have no access to freshwater, and consequently are unsuitable for inland saline aquaculture. The main saline water resources likely to be of interest to saline aquaculture are the Carnarvon Basin, the shallow groundwater associated with the wheatbelt, Ord River Irrigation Area and possibly the southern part of the Western fractured rock province. The

shallow groundwater resources associated with the WA wheatbelt and the Ord River are covered in Section 9.10.2 and 9.10.3.

The Carnarvon Basin:
The Carnarvon Basin, centred on the town of Carnarvon, extends for 800 km along the northwest coast of Western Australia, and is up to 200 km wide. The western part of the Basin consists of gently westerly dipping Cretaceous and Tertiary sediments overlying Palaeozoic rocks. The groundwater in this area is characterised by comparatively high salinity. The basal Birdrong Sandstone in the western part of the Basin provides a hydrothermal saline artesian aquifer over much of the coastal plain. The groundwater is characterised by temperatures up to 60^{o}C and salinities in the range 3,000-10,000 mg/L, although these exceed 14,000 mg/L in the south. Brackish groundwater is also found in the Tumblagooda Sandstone that also occurs in the south of the Basin. Tertiary limestone containing a thin layer of freshwater overlying saline groundwater comprises an unconfined karst aquifer at North West Cape and Exmouth. Small supplies of high salinity groundwater can often also be obtained from the thin alluvial cover throughout the Basin. Large supplies of fresh groundwater are available locally in the riverbed sands and gravels of the major rivers. The riverbed sand of the Gascoyne River is extensively used for irrigation at Carnarvon. Shallow brine is extracted for salt production at Lake MacLeod 90 km to the north.

Other major sedimentary basins in WA:
The groundwater resources of the Canning Basin are extensive and largely fresh. However, large parts of the Basin are uninhabited because of the overlying sands of the Great Sandy Desert. Broome is the only major population centre in the area.

The Perth Basin is similar to the Canarvon Basin in that it extends for 800 km along the coast, but is only 15-90 km wide. It is the largest developed groundwater resource in WA. It supplies most of Perth's population and that of many towns nearby. Perth Basin's groundwaters are mainly fresh, although some higher salinity groundwater can be found in some superficial aquifers.

The Officer Basin is an inland sedimentary basin in located in the lower central eastern part of WA and the central west of SA. It contains a mixture of fresh and saline groundwater resources, however its location - occupying the Gibson and Great Victoria deserts – means that it is largely undeveloped.

The Eucla Basin in southeastern WA and southwestern SA lies at the head of the Great Australian Bight, and extends about 300 km inland. It is characterised by very high groundwater salinities. However, its isolation and lack of freshwater makes this groundwater resource unsuitable for inland saline aquaculture.

The Western fractured rock province:
The western fractured rock province occurs over most of southern and western WA, and includes Archean granite and greenstone terranes, and Proterozoic metamorphic belts and sedimentary rocks. These are overlain in places by a thin cover of superficial deposits and weathering products, and Cainozoic alluvial sediments in Tertiary palaeo-drainage lines. The groundwater salinity of the southern part of the western fractured rock province is high, and may represent some opportunities for saline aquaculture. The highest yielding and most saline aquifers are the alluvial sediments and calcretes in the palaeo-drainage lines. In the Kalgoorlie region groundwater from these palaeo-drainages - with salinities as high as 180,000 mg/L - is used for ore processing. Fresh groundwater is generally not available in this province. Very limited surface freshwater may be available in some areas closer to the coast. The discussion dealing with the WA wheatbelt, and a proposed seawater pipeline from Esperance to Kalgoorlie are also relevant here.

8.9.6. Northern Territory

Overview:
The Northern Territory was not a focus of this inventory study. The NT government groundwater Internet site - http://www.lpe.nt.gov.au/dlpe/advis/WATER/ground provided graphical overview of the extent, salinity and yield of groundwater in the Territory. Saline or brackish groundwater is mainly found in the southern part of the Territory, and tends to be localised low-yield or surficial aquifers. Groundwater in the northern part of the NT tends to be fresh except beneath the low-lying coastal plains. In the southern part of the NT, extensive areas of saline groundwater exist, however most of these are too isolated and lacking in freshwater to be of interest to saline aquaculture. One area of saline groundwater that could be of interest, nevertheless is the Amadeus Basin near Alice Springs where saline and fresh groundwater are found in close proximity.

The Amadeus Basin:
The only notable saline-brackish groundwater resource near a major population centre is the Amadeus Basin located in central Australia adjacent to Alice Springs. It is a late Proterozoic-early Palaeozoic sedimentary basin consisting of folded sandstones, shales and siltstones, with beds of fractured and porous sandstone forming the aquifer. The salinity of this aquifer is variable, ranging from fresh to saline depending on depth. Alice Springs draws significant quantities of good quality water from the Mereenie Sandstone of this Basin. Bore flow, depending on location and depth, are typically more than 5 L/sec.

The Amadeus Basin is included in this saline inventory because Alice Springs has access to both saline and fresh groundwater, from the Basin as well as from adjacent fractured rock and surficial aquifers. Furthermore, infrastructure, transport and labour is also readily available. Alice Springs has a hot arid continental climate with a mean daily summer maximum temperature between 31-36^{o}C, and a mean winter temperature between 20-27^{o}C. Its annual rainfall of 280 mm falls mostly during the summer.

Additional groundwater information may be obtained from Scott Bowker from the Natural Resources Division of the NT Department of Lands Planning and Environment on 08-8951 8607.

8.9.7. Queensland

Queensland was not a major focus of this study. Nevertheless a cursory examination of its hydrogeology suggests that the State contains limited groundwater resources that are likely to be suitable for saline aquaculture. The Great Artesian Basin does contain saline groundwaters, particularly in the southwest corner of the State, however this resource is probably too isolated to be useful for aquaculture. The Clarence-Morton Basin, which extends into NSW, does contain some saline groundwater resources that could potentially be suitable for aquaculture. The fractured rock province located along the east part of the State does provide some very low yield brackish groundwater, which could be suitable for aquaculture in specific localities. The only other significant saline/brackish groundwater resource that may have some aquaculture potential is found in the lower western Cape York Peninsula around the Gilbert, Norman and Flinders rivers near Karumba and Normanton. These aquifers are part of the Carpentaria and Karumba sedimentary basins.

8.9.8. Tasmania

Tasmania was not a focus of this inventory study. A cursory examination of its hydrogeology revealed no saline groundwater resources in either the small Tasmania and Bass sedimentary basins or fractured rock provinces.

Table 6: Saline and Brackish Groundwater Resources Potentially Suitable for Saline Aquaculture

Sedimentary basin or fractured rock province	**Aquifers and occurrence**	**Comment**	**Depth to aquifer (m)**	**Aquifer thickness (m)**	**Salinity range (mg/L)**	**Bore yield (L/sec)**
Murray Basin - NSW, VIC & SA	Parilla Sands: widespread occurrence main development NW of a line through Horsham and Echuca	Water-table aquifers yield high salinity water throughout the area	15-20 -Outcrops in southern Basin	Generally 40-60 - in some places <150 m	5,000-40,000 - Typically 30,000	2-5
	Calivil Formation & Renmark Group: extensive occurrence in the Riverine Plain and along the margins of the western Highlands in the St Arnaud-Dimboola-Horsham area		25-130	20-60 m	500-40,000	<125
	Lower Renmark Group: basal Tertiary aquifer occurs throughout most of the Murray Basin		50-420	<200 m around Mildura - thinner under Riverine Plains	1,000-20,000	<50
Otway Basin VIC	Newer Volcanics: Broad zone west from Geelong to Hamilton	Brackish-saline (3,500-13,000 mg/L) water-tables are found in the northern half of Otway Basin			2,000-8,000 - Occasionally 13,500	<1.5 Occasionally <60
	Dilwyn Formation: Stretches from Hamilton down to Warrnambool then up to Camperdown and Geelong	Geothermal (50^{o}C) around Portland			3,500-5,000	<115
Gippsland Basin VIC	Gippsland Limestone	Generally fresh groundwater but brackish around Sale	Relatively shallow		~3,500	2-10
Port Phillip Basin VIC	Unspecified aquifers	Limited saline resource	Relatively shallow		<6,000	<1.5-50
Sydney Basin NSW	Wianamatta shales: Cumberland Plain west and southwest of Sydney (see Appendix 3 for Chemistry)				Mainly saline	0.1-2
	Basal Permian sediments: Underlies most of the Basin – outcrops near the margins		30-100		Mainly brackish	0.25-2
	Narrabeen Group: northern part of the Sydney Basin				Mainly brackish	0.2-2

Table 6: (Continued): Saline and brackish groundwater resources potentially suitable for saline aquaculture

Sedimentary basin or fractured rock province	Aquifers and occurrence	Comment	Depth to aquifer (m)	Aquifer thickness (m)	Salinity range (mg/L)	Bore yield (L/sec)
Clarence Morton Basin, NSW & QLD	Basal Triassic coal measures: south and southeast of Basin near Grafton				Saline	
	Walloon Coal measures: near centre of Basin on the NSW-Qld border	Overlying Kangaroo Ck Sandstone provides low yield freshwater	30<		Brackish or saline	
Western Slopes and Plains fractured rock province NSW	Brackish groundwater north of the Murrumbidgee River becoming saline further north of the Lachlan River	Groundwater difficult to find with very low yield			Mainly brackish - 10,000< N of Lachlan River	<0.4
Eyre Peninsula fractured rock province SA	Eyre Peninsula region around Port Lincoln, Whyalla and Port Pirie	Overlying Quaternary sediments provide freshwater	Shallow		Saline	Low
Carnarvon Basin WA	Basal Birdrong sandstone: West coast of WA centred on Carnarvon and Exmouth	Geothermal water (60°C) – significant fresh groundwater is found in the Gascoyne River riverbed.			3,000-10,000+	
	Tumblagooda Sandstone: South of the Basin					
Western fractured rock province WA	Wheatbelt and Kalgoorlie areas of southwestern WA	Saline groundwater available from water-tables and palaeo-drainage lines	Shallow		Saline - sometimes highly saline in palaeo-drainage	Can be high, especially from palaeo-drainage
Amadeus Basin NT	Unspecified aquifers – only of interest around Alice Springs	Fresh groundwater is available from the Mereenie Sandstone	Moderate depth			5

8.10. Other Saline Water Resource Opportunities

8.10.1. Urban Groundwater Interception Schemes

Background:
Rising saline groundwater has generally been thought of as a rural problem affecting agricultural land. However the large-scale regional nature of the problem has resulted in many rural urban centres increasingly being also afflicted by shallow saline groundwater. Urban cities such as Wagga Wagga, Dubbo and Bendigo, as well as many other smaller towns throughout NSW, Victoria and southwest WA, are experiencing increasing damage and degradation of urban infrastructure and domestic housing. In Wagga Wagga over 60% of the urban area is at risk from highly saline water-tables that are rising half a metre per year (Crabb, 1997). Preliminary studies have show that local government is already experiencing salinity and rising watertable-induced costs approaching $10 million (Oliver *et al.,* 1996). Because of their ratings base many of these rural cities and towns are capable, and are likely, in the near future of undertaking groundwater interception schemes to protect and maintain urban property and infrastructure. Commercial activities such as aquaculture or salt harvesting that may be able to share some of the cost of establishing or running of such schemes and provide some return to the community are likely to be attractive to local government.

Salt harvesting, which removes salt out of the system, may on the surface appear to be the more attractive of these options. However, the low value of this commodity and the high transport cost to major markets make salt harvesting unlikely to be viable in many instances. Aquaculture on the other hand is a much more likely proposition. Linking aquaculture with urban groundwater interception schemes would have, in addition to proximity to infrastructure and labour supply, strong community and council support. The latter are invariably enthusiastic about attracting new industry to their area, particularly where this assists in the management of a major urban problem. Further, given that these groundwater interception schemes have yet to be constructed, there is an opportunity to integrate groundwater disposal requirements with aquaculture requirements.

The Murray-Darling Basin:
A significant number of rural cities and towns in the Murray-Darling Basin are experiencing infrastructure damage by rising saline groundwaters. Table 7 is a list of communities in the Murray-Darling Basin, identified by state-based groundwater experts, that are experiencing, or threatened by rising saline water-tables (Crabb, 1997). It includes towns not currently experiencing significant problems, but which are located in areas of rapidly rising groundwater - both irrigation and dryland salinity induced. Rural shires experiencing significant groundwater damage to roads and other infrastructure are not included in the list.

Table 7: Rural Towns in the Murray-Darling Basin Currently Experiencing or Threatened by Rising Saline Groundwater Tables

Victoria		**New South Wales**	
Kerang	Bendigo	Wakool	Condobilin
Cohuna	Lockington	Finley	Dubbo
Pyramid Hill	Dingee	Wagga Wagga	Wellington
Gunbower	Kotupna	Griffith	Mudgee
Boort	Tongala	Leeton	Peak Hill
Mitiamo	Lancaster	Cootamundra	Rylstone
Wedderburn	Kyabram	Yass	Orange
Inglewood	Tatura	Boorowa	Blaney
Bridgewater	Merrigum	Grenfell	Queanbeyan
Dunolly	Girgarre	Cowra	Forbes
Maldon	Stanhope	Lake Cargelligo	
Castlemaine	Strathmerton	**South Australia**	
		Paringa	

The wheatbelt of southwest Western Australia:
The wheatbelt of southwest WA has long experienced high salinity groundwater levels over large areas, such that surface runoff and rivers are quite saline in places. The cause of the rising saline groundwater is tree clearing and dryland salinity rather than irrigation. This has implications for groundwater pumping because the absence of a leaching process resulting from irrigated freshwater means that soil salinity only improves very slowly with pumping. Nevertheless small-scale, groundwater pumping is undertaken by some individuals. The saline groundwater effluent is disposed of to salt lakes, saline rivers or shallow constructed areas from which salt can be harvested. These private pumping schemes may be windmill-based, pumping in the order of 30,000-50,000 L/day (11-18 ML/yr), or small submersible electric pumps pumping at the rate of 50,000 L/hr (42 ML/yr). Salinities of the groundwater are typically between 10,000 and 20,000 mg/L. There is also a small amount of groundwater pumping in the vineyard region of the lower southwest, however salinities in this area are much lower – typically less than 3,000 mg/L.

Despite the considerable concern by agencies and communities about this expanding problem, no regional groundwater pumping is currently undertaken or proposed. The only large-scale saline groundwater pumping that is currently undertaken is associated with the restoration of the high conservation-value Lake Toolibin near Narrogen. This is a freshwater lake whose unique ecology was threatened by regional rising saline groundwater. This pumping scheme has been in operation for over 8 years, with the effluent disposed of to a nearby saline lake.

Rising saline water-tables not only affect agricultural land; some 30 wheatbelt towns are also affected by saline groundwaters (see Table 8). While there has been some *ad hoc* groundwater pumping by some of these communities, a more systematic approach is being developed by communities. A report for the town of Merridin - population ~4,000 - has recommended groundwater pumping and the use of evaporation basins in conjunction with aquaculture. Implementation of the study is expected over the next 12-18 months. Similarly Katanning (population ~4,000) has also experienced urban damage as a result of shallow saline groundwater. The local shire plans groundwater pumping – possibly also in association with aquaculture - over the next 12-18 months. The local Aboriginal Corporation has established a pilot-scale saline aquaculture plant in the area, however it does not use saline water from the town site.

A number of other towns such as Brookton and Corrigin (population ~3,000) have also experienced urban damage problems as a result of high water-tables. The relatively low salinity of the groundwater has meant that pumped groundwater can in the short term be used for irrigation without requiring evaporating basins.

Mark Pridham from the Rural Towns Program of Agriculture WA on 08-9368 3333 or Dr Bob Nulsen, Manager Natural Resources Division, Agriculture WA on 08-9368 3484 can provide more detail on these schemes. Dr Ramsis Salama, CSIRO Land & Water, Perth (08-9333 6208) can provide general information on shallow saline groundwater in Western Australia.

Table 8: Rural Towns in Southwest WA Currently Experiencing or Threatened by Rising Saline Groundwater Tables

Bakers Hill	Dumbleyung	Moora	Pingelly
Bencubbin	Katanning	Morawa	Pingrup
Brookton	Kellerberrin	Mukinbudin	Quairading
Bruce Rock	Nyabing	Mullewa	Tambellup
Corrigin	Koorda	Narembeen	Wagin
Cranbrook	Lake Grace	Perenjori	Wongan Hills
Dowerin	Merredin	Piawaning	Woodanilling

8.10.2. Small-Scale Shallow Groundwater Opportunities

Rising shallow saline groundwater tables have become a rapidly expanding problem in massive areas of southeastern and southwestern Australia. The result of irrigation in some areas and large-scale tree clearing and resultant dryland salinity in other areas, it now threatens both agricultural productivity and the environment over much of these areas. Serial biological concentration (SBC) is a farm-scale groundwater management system developed to optimize the use of shallow saline groundwater and reduce the volume of saline effluent before evaporative disposal. It provides an opportunity to integrate evaporative disposal into farm operations, whilst at the same time enhancing economic returns through the use of an integrated agronomic-aquaculture system.

Moderately saline groundwater in a salt affected part of a farm is used to irrigate small tile-drained areas planted to salt-tolerant relatively high-value trees, crops or grasses in a progressive sequence. The drainage effluent collected from under the last irrigated paddock is then pumped through a series of small evaporation ponds that are used for saline aquaculture. Aquaculture trials associated with SBC have been undertaken by the Marine and Freshwater Resources Institute of Victoria over the past three years. These have shown promise with a number of fresh and marine fish and mollusc species. Further detail can be found in Heuperman (1998).

This study has not attempted to include localised shallow saline groundwater in the saline water resources inventory, nor has the concept of SBC been fully explored. A map of shallow saline groundwater in the Murray-Darling Basin can be found in Crabb (1997).

Alfred Hueperman from the Institute of Sustainable Irrigated Agriculture at Tatura (03-5833 5245) or John Blackwell at CSIRO Land & Water at Griffith (02-6960 1521) can be contacted for more information on such schemes.

8.10.3. *The Ord River Irrigation Area in WA*

Irrigation in the Ord River area around Kununurra in the northern part of Western Australia is experiencing the same saline ground water-table problems as irrigation areas in the Murray-Darling Basin. The rapidly rising groundwater mound under this very large irrigation region will have to be addressed quickly, if its likely severe impact on agricultural production and the environment is to be avoided. Even though not all of the Ord Irrigation Area exhibits saline groundwater tables, extensive drainage systems and significant saline disposal schemes will have to be developed to manage the problem. Disposal volumes are likely to be in excess of 20,000 ML. Expansion of irrigation onto the Ord River Estuary, which has limited capacity for accommodating increased groundwater recharge, will result in additional problems in the region in the near future.

A large 3-4 year multi-disciplinary study involving Agriculture WA, CSIRO Land & Water and a number of other organisations has just been instigated. This project will seek to elucidate the nature of the problem, the long and short-term impacts, and the options available for management. Richard George, State Groundwater Manager, from WA Agriculture in Bunbury may be able to provide more detail.

8.10.4. *The Proposed Esperance-Kalgoorlie Seawater Pipeline*

The continued expansion of mining in the Kalgoorlie-Boulder region is resulting in an increasing demand for water for mineral processing. Fresh water has long been supplied to the region by the 560 km Perth-Kalgoorlie pipeline. The large demand for process water for the gold and nickel mines has largely been met by local hypersaline groundwater. However, the finite nature of this resource, and the significant increase in gold processing costs resulting from the high magnesium content of this hypersaline process water has resulted in an evaluation of additional water supplies. A study by the Water Corporation of WA has identified a proposal to construct an Esperance to Kalgoorlie seawater pipeline as the next major water supply option. Estimated costs of delivered water to Kalgoorlie are currently (1999) in the order of $0.75-$1.50 /kL assuming a nominal pipeline capacity of 35 ML/day. These costs are close to market demand figures. Although the seawater pipeline is yet to be proven as economically viable, the Water Corporation is considering various spin-off benefits.

It would appear that the development of such a seawater pipeline would provide an ideal opportunity for the establishment of an inland saline aquaculture industry – either at the Esperance or at the Kalgoorlie end. Such a saline resource would have the benefit of a plentiful and constant supply, uniform seawater salinity and would possibly also provide an opportunity for disposal of saline waste water. On the negative side there is the possibility of introduction of disease and wild strains of aquaculture species, although the seawater is likely to be chlorinated to prevent bacterial growth in the pipeline.

The city of Kalgoorlie-Boulder is a thriving and expanding mining community of some 30,000 people with all the associated services, and while isolated, is served by excellent road, rail and airline transport facilities. The climate of the region is hot and arid. Land outside of the city not allocated to mining is leasehold land, which is likely to be relatively inexpensive.

Esperance is a port and service centre for the western part of the wheatbelt, as well as being the home of a significant fishing industry. It is a community of about 10,000 people with all the associated services, and has road, rail, airline and sea links with the outside world. Esperance has the advantage of an existing seafood industry and distribution system that an inland saline aquaculture industry could plug into. The climate of Esperance is dry Mediterranean. Land in the region is used for grazing and cropping.

The best contact for further information would appear to be Mark Herbert of the Water Corporation of WA.

8.10.5. Saline Water in Coal Mines

Some coal mines in the Sydney Basin (see Section 9.9.3) contain and generate extremely large quantities of water. In some cases this mine water is comparatively fresh such as in the underground mines around Lithgow, whereas in other cases, particularly in the Hunter region this water can be moderately saline. The saline water results from the coal mines intersecting saline marine sediments which contain or generate significant quantities of salt water. Mine drainage water can sometimes be acidic as a result of the oxidation of pyrite – in the Hunter Valley this is particularly the case with water from the Greta Seam around Cessnock. Acidification can sometimes also result in higher levels of heavy metals. In other areas, particularly the upper Hunter Valley around Scone, acidification of mine drainage water does not seem to be a problem.

To manage this saline mine drainage, virtually all of the mines in the Hunter Valley have constructed large discharge-holding dams on-site. This enables them to discharge this brackish water into the Hunter River during high flow periods as part of a salinity trading and management system managed by DLWC. Significant volumes of water are involved in such discharges. For example, the Howie open-cut mine discharged some 105 ML of mine drainage into the Hunter River at the beginning this year. This had a salinity of 2,500-3,000 mg/L and a pH of around 7.9-8.0. Typical mine-drainage salinities range between 2,500-3,500 mg/L. In the Hunter Valley there are probably about 6 open-cut coal mines the size of the Howie mine, and dozen or so smaller mines.

It is quite likely that coal mines in Queensland and other states will similarly generate significant brackish or saline water. Greg Summerhayes from the NSW Department of Mineral Resources at Singleton on 02- 9646 1344 can provide further information on coal mine drainage water.

The preceding is merely a brief overview of brackish or saline water associated with coal mines. No rigorous evaluation or assessment of the suitability of such resources for saline aquaculture has been attempted, although they clearly exhibit considerable potential.

8.11. Resource Assessment Criteria

8.11.1. Assessment Categories and Suitability Criteria

Thirteen broad resource assessment categories were developed for determining the overall suitability of identified resources for inland saline aquaculture. These were:

- Resource availability.
- Resource salinity.
- Ionic composition.
- Other water quality.
- Availability of freshwater.
- Availability of land.
- Nature of soil.
- Environmental sensitivity.
- Existing structures.
- Availability of labour and commercial services.
- Proximity of power supply.
- Proximity to transport corridors.
- Opportunities for cost-sharing.

A score for each of these criteria was allocated. The importance of each category is reflected in the maximum score. For example, the maximum score for "availability of labour and commercial services" was 3 while the maximum score for "resource availability" was 10 indicating we felt resource availability was more important than labour availability. The resource requirements of each major type of inland saline aquaculture activity are not identical. Consequently each of the above resource assessment categories was divided and scored into three or four criteria according to its suitability for:

- Marine hatcheries.
- Grow-out of stenohaline fish in recirculating tanks.
- Grow-out of stenohaline fish in ponds.
- Grow-out of diadromous fish in recirculating tanks.
- Grow-out of diadromous fish in ponds.
- Grow-out of freshwater native fish in recirculating tanks.
- Grow-out of freshwater native fish with in ponds.

The suitability criteria and associated scores for each of the thirteen assessment categories and each of the aquaculture types are indicated in Table 9. The suitability criteria and scores were derived by Geoff Allan and Stewart Fielder from New South Wales Fisheries and Bob Banens from Atech Pty Ltd. The application of these suitability criteria enabled saline water resources to be evaluated with respect to each of the resource assessment categories, and the scores to be added up to determine the overall suitability for the aquaculture type. In some cases quantitative information is used for scoring suitability, in others a qualitative assessment is used. Each of the resource assessment categories and the associated suitability criteria are briefly discussed below.

Resource availability:
In addition to water resource volume and supply rate, continuity of supply and ready access to the resource are also likely to be important for the establishment of a saline aquaculture industry. Because it is difficult to set precise resource requirements or obtain specific resource availability information, the suitability criteria are necessarily qualitative.

- ❖ More than adequate resource volume, supply rate, continuity of supply and easy accessibility to the resource.
- ❖ Adequate volume or supply rate, occasional discontinuities in supply, resource reasonably accessible.
- ❖ Limited resource or supply, continuity of supply not entirely assured, or adequate supply not readily accessible.
- ❖ Limited volume, erratic supply, not easily accessible resource, or insufficient information.

Resource salinity:
This aspect does not relate to the specific salinity level of the resource, but rather the variability in salinity of the resource. Thus deeper groundwater tends to have a relatively constant salinity, whilst surficial or water-table aquifers, for example, have salinities that may fluctuate depending on rainfall.

- ❖ Very constant salinity and/or range of salinity levels available.
- ❖ Some degree of variation in salinity over a year or years.
- ❖ Significant variations in salinity over a year or years.
- ❖ Insufficient information.

Ionic composition:
The composition of salt in the water resource – in terms of the ratios of ions – can be important for both marine hatcheries and the growth of stenohaline fish. Diadromous and freshwater native fish are not particularly affected by ionic composition. Potassium-deficient saline waters – the result of adsorption onto clays – may necessitate the addition of this salt for some aspects of aquaculture. Mineral waters dominated by carbonate-bicarbonate and calcium and magnesium salts are generally not suitable for aquaculture.

- ❖ Ionic composition within 20% of seawater.
- ❖ Ionic composition within 30% of seawater.
- ❖ Ionic composition within 100% of seawater.
- ❖ Ionic composition more than 100% different from seawater.

Water quality:
This largely relates to the origins of the saline water resource rather than to specific water quality information. Thus saline groundwater obtained from deeper sedimentary aquifers such as through groundwater interception schemes is presumed to be pristine. On the other hand groundwater obtained from water-table aquifers under irrigated areas could potentially contain nutrients or pesticides, depending on the land use.

- ❖ Largely unadulterated saline water resource.
- ❖ Potential for some contaminants such as nutrients in the saline water resource.
- ❖ Potential for significant contaminants such as pesticides in the saline resource.
- ❖ Insufficient information.

Potential availability of freshwater:
This makes no assessment about the actual availability of freshwater resources - these may need to be bought on the market, negotiated or otherwise obtained.

- Adequate freshwater is potentially available, accessible or provided nearby.
- Freshwater is available within 5 kilometres of the site.
- Freshwater is available further away but may involve construction of a pump site and/or drilling a bore as well as a pipeline.
- Freshwater is not readily available nearby, or insufficient information.

Availability of land:
Generally low-cost low-value land would be more suitable for the establishment of an aquaculture industry. This may include grazing, degraded, salinised or marginal irrigation land. Moderate-value land would typically include good grazing lands, whereas high-value land may include land used for irrigated horticulture or dairying. Unallocated Crown land is assumed to be low-value land.

- Unallocated Crown land.
- Low-value private or leasehold land.
- Moderate-value private or leasehold land.
- High-value private or leasehold land, public reserve, or insufficient information.

Soil suitability
The soil type in the vicinity of a saline water resource is not particularly important in the case of hatchery or recirculation based aquaculture, however it may be important if constructed ponds are to be used for saline aquaculture. It is generally better if ponds can be constructed without requiring liners to prevent seepage.

- Clayey soils.
- Duplex soils.
- Sandy soils.
- Insufficient information.

Environmental sensitivity:
This is essentially a subjective assessment of compatibility of aquaculture with the surrounding land use, and the environmental sensitivity of the water resource itself. Very important and sensitive environments may include Ramsar listed wetlands, while moderately important or sensitive environments may include wetlands listed in the *Directory of Important Wetlands in Australia* or on the River Murray flood plain. Less sensitive areas may include other natural unlisted wetlands or important recreation areas. It is important to note that listing in Ramsar or DIWA does not preclude use of a wetland environment for aquaculture. It merely means that certain requirements associated with the status of such wetlands would have to be met.

- Environmentally insensitive location.
- Location has some degree of environmental sensitivity.
- Moderately important or environmentally sensitive location.
- Very important or sensitive wetland or flood plain area, or insufficient information.

Existing structures:
Existing structures are important as these may enable the establishment of an aquaculture industry based around their shared use, which would lower start-up costs. Resource infrastructure might include groundwater pumps, pipelines and disposal basins, as well as freshwater pipelines or power lines associated with a saline water interception or disposal facility.

- Developed saline water resource such as a groundwater interception scheme.
- Partially developed saline water resource.
- Potential new groundwater pumping schemes.
- Undeveloped saline water resource (e.g. groundwater), or insufficient information.

Availability of labour and commercial services:

- Town of >2,000 within 25 km.
- Town of 500-2,000 within 25 km and/or town of >2,000 within 25-50 km.
- Any town within 50 km.
- No towns within 50 km or insufficient information.

Proximity of electricity supply:

- Electricity available within 2 km.
- Electricity available within 2-25 km.
- Electricity available within 25-50 km.
- Electricity not available within 50 km; scheme not yet developed; or insufficient information.

Proximity to transport:

- Highway and rail or sea-port, or airport/commercial airline within 25 km.
- Highway only within 25 km.
- Main transport corridor more than 25 km away.
- Insufficient information.

Opportunity for cost-sharing new developments:
Some organisations or communities are likely in the near future to undertake the development of groundwater management schemes to protect property and/or sustain agricultural production. The establishment of an aquaculture industry in such areas may enable some degree of piggybacking in terms of the cost of establishing or running such a commercial enterprise. Alternatively there may be opportunities to adapt a proposed scheme to suit commercial aquaculture activities.

- High opportunity for cost-sharing in conjunction with potential new development.
- Some opportunity for cost-sharing with new developments or potential to tie into established pumps, pipes and disposal basin infrastructure.
- Limited opportunity for cost-sharing.
- No opportunity for cost-sharing, or insufficient information.

Table 9: Assessment Criteria for Various Types of Aquaculture (bracketed numbers indicate relevant assessment tables)

Assessment Criteria	Marine Hatcheries (8.10)	*Grow-out – Stenohaline*		*Grow-out – Diadromous*		*Freshwater Natives*	
		Recirculating (8.11)	**Ponds (8.12)**	**Recirculating (8.13)**	**Ponds (8.14)**	**Recirculating (8.15)**	**Ponds (8.16)**
Resource availability (quantity)	**10** >50 x 10^3 L/d **5** 30-50 x 10^3 L/d **1** <30 x 10^3 L/d	**10** >50 x 10^3 L/d **5** 30-50 x 10^3 L/d **1** <30 x 10^3 L/d	**10** >2 x 10^6 L/d **5** 1-2 x 10^6 L/d **1** <1 x 10^6 L/d	**10** >50 x 10^3 L/d **5** 30-50 x 10^3 L/d **1** <30 x 10^3 L/d	**10** >2 x 10^6 L/d **5** 1-2 x 10^6 L/d **1** <1 x 10^6 L/d	**10** >50 x 10^3 L/d **5** 30-50 x 10^3 L/d **1** <30 x 10^3 L/d	**10** >2 x 10^6 L/d **5** 1-2 x 10^6 L/d **1** <1 x 10^6 L/d
Salinity	**10** 30,000-35,000 mg/L **5** 20,000-30,000 or 35,000-45,000 mg/L **1** <20,000 or >45,000 mg/L	**10** 30,000-35,000 mg/L **5** 20,000-30,000 or 35,000-45,000 mg/L **1** <20,000 or >45,000 mg/L	**10** 30,000-35,000 mg/L **5** 20,000-30,000 or 35,000-45,000 mg/L **1** <20,000 or >45,000 mg/L	**10** 0-35,000 mg/L **1** >35,000 mg/L	**10** 0-35,000 mg/L **1** >35,000 mg/L	**10** 0-10,000 mg/L **1** >10,000 mg/L	**10** 0-10,000 mg/L **1** >10,000 mg/L
Ionic composition	**10** ±20% seawater **5** ±30% seawater **1** >30% different	**10** ±20% seawater **5** ±30% seawater **1** >30% different	**10** ±20% seawater **5** ±30% seawater **1** >30% different	**10** within ±100% **5** bigger difference	**10** within ±100% **5** bigger difference	**10** within ±100% **5** bigger difference	**10** within ±100% **5** bigger difference
Other water quality factors (e.g. potential nutrient, pesticide or other contamination)	**3** Largely unadulterated saline water resource **2** Potential for some contaminants such as nutrients in the saline water resource **1** Potential for significant contaminants such as pesticides in the saline resource	**3** Largely unadulterated saline water resource **2** Potential for some contaminants such as nutrients in the saline water resource **1** Potential for significant contaminants such as pesticides in the saline resource	**3** Largely unadulterated saline water resource **2** Potential for some contaminants such as nutrients in the saline water resource **1** Potential for significant contaminants such as pesticides in the saline resource	**3** Largely unadulterated salinewater resource **2** Potential for some contaminants such as nutrients in the saline water resource **1** Potential for significant contaminants such as pesticides in the saline resource	**3** Largely unadulterated saline water resource **2** Potential for some contaminants such as nutrients in the saline water resource **1** Potential for significant contaminants such as pesticides in the saline resource	**3** Largely unadulterated saline water resource **2** Potential for some contaminants such as nutrients in the saline water resource **1** Potential for significant contaminants such as pesticides in the saline resource	**3** Largely unadulterated saline water resource **2** Potential for some contaminants such as nutrients in the saline water resource **1** Potential for significant contaminants such as pesticides in the saline resource
Freshwater availability	**10** >5 x 10^3 L/d nearby (<5 km) **5** >5 x 10^3L/d >5 km away **0** <5 x 10^3 L/d or >10 km away	**10** >5 x 10^3 L/d nearby (<5 km) **5** >5 x 10^3L/d >5 km away **0** <5 x 10^3 L/d or >10 km away	**10** >5 x 10^3 L/d nearby (<5 km) **5** >5 x 10^3L/d >5 km away **0** <5 x 10^3 L/d or >10 km away	**10** >5 x 10^3 L/d nearby (<5 km) **5** >5 x 10^3L/d >5 km away **0** <5 x 10^3 L/d or >10 km away	**10** >5 x 10^3 L/d nearby (<5 km) **5** >5 x 10^3L/d >5 km away **0** <5 x 10^3 L/d or >10 km away	**10** >5 x 10^3 L/d nearby (<5 km) **5** >5 x 10^3L/d >5 km away **0** <5 x 10^3 L/d or >10 km away	**10** >5 x 10^3 L/d nearby (<5 km) **5** >5 x 10^3L/d >5 km away **0** <5 x 10^3 L/d or >10 km away
Land availability	**10** >2 ha suitable land available **5** 1-2 ha suitable land available **0** <1 ha suitable land available	**10** >1 ha available (i.e. not precluded by Nature Reserve, National Park, Native Title etc.)	**10** >25 ha available **5** 10-25 ha available **1** <10 ha available	**10** >1 ha available (i.e. not precluded by Nature Reserve, National Park, Native Title etc.)	**10** >25 ha available **5** 10-25 ha available **1** <10 ha available	**10** >1 ha available (i.e. not precluded by Nature Reserve, National Park, Native Title etc.)	**10** >25 ha available **5** 10-25 ha available **1** <10 ha available

Table 9: (Continued): Assessment criteria for various types of aquaculture – bracketed numbers indicate relevant assessment tables

Assessment Criteria	Marine Hatcheries (8.10)	*Grow-out – Stenohaline*		*Grow-out – Diadromous*		*Freshwater Natives*	
		Recirculating (8.11)	**Ponds (8.12)**	**Recirculating (8.13)**	**Ponds (8.14)**	**Recirculating (8.15)**	**Ponds (8.16)**
Soil type	**10** Suitable for building on **0** Water logged or unsuitable	**10** Suitable for building on **0** Water logged or unsuitable	**10** Sandy loam, holds water, easy to work (push up pond walls) **5** Clayey or sandy soils (harder to work but still OK) **0** Rocky or needs liners	**10** Suitable for building on **0** Water logged or unsuitable	**10** Sandy loam, holds water, easy to work (push up pond walls) **5** Clayey or sandy soils (harder to work but still OK) **0** Rocky or needs liners	**10** Suitable for building on **0** Water logged or unsuitable	**10** Sandy loam, holds water, easy o work (push up pond walls) **5** Clayey or sandy soils (harder to work but still OK) **0** Rocky or needs liners
Environmental sensitivity	**3** Environmentally insensitive location **2** Location has some degree of environmental sensitivity **1** Moderately important or environmentally sensitive	**3** Environmentally insensitive location **2** Location has some degree of environmental sensitivity **1** Moderately important or environmentally sensitive	**3** Environmentally insensitive location **2** Location has some degree of environmental sensitivity **1** Moderately important or environmentally sensitive	**3** Environmentally insensitive location **2** Location has some degree of environmental sensitivity **1** Moderately important or environmentally sensitive	**3** Environmentally insensitive location **2** Location has some degree of environmental sensitivity **1** Moderately important or environmentally sensitive	**3** Environmentally insensitive location **2** Location has some degree of environmental sensitivity **1** Moderately important or environmentally sensitive	**3** Environmentally insensitive location **2** Location has some degree of environmental sensitivity **1** Moderately important or environmentally sensitive
Existing structures (e.g. pipes, pumps, evaporation ponds)	**10** Developed scheme e.g. for groundwater interception which includes pumps, pipes and evaporation/disposal basin facility **5** Partially developed scheme (some facilities) **3** Proposed scheme **0** No scheme	**10** Developed scheme e.g. for groundwater interception which includes pumps, pipes and evaporation/disposal basin facility **5** Partially developed scheme (some facilities) **3** Proposed scheme **0** No scheme	**10** Developed scheme e.g. for groundwater interception which includes pumps, pipes and evaporation/disposal basin facility **5** Partially developed scheme (some facilities) **3** Proposed scheme **0** No scheme	**10** Developed scheme e.g. for groundwater interception which includes pumps, pipes and evaporation/ disposal basin facility **5** Partially developed scheme (some facilities) **3** Proposed scheme **0** No scheme	**10** Developed scheme e.g. for groundwater interception which includes pumps, pipes and evaporation/disposal basin facility **5** Partially developed scheme (some facilities) **3** Proposed scheme **0** No scheme	**10** Developed scheme e.g. for groundwater interception which includes pumps, pipes and evaporation/disposal basin facility **5** Partially developed scheme (some facilities) **3** Proposed scheme **0** No scheme	**10** Developed scheme e.g. for groundwater interception which includes pumps, pipes and evaporation/disposal basin facility **5** Partially developed scheme (some facilities) **3** Proposed scheme **0** No scheme
Infrastructure – Labour and Services	**3** Town of >2000 within 25 km **2** Town of 500-2000 within 25 km and /or town of >2000 within 25-50 km **1** Any town within 50 km	**3** Town of >2000 within 25 km **2** Town of 500-2000 within 25 km and /or town of >2000 within 25-50 km **1** Any town within 50 km	**3** Town of >2000 within 25 km **2** Town of 500-2000 within 25 km and /or town of >2000 within 25-50 km **1** Any town within 50 km	**3** Town of >2000 within 25 km **2** Town of 500-2000 within 25 km and /or town of >2000 within 25-50 km **1** Any town within 50 km	**3** Town of >2000 within 25 km **2** Town of 500-2000 within 25 km and /or town of >2000 within 25-50 km **1** Any town within 50 km	**3** Town of >2000 within 25 km **2** Town of 500-2000 within 25 km and /or town of >2000 within 25-50 km **1** Any town within 50 km	**3** Town of >2000 within 25 km **2** Town of 500-2000 within 25 km and /or town of >2000 within 25-50 km **1** Any town within 50 km

Table 9: (Continued): Assessment criteria for various types of aquaculture – bracketed numbers indicate relevant assessment tables

Assessment Criteria	Marine Hatcheries (8.10)	*Grow-out – Stenohaline*		*Grow-out – Diadromous*		*Freshwater Natives*	
		Recirculating (8.11)	**Ponds (8.12)**	**Recirculating (8.13)**	**Ponds (8.14)**	**Recirculating (8.15)**	**Ponds (8.16)**
Infastructure – Power	**10** Electricity available within 2 km **5** Electricity available 2-25 km **1** Electricity available 25-50 km	**10** Electricity available within 2 km **5** Electricity available 2-25 km **1** Electricity available 25-50 km	**10** Electricity available within 2 km **5** Electricity available 2-25 km **1** Electricity available 25-50 km	**10** Electricity available within 2 km **5** Electricity available 2-25 km **1** Electricity available 25-50 km	**10** Electricity available within 2 km **5** Electricity available 2-25 km **1** Electricity available 25-50 km	**10** Electricity available within 2 km **5** Electricity available 2-25 km **1** Electricity available 25-50 km	**10** Electricity available within 2 km **5** Electricity available 2-25 km **1** Electricity available 25-50 km
Infrastructure – Transport	**10** Highway, rail and/or airport or commercial airline nearby **5** Highway nearby **1** Located some distance away from main transport corridor	**10** Highway, rail and/or airport or commercial airline nearby **5** Highway nearby **1** Located some distance away from main transport corridor	**10** Highway, rail and/or airport or commercial airline nearby **5** Highway nearby **1** Located some distance away from main transport corridor	**10** Highway, rail and/or airport or commercial airline nearby **5** Highway nearby **1** Located some distance away from main transport corridor	**10** Highway, rail and/or airport or commercial airline nearby **5** Highway nearby **1** Located some distance away from main transport corridor	**10** Highway, rail and/or airport or commercial airline nearby **5** Highway nearby **1** Located some distance away from main transport corridor	**10** Highway, rail and/or airport or commercial airline nearby **5** Highway nearby **1** Located some distance away from main transport corridor
Cost-sharing opportunities (e.g. with groundwater interception and disposal schemes)	**10** High cost-sharing opportunity with new or existing development **5** Some cost-sharing opportunity **1** Limited cost-sharing opportunity	**10** High cost-sharing opportunity with new or existing development **5** Some cost-sharing opportunity **1** Limited cost-sharing opportunity	**10** High cost-sharing opportunity with new or existing development **5** Some cost-sharing opportunity **1** Limited cost-sharing opportunity	**10** High cost-sharing opportunity with new or existing development **5** Some cost-sharing opportunity **1** Limited cost-sharing opportunity	**10** High cost-sharing opportunity with new or existing development **5** Some cost-sharing opportunity **1** Limited cost-sharing opportunity	**10** High cost-sharing opportunity with new or existing development **5** Some cost-sharing opportunity **1** Limited cost-sharing opportunity	**10** High cost-sharing opportunity with new or existing development **5** Some cost-sharing opportunity **1** Limited cost-sharing opportunity

8.12. Saline Resource Assessment

8.12.1. General

The following represents the application of the assessment criteria developed in the previous chapter to saline resources identified as having potential for inland saline aquaculture. This assessment has been applied for each of the aquaculture types.

1. Marine hatcheries (Table 10).
2. Grow-out of stenohaline fish using recirculating facilities (Table 11).
3. Grow-out of stenohaline fish using ponds (Table 12).
4. Grow-out of diadromous fish using recirculating facilities (Table 13).
5. Grow-out of diadromous fish using ponds (Table 14).
6. Grow-out of freshwater native fish using recirculating facilities (Table 15).
7. Grow-out of freshwater native fish using ponds (Table 16).

Each of the above tables has parts A, B, C and D representing different types of saline water resources.

8.12.2. Assessing the Suitability of Saline Resources

The results in Tables 10 to 15 represent a preliminary and indicative assessment of the suitability of saline water resources for various types of aquaculture. Where possible, individual criteria assessments have been based on quantitative or qualitative information. In many cases, however, particularly for resources other than existing salt interception schemes, an educated judgement has been made. Individual scores for each of the thirteen criteria have been summed to provide an overall assessment of the particular resource, and generally the higher the score the better. It is important to note that minor differences in scores are unlikely to be significant, and it is important to refer back to the text or other information sources for any comparative evaluation. Overall scores that are bracketed indicate that one or more of the criteria could not be scored.

The weightings and assessment scores have been explicitly presented, so that individuals can undertake their own weighting and assessment.

Two types of assessment criteria have been used for this resource assessment namely:

- General criteria that are common to each of the aquaculture types such as environmental sensitivity, infrastructure and cost-sharing.
- Aquaculture-specific criteria such as resource requirement, salinity, ionic composition, land availability and soil type.

8.12.3. Overview of Assessment Outcomes

A number of saline water resources scored highly under the majority of aquaculture types. These included:

- The Esperance-Kalgoorlie seawater pipeline.
- Most groundwater interception schemes.
- Most of the Kerang Lakes.
- Urban groundwater pumping.
- The aquifers of the Murray Hydrogeological Basin.
- Coal mine drainage water.

It should be pointed out nevertheless that these findings are the result of a preliminary and indicative assessment, tentative scoring criteria, and often with limited resources information. Other resources, such as the Western District Volcanic Lakes, may score better under different criteria or weightings, or have qualities that make them more attractive to the establishment of saline aquaculture.

Marine hatcheries:
Saline water resources that scored well in relation to marine hatcheries included most groundwater interception schemes and the associated aquifers of the Murray Hydrogeological Basin. However, interception schemes also involving irrigation drainage did not score as high. The Wianamatta Shale of the Sydney Basin was another groundwater aquifer that scored well. Other resources to score well included urban groundwater pumping, coal mine drainage water, and most of the Kerang saline lakes. The proposed Esperance-Kalgoorlie seawater pipeline scored highest of all the identified resources.

Grow-out of stenohaline fish using recirculating facilities:
The saline water resources that scored well for this type of aquaculture were almost identical to those listed for marine hatcheries.

Grow-out of stenohaline fish using ponds:
Here also the saline water resources that scored well for this type of aquaculture were largely the same as those listed for marine hatcheries.

Grow-out of diadromous fish using recirculating facilities:
Likely suitable saline water resources for this aquaculture type included virtually all groundwater interception schemes and groundwaters, including Eyre Peninsula Region in South Australia. Urban groundwater pumping, shallow groundwater pumping in the Ord River Irrigation Area, the Esperance-Kalgoorlie seawater pipeline, coal mine drainage water, and all the Kerang Lakes also scored highly.

Grow-out of diadromous fish using ponds:
Saline resources that scored well under this category included virtually all groundwaters, all of the Kerang Lakes, urban groundwater pumping, shallow groundwater pumping in the Ord River Irrigation Area, the Esperance-Kalgoorlie seawater pipeline and coal mine drainage water. Most groundwater interception schemes also scored highly in this category.

Grow-out of freshwater native fish using recirculating facilities:
Resources to score well in this aquaculture category included groundwater interception schemes, particularly those that are more brackish or include more dilute irrigation drainage water. Urban groundwater pumping, shallow groundwater pumping in the Ord River Irrigation Area, the Esperance-Karoorlie seawater pipeline, a few of the Kerang Lakes and significant number of the groundwater resources also scored fairly high. Coal mine drainage water scored the highest for this category.

Grow-out of freshwater native fish using ponds:
The brackish water requirements of freshwater native fish meant that only a couple of groundwater interception schemes scored highly. However, urban groundwater pumping, groundwater pumping in the Ord Irrigation Area, coal mine drainage, the proposed Esperance-Karoorlie seawater pipeline, and a couple of the fresher Kerang lakes scored well for this category. Most groundwater resources also scored comparatively well for this aquaculture type.

Table 10: Ranking of Identified Saline Water Resource Interception and or Disposal Schemes for Marine Hatcheries (A)

Saline water resource and nearest major location	**Resource availability (10, 5, 1)**	**Resource salinity (10, 5, 1)**	**Ionic makeup (10, 5, 1)**	**Other water quality (3, 2, 1)**	**Freshwater availability (10, 5, 0)**	**Land availability (10, 5, 0)**	**Soil type (10, 5, 0)**	**Environ-mental sensitivity (3, 2, 1)**	**Existing structures (10, 5, 3, 1)**	**Labour & services availability (3, 2, 1)**	**Electricity supply proximity (10, 5, 1)**	**Transport proximity (10, 5, 1)**	**Cost sharing opportunity (10, 5, 1)**	**Overall score (max 109)**
Woolpunda Goundwater Interception Scheme - Stockyard Plain Basin, Waikerie, SA	10	5	10	3	10	10	10	2	10	3	5	5	5	88
Waikerie Salt Interception Scheme - Stockyard Plain Basin, Waikerie, SA	10	1	10	3	10	10	10	2	10	3	5	5	5	84
Noora Drainage Diversion Scheme, Berri / Loxton, SA	5	1	na	2	5	10	10	2	10	3	5	5	5	(63)
Rufus River Goundwater Interception Scheme, Lake Victoria, NSW	10	10	na	3	5	10	10	3	10	1	5	1	5	(73)
Mildura-Merbein Goundwater Interception Scheme, Mildura, Vic	10	5	10	3	10	10	10	3	10	3	5	10	5	94
Buronga Salt Interception Scheme, Mildura, Vic	10	5	10	3	5	10	10	3	10	2	5	10	5	88
Mallee Cliffs Salt Interception Scheme, Mildura, Vic	10	10	10	3	10	10	10	2	10	2	5	10	5	97
Wakool Salinity Control Scheme, Wakool, NSW	10	1	5	2	10	10	10	3	10	2	10	1	10	84
Barr Creek Salinity Control Scheme, Kerang, Vic	10	1	na	2	10	10	10	1	10	3	10	5	5	(77)
Girgarre Basin Salinity Control Project, Stanhope, Vic	10	1	5	2	5	10	10	3	10	2	10	1	5	74
Pyramid Hill Groundwater Interception &Salt Harvesting Scheme, Kerang, Vic (private)	10	5	5	2	10	10	10	3	5	2	10	5	?	(77)

Table.10B: Ranking of proposed groundwater disposal schemes and other potential saline water resources for marine hatcheries

Saline water resource and nearest major location	**Resource availability (10, 5, 1)**	**Resource salinity (10, 5, 1)**	**Ionic makeup (10, 5, 1)**	**Other water quality (3, 2, 1)**	**Freshwater availability (10, 5, 0)**	**Land availability (10, 5, 0)**	**Soil type (10, 5, 0)**	**Environ-mental sensitivity (3, 2, 1)**	**Existing structures (10, 5, 3, 0)**	**Labour & services availability (3, 2, 1)**	**Electricity supply proximity (10, 5, 1)**	**Transport proximity (10, 5, 1)**	**Cost sharing opportunity (10, 5, 1)**	**Overall score (max 109)**
Qualco-Sunlands Groundwater Interception & Salinity Control Scheme /Stockyard Basin, Waikerie, SA	10	5	10	2	10	10	10	2	5	3	5	5	10	87
Waikerie Stage II Salt Interception Scheme / Stockyard Basin, Waikerie, SA	10	5	10	3	10	10	10	2	5	3	5	5	10	88
Pyramid Creek Groundwater Interception Scheme, Kerang, Vic	10	5	5	3	10	10	10	3	3	3	5	5	10	82
Lindsay River Groundwater Interception Scheme, Mildura, Vic	10	5	5	3	5	10	10	1	3	1	5	1	10	69
Chowilla Groundwater Interception Scheme, Renmark, SA	10	10	5	3	5	10	10	1	3	3	5	5	10	80
Bookpurnong-Loxton Groundwater Interception & Drainage Scheme / Noora Basin, Berri / Loxton, SA	10	5	1	2	5	10	10	2	3	3	5	5	10	71
North Pike-Murtho Salt Interception Scheme, Paringa, SA	10	1	5	3	10	10	10	3	0	3	5	5	10	75
Yanda Creek Groundwater Interception Scheme, Louth (Darling River), NSW	10	1	1	3	5	10	10	2	0	1	1	1	10	55
Urban groundwater pumping schemes– various in MDB and WA e.g. Wagga, NSW	10	1	1	1	10	10	10	3	3	3	10	10	10	82
Ord River Irrigation Area groundwater pumping schemes, Kununurra, WA	10	1	1	2	10	10	10	3	3	2	5	5	10	72
Esperance-Kalgoorlie seawater pipeline, Esperance and Kalgoorlie, WA	10	10	10	3	10	10	10	3	3	3	10	10	10	102
On-farm Serial Biological-Concentration projects, Murray-Darling Basin and WA	5	1	1	2	0	10	10	3	0	1	5	1	10	49
Coal mine drainage water – various NSW and QLD	10	1	1	1	10	10	10	3	5	3	10	10	10	84

Table 10C: Ranking of Victorian permanent saline lakes for marine hatcheries

Saline water resource and nearest major location	**Resource availability (10, 5, 1)**	**Resource salinity (10, 5, 1)**	**Ionic makeup (10, 5, 1)**	**Other water quality (3, 2, 1)**	**Freshwater availability (10, 5, 0)**	**Land availability (10, 5, 0)**	**Soil type (10, 5, 0)**	**Environ-mental sensitivity (3, 2, 1)**	**Existing structures (10, 5, 3, 0)**	**Labour & services availability (3, 2, 1)**	**Electricity supply proximity (10, 5, 1)**	**Transport proximity (10, 5, 1)**	**Cost sharing opportunity (10, 5, 1)**	**Overall score (max 109)**
Lake Corangamite, Colac, Vic	10	5	5	2	5	10	10	1	0	3	10	5	1	67
Lake Bullen Merri, Colac, Vic	10	1	5	2	5	10	10	2	0	3	10	5	1	64
Lake Purrumbete, Colac, Vic	10	1	5	2	5	10	10	2	0	3	10	5	1	64
Lake Martin, Colac, Vic	10	1	5	2	5	10	10	1	0	3	10	5	1	63
Lake Gnarpurt, Colac, Vic	10	1	5	2	5	10	10	1	0	3	10	5	1	63
Lake Colac, Colac, Vic	10	1	5	2	5	10	10	2	0	3	10	5	1	64
Lake Gnotuk, Colac, Vic	10	1	5	2	5	10	10	1	0	3	10	5	1	63
Lake Colongulac, Colac, Vic	10	1	5	2	5	10	10	1	0	3	10	5	1	63
East Basin Lake, Colac, Vic	10	na	na	2	5	10	10	1	0	3	10	5	1	(57)
West Basin Lake, Colac, Vic	10	na	na	2	5	10	10	1	0	3	10	5	1	(57)
Lake Tutchewop, Kerang, Vic	10	1	na	2	10	10	10	1	5	3	10	10	10	(82)
Cullens Lake, Kerang, Vic	10	1	na	2	10	10	10	1	5	3	10	10	5	(77)
Lake Kelly, Kerang, Vic	10	5	na	2	10	10	10	1	5	3	10	10	10	(86)
Lake William, Kerang, Vic	10	1	na	2	10	10	10	1	5	3	10	10	10	(82)
Lake Elizabeth, Kerang, Vic	10	5	na	2	10	10	10	2	5	3	10	10	5	(82)
Lake Wandella, Kerang, Vic	10	10	na	2	10	10	10	2	5	3	10	10	5	(87)
Little Lake Kelly, Kerang, Vic	10	5	na	2	10	10	10	2	5	3	10	10	10	(87)
Lake Charm, Kerang, Victoria	10	1	na	2	10	10	10	1	5	3	10	10	10	(82)
Lookout Lake, Kerang, Vic	10	1	na	2	10	10	10	2	5	3	10	10	5	(78)

Table 10D: Ranking of deeper regional sedimentary and fractured-rock groundwater resources for marine hatcheries

Sedimentary basin and aquifer	Resource availability (10, 5, 1)	Resource salinity (10, 5, 1)	Ionic makeup (10, 5, 1)	Other water quality (3, 2, 1)	Freshwater availability (10, 5, 0)	Land availability (10, 5, 0)	Soil type (10, 5, 0)	Environ-mental sensitivity (3, 2, 1)	Existing structures (10, 5, 3, 0)	Labour & services availability (3, 2, 1)	Electricity supply proximity (10, 5, 1)	Transport proximity (10, 5, 1)	Cost sharing opportunity (10, 5, 1)	Overall score (max 109)
Murray Basin NSW, Vic & SA														
Parilla Sands	10	10	10	3	10	10	10	3	0	3	10	10	1	90
Calivil Fromation & Renmark Group	10	10	10	3	10	10	10	3	0	3	10	10	1	90
Lower Renmark Group	10	10	10	3	10	10	10	3	0	3	10	10	1	90
Otway Basin Vic														
Newer Volcanics	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Dylwin Formation	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Gippsland Basin Vic														
Gippsland Limestone	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Port Phillip Basin Vic														
Unspecified aquifers	10	1	na	2	10	10	10	3	0	3	10	10	1	(70)
Sydney Basin NSW														
Wianamatta Shales	10	1	10	3	10	10	10	3	0	3	10	10	1	81
Narrabeen Group	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Basal Permian sediments	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Clarence-Morton Basin NSW-QLD														
Walloon Coal Measures	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Basal Triassic coal measures	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Carnarvon Basin WA														
Tumbalagooda Sandstone	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Basal Birdrong Sandstone	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)

Table 10D (continued): Ranking of deeper regional sedimentary and fractured-rock groundwater resources for marine hatcheries

Sedimentary basin or aquifer	Resource availability (10, 5, 1)	Resource salinity (10, 5, 1)	Ionic makeup (10, 5, 1)	Other water quality (3, 2, 1)	Freshwater availability (10, 5, 0)	Land availability (10, 5, 0)	Soil type (10, 5, 0)	Environ-mental sensitivity (3, 2, 1)	Existing structures (10, 5, 3, 0)	Labour & services availability (3, 2, 1)	Electricity supply proximity (10, 5, 1)	Transport proximity (10, 5, 1)	Cost sharing opportunity (10, 5, 1)	Overall score (max 109)
Amadeus Basin NT														
Unspecified aquifers	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Western Slopes and Plains fractured rock province, NSW	10	1	na	3	10	10	10	3	0	3	10	5	1	(66)
Eyre Peninsula fractured rock province, Pt Lincoln / Whyalla, SA	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Western fractured rock province, WA	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)

Table 11: Ranking of Saline Water Resource Interception and Disposal Schemes for Grow-Out of Stenohaline Fish Based on Recirculation (A)

Saline water resource and nearest major location	**Resource availability (10, 5, 1)**	**Resource salinity (10, 5, 1)**	**Ionic makeup (10, 5, 1)**	**Other water quality (3, 2, 1)**	**Freshwater availability (10, 5, 0)**	**Land availability (10, 5, 0)**	**Soil type (10, 5, 0)**	**Environ-mental sensitivity (3, 2, 1)**	**Existing structures (10, 5, 3, 1)**	**Labour & services availability (3, 2, 1)**	**Electricity supply proximity (10, 5, 1)**	**Transport proximity (10, 5, 1)**	**Cost sharing opportunity (10, 5, 1)**	**Overall score (max 109)**
Woolpunda Goundwater Interception Scheme - Stockyard Plain Basin, Waikerie, SA	10	5	10	3	10	10	10	2	10	3	5	5	5	88
Waikerie Salt Interception Scheme - Stockyard Plain Basin, Waikerie, SA	10	1	10	3	10	10	10	2	10	3	5	5	5	84
Noora Drainage Diversion Scheme, Berri / Loxton, SA	5	1	na	2	5	10	10	2	10	3	5	5	5	(63)
Rufus River Goundwater Interception Scheme, Lake Victoria, NSW	10	10	na	3	5	10	10	3	10	1	5	1	5	(73)
Mildura-Merbein Goundwater Interception Scheme, Mildura, Vic	10	5	10	3	10	10	10	3	10	3	5	10	5	94
Buronga Salt Interception Scheme, Mildura, Vic	10	5	10	3	5	10	10	3	10	2	5	10	5	88
Mallee Cliffs Salt Interception Scheme, Mildura, Vic	10	10	10	3	10	10	10	2	10	2	5	10	5	97
Wakool Salinity Control Scheme, Wakool, NSW	10	1	5	2	10	10	10	3	10	2	10	1	10	84
Barr Creek Salinity Control Scheme, Kerang, Vic	10	1	na	2	10	10	10	1	10	3	10	5	5	(77)
Girgarre Basin Salinity Control Project, Stanhope, Vic	10	1	5	2	5	10	10	3	10	2	10	1	5	74
Pyramid Hill Groundwater Interception &Salt Harvesting Scheme, Kerang, Vic (private)	10	5	5	2	10	10	10	3	5	2	10	5	?	(77)

Table 11B: Ranking of proposed groundwater disposal schemes and potential resources for grow-out of stenohaline fish based on recirculation

Saline water resource and nearest major location	**Resource availability (10, 5, 1)**	**Resource salinity (10, 5, 1)**	**Ionic makeup (10, 5, 1)**	**Other water quality (3, 2, 1)**	**Freshwater availability (10, 5, 0)**	**Land availability (10, 5, 0)**	**Soil type (10, 5, 0)**	**Environ-mental sensitivity (3, 2, 1)**	**Existing structures (10, 5, 3, 0)**	**Labour & services availability (3, 2, 1)**	**Electricity supply proximity (10, 5, 1)**	**Transport proximity (10, 5, 1)**	**Cost sharing opportunity (10, 5, 1)**	**Overall score (max 109)**
Qualco-Sunlands Groundwater Interception & Salinity Control Scheme /Stockyard Basin, Waikerie, SA	10	5	10	2	10	10	10	2	5	3	5	5	10	87
Waikerie Stage II Salt Interception Scheme / Stockyard Basin, Waikerie, SA	10	5	10	3	10	10	10	2	5	3	5	5	10	88
Pyramid Creek Groundwater Interception Scheme, Kerang, Vic	10	5	5	3	10	10	10	3	3	3	5	5	10	82
Lindsay River Groundwater Interception Scheme, Mildura, Vic	10	5	5	3	5	10	10	1	3	1	5	1	10	69
Chowilla Groundwater Interception Scheme, Renmark, SA	10	10	5	3	5	10	10	1	3	3	5	5	10	80
Bookpurnong-Loxton Groundwater Interception & Drainage Scheme / Noora Basin, Berri / Loxton, SA	10	5	1	2	5	10	10	2	3	3	5	5	10	71
North Pike-Murtho Salt Interception Scheme, Paringa, SA	10	1	5	3	10	10	10	3	0	3	5	5	10	75
Yanda Creek Groundwater Interception Scheme, Louth (Darling River), NSW	10	1	1	3	5	10	10	2	0	1	1	1	10	55
Urban groundwater pumping schemes– various in MDB and WA e.g. Wagga, NSW	10	1	1	1	10	10	10	3	3	3	10	10	10	82
Ord River Irrigation Area groundwater pumping schemes, Kununurra, WA	10	1	1	2	10	10	10	3	3	2	5	5	10	72
Esperance-Kalgoorlie seawater pipeline, Esperance and Kalgoorlie, WA	10	10	10	3	10	10	10	3	3	3	10	10	10	102
On-farm Serial Biological-Concentration projects, Murray-Darling Basin and WA	5	1	1	2	0	10	10	3	0	1	5	1	10	49
Coal mine drainage water – various NSW and QLD	10	1	1	1	10	10	10	3	5	3	10	10	10	84

Table 11C: Ranking of Victorian permanent saline lakes for grow-out of stenohaline fish based on recirculating facilites

Saline water resource and nearest major location	Resource availability (10, 5, 1)	Resource salinity (10, 5, 1)	Ionic makeup (10, 5, 1)	Other water quality (3, 2, 1)	Freshwater availability (10, 5, 0)	Land availability (10, 5, 0)	Soil type (10, 5, 0)	Environ-mental sensitivity (3, 2, 1)	Existing structures (10, 5, 3, 0)	Labour & services availability (3, 2, 1)	Electricity supply proximity (10, 5, 1)	Transport proximity (10, 5, 1)	Cost sharing opportunity (10, 5, 1)	Overall score (max 109)
Lake Corangamite, Colac, Vic	10	5	5	2	5	10	10	1	0	3	10	5	1	67
Lake Bullen Merri, Colac, Vic	10	1	5	2	5	10	10	2	0	3	10	5	1	64
Lake Purrumbete, Colac, Vic	10	1	5	2	5	10	10	2	0	3	10	5	1	64
Lake Martin, Colac, Vic	10	1	5	2	5	10	10	1	0	3	10	5	1	63
Lake Gnarpurt, Colac, Vic	10	1	5	2	5	10	10	1	0	3	10	5	1	63
Lake Colac, Colac, Vic	10	1	5	2	5	10	10	2	0	3	10	5	1	64
Lake Gnotuk, Colac, Vic	10	1	5	2	5	10	10	1	0	3	10	5	1	63
Lake Colongulac, Colac, Vic	10	1	5	2	5	10	10	1	0	3	10	5	1	63
East Basin Lake, Colac, Vic	10	na	na	2	5	10	10	1	0	3	10	5	1	(57)
West Basin Lake, Colac, Vic	10	na	na	2	5	10	10	1	0	3	10	5	1	(57)
Lake Tutchewop, Kerang, Vic	10	1	na	2	10	10	10	1	5	3	10	10	10	(82)
Cullens Lake, Kerang, Vic	10	1	na	2	10	10	10	1	5	3	10	10	5	(77)
Lake Kelly, Kerang, Vic	10	5	na	2	10	10	10	1	5	3	10	10	10	(86)
Lake William, Kerang, Vic	10	1	na	2	10	10	10	1	5	3	10	10	10	(82)
Lake Elizabeth, Kerang, Vic	10	5	na	2	10	10	10	2	5	3	10	10	5	(82)
Lake Wandella, Kerang, Vic	10	10	na	2	10	10	10	2	5	3	10	10	5	(87)
Little Lake Kelly, Kerang, Vic	10	5	na	2	10	10	10	2	5	3	10	10	10	(87)
Lake Charm, Kerang, Victoria	10	1	na	2	10	10	10	1	5	3	10	10	10	(82)
Lookout Lake, Kerang, Vic	10	1	na	2	10	10	10	2	5	3	10	10	5	(78)

Table 11D: Ranking of regional sedimentary and fractured-rock groundwaters for grow-out of stenohaline fish based on recirculating facilities

Sedimentary basin and aquifer	**Resource availability (10, 5, 1)**	**Resource salinity (10, 5, 1)**	**Ionic makeup (10, 5, 1)**	**Other water quality (3, 2, 1)**	**Freshwater availability (10, 5, 0)**	**Land availability (10, 5, 0)**	**Soil type (10, 5, 0)**	**Environ-mental sensitivity (3, 2, 1)**	**Existing structures (10, 5, 3, 0)**	**Labour & services availability (3, 2, 1)**	**Electricity supply proximity (10, 5, 1)**	**Transport proximity (10, 5, 1)**	**Cost sharing opportunity (10, 5, 1)**	**Overall score (max 109)**
Murray Basin NSW, Vic & SA														
Parilla Sands	10	10	10	3	10	10	10	3	0	3	10	10	1	90
Calivil Fromation & Renmark Group	10	10	10	3	10	10	10	3	0	3	10	10	1	90
Lower Renmark Group	10	10	10	3	10	10	10	3	0	3	10	10	1	90
Otway Basin Vic														
Newer Volcanics	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Dylwin Formation	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Gippsland Basin Vic														
Gippsland Limestone	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Port Phillip Basin Vic														
Unspecified aquifers	10	1	na	2	10	10	10	3	0	3	10	10	1	(70)
Sydney Basin NSW														
Wianamatta Shales	10	1	10	3	10	10	10	3	0	3	10	10	1	81
Narrabeen Group	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Basal Permian sediments	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Clarence-Morton Basin NSW-QLD														
Walloon Coal Measures	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Basal Triassic coal measures	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Carnarvon Basin WA														
Tumbalagooda Sandstone	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Basal Birdrong Sandstone	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)

Table 11D (continued): Ranking of regional sedimentary and fractured-rock groundwaters for grow-out of stenohaline fish based on recirculating facilities

Sedimentary basin or aquifer	**Resource availability (10, 5, 1)**	**Resource salinity (10, 5, 1)**	**Ionic makeup (10, 5, 1)**	**Other water quality (3, 2, 1)**	**Freshwater availability (10, 5, 0)**	**Land availability (10, 5, 0)**	**Soil type (10, 5, 0)**	**Environ-mental sensitivity (3, 2, 1)**	**Existing structures (10, 5, 3, 0)**	**Labour & services availability (3, 2, 1)**	**Electricity supply proximity (10, 5, 1)**	**Transport proximity (10, 5, 1)**	**Cost sharing opportunity (10, 5, 1)**	**Overall score (max 109)**
Amadeus Basin NT														
Unspecified aquifers	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Western Slopes and Plains fractured rock province, NSW	10	1	na	3	10	10	10	3	0	3	10	5	1	(66)
Eyre Peninsula fractured rock province, Pt Lincoln / Whyalla, SA	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Western fractured rock province, WA	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)

Table 12: Ranking of Identified Saline Water Resource Interception and or Disposal Schemes for Grow-Out of Stenohaline Fish Using Ponds (A)

Saline water resource and nearest major location	**Resource availability (10, 5, 1)**	**Resource salinity (10, 5, 1)**	**Ionic makeup (10, 5, 1)**	**Other water quality (3, 2, 1)**	**Freshwater availability (10, 5, 0)**	**Land availability (10, 5, 0)**	**Soil type (10, 5, 0)**	**Environ-mental sensitivity (3, 2, 1)**	**Existing structures (10, 5, 3, 1)**	**Labour & services availability (3, 2, 1)**	**Electricity supply proximity (10, 5, 1)**	**Transport proximity (10, 5, 1)**	**Cost sharing opportunity (10, 5, 1)**	**Overall score (max 109)**
Woolpunda Goundwater Interception Scheme - Stockyard Plain Basin, Waikerie, SA	10	5	10	3	10	10	5	2	10	3	5	5	5	83
Waikerie Salt Interception Scheme - Stockyard Plain Basin, Waikerie, SA	10	1	10	3	10	10	5	2	10	3	5	5	5	79
Noora Drainage Diversion Scheme, Berri / Loxton, SA	5	1	na	2	5	10	5	2	10	3	5	5	5	(58)
Rufus River Goundwater Interception Scheme, Lake Victoria, NSW	10	10	na	3	5	10	5	3	10	1	5	1	5	(68)
Mildura-Merbein Goundwater Interception Scheme, Mildura, Vic	10	5	10	3	10	10	5	3	10	3	5	10	5	89
Buronga Salt Interception Scheme, Mildura, Vic	10	5	10	3	5	10	5	3	10	2	5	10	5	83
Mallee Cliffs Salt Interception Scheme, Mildura, Vic	10	10	10	3	10	10	5	2	10	2	5	10	5	92
Wakool Salinity Control Scheme, Wakool, NSW	10	1	5	2	10	10	5	3	10	2	10	1	10	79
Barr Creek Salinity Control Scheme, Kerang, Vic	10	1	na	2	10	10	5	1	10	3	10	5	5	(72)
Girgarre Basin Salinity Control Project, Stanhope, Vic	10	1	5	2	5	10	5	3	10	2	10	1	5	69
Pyramid Hill Groundwater Interception &Salt Harvesting Scheme, Kerang, Vic (private)	1	5	5	2	10	5	0	3	5	2	10	5	?	(53)

Table 12B: Ranking of proposed groundwater disposal schemes and potential saline water resources for grow-out of stenohaline fish using ponds

Saline water resource and nearest major location	**Resource availability (10, 5, 1)**	**Resource salinity (10, 5, 1)**	**Ionic makeup (10, 5, 1)**	**Other water quality (3, 2, 1)**	**Freshwater availability (10, 5, 0)**	**Land availability (10, 5, 0)**	**Soil type (10, 5, 0)**	**Environ-mental sensitivity (3, 2, 1)**	**Existing structures (10, 5, 3, 0)**	**Labour & services availability (3, 2, 1)**	**Electricity supply proximity (10, 5, 1)**	**Transport proximity (10, 5, 1)**	**Cost sharing opportunity (10, 5, 1)**	**Overall score (max 109)**
Qualco-Sunlands Groundwater Interception & Salinity Control Scheme /Stockyard Basin, Waikerie, SA	10	5	10	2	10	10	10	2	5	3	5	5	10	87
Waikerie Stage II Salt Interception Scheme / Stockyard Basin, Waikerie, SA	10	5	10	3	10	10	10	2	5	3	5	5	10	88
Pyramid Creek Groundwater Interception Scheme, Kerang, Vic	10	5	5	3	10	10	10	3	3	3	5	5	10	82
Lindsay River Groundwater Interception Scheme, Mildura, Vic	10	5	5	3	5	10	10	1	3	1	5	1	10	69
Chowilla Groundwater Interception Scheme, Renmark, SA	10	10	5	3	5	10	10	1	3	3	5	5	10	80
Bookpurnong-Loxton Groundwater Interception & Drainage Scheme / Noora Basin, Berri / Loxton, SA	10	5	1	2	5	10	10	2	3	3	5	5	10	71
North Pike-Murtho Salt Interception Scheme, Paringa, SA	10	1	5	3	10	10	10	3	0	3	5	5	10	75
Yanda Creek Groundwater Interception Scheme, Louth (Darling River), NSW	10	1	1	3	5	10	10	2	0	1	1	1	10	55
Urban groundwater pumping schemes– various in MDB and WA e.g. Wagga, NSW	5	1	1	1	10	10	10	3	3	3	10	10	10	77
Ord River Irrigation Area groundwater pumping schemes, Kununurra, WA	10	1	1	2	10	10	10	3	3	2	5	5	10	72
Esperance-Kalgoorlie seawater pipeline, Esperance and Kalgoorlie, WA	10	10	10	3	10	10	10	3	3	3	10	10	10	102
On-farm Serial Biological-Concentration projects, Murray-Darling Basin and WA	1	1	1	2	0	5	10	3	0	1	5	1	10	40
Coal mine drainage water – various NSW and QLD	10	1	1	1	10	10	10	3	5	3	10	10	10	84

Table 12C: Ranking of Victorian permanent saline lakes for grow-out of stenohaline fish using ponds

Saline water resource and nearest major location	**Resource availability (10, 5, 1)**	**Resource salinity (10, 5, 1)**	**Ionic makeup (10, 5, 1)**	**Other water quality (3, 2, 1)**	**Freshwater availability (10, 5, 0)**	**Land availability (10, 5, 0)**	**Soil type (10, 5, 0)**	**Environ-mental sensitivity (3, 2, 1)**	**Existing structures (10, 5, 3, 0)**	**Labour & services availability (3, 2, 1)**	**Electricity supply proximity (10, 5, 1)**	**Transport proximity (10, 5, 1)**	**Cost sharing opportunity (10, 5, 1)**	**Overall score (max 109)**
Lake Corangamite, Colac, Vic	10	5	5	2	5	10	10	1	0	3	10	5	1	67
Lake Bullen Merri, Colac, Vic	10	1	5	2	5	10	10	2	0	3	10	5	1	64
Lake Purrumbete, Colac, Vic	10	1	5	2	5	10	10	2	0	3	10	5	1	64
Lake Martin, Colac, Vic	10	1	5	2	5	10	10	1	0	3	10	5	1	63
Lake Gnarpurt, Colac, Vic	10	1	5	2	5	10	10	1	0	3	10	5	1	63
Lake Colac, Colac, Vic	10	1	5	2	5	10	10	2	0	3	10	5	1	64
Lake Gnotuk, Colac, Vic	10	1	5	2	5	10	10	1	0	3	10	5	1	63
Lake Colongulac, Colac, Vic	10	1	5	2	5	10	10	1	0	3	10	5	1	63
East Basin Lake, Colac, Vic	10	na	na	2	5	10	10	1	0	3	10	5	1	(57)
West Basin Lake, Colac, Vic	10	na	na	2	5	10	10	1	0	3	10	5	1	(57)
Lake Tutchewop, Kerang, Vic	10	1	na	2	10	10	10	1	5	3	10	10	10	(82)
Cullens Lake, Kerang, Vic	10	1	na	2	10	10	10	1	5	3	10	10	5	(77)
Lake Kelly, Kerang, Vic	10	5	na	2	10	10	10	1	5	3	10	10	10	(86)
Lake William, Kerang, Vic	10	1	na	2	10	10	10	1	5	3	10	10	10	(82)
Lake Elizabeth, Kerang, Vic	10	5	na	2	10	10	10	2	5	3	10	10	5	(82)
Lake Wandella, Kerang, Vic	10	10	na	2	10	10	10	2	5	3	10	10	5	(87)
Little Lake Kelly, Kerang, Vic	10	5	na	2	10	10	10	2	5	3	10	10	10	(87)
Lake Charm, Kerang, Victoria	10	1	na	2	10	10	10	1	5	3	10	10	10	(82)
Lookout Lake, Kerang, Vic	10	1	na	2	10	10	10	2	5	3	10	10	5	(78)

Table 12D: Ranking of deeper regional sedimentary and fractured-rock groundwater resources for grow-out of stenohaline fish using ponds

Sedimentary basin and aquifer	**Resource availability (10, 5, 1)**	**Resource salinity (10, 5, 1)**	**Ionic makeup (10, 5, 1)**	**Other water quality (3, 2, 1)**	**Freshwater availability (10, 5, 0)**	**Land availability (10, 5, 0)**	**Soil type (10, 5, 0)**	**Environ-mental sensitivity (3, 2, 1)**	**Existing structures (10, 5, 3, 0)**	**Labour & services availability (3, 2, 1)**	**Electricity supply proximity (10, 5, 1)**	**Transport proximity (10, 5, 1)**	**Cost sharing opportunity (10, 5, 1)**	**Overall score (max 109)**
Murray Basin NSW, Vic & SA														
Parilla Sands	10	10	10	3	10	10	10	3	0	3	10	10	1	90
Calivil Fromation & Renmark Group	10	10	10	3	10	10	10	3	0	3	10	10	1	90
Lower Renmark Group	10	10	10	3	10	10	10	3	0	3	10	10	1	90
Otway Basin Vic														
Newer Volcanics	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Dylwin Formation	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Gippsland Basin Vic														
Gippsland Limestone	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Port Phillip Basin Vic														
Unspecified aquifers	10	1	na	2	10	10	10	3	0	3	10	10	1	(70)
Sydney Basin NSW														
Wianamatta Shales	10	1	10	3	10	10	10	3	0	3	10	10	1	81
Narrabeen Group	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Basal Permian sediments	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Clarence-Morton Basin NSW-QLD														
Walloon Coal Measures	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Basal Triassic coal measures	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Carnarvon Basin WA														
Tumbalagooda Sandstone	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Basal Birdrong Sandstone	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)

Table 12D (continued): Ranking of deeper regional sedimentary and fractured-rock groundwater resources for grow-out of stenohaline fish using ponds

Sedimentary basin or aquifer	**Resource availability (10, 5, 1)**	**Resource salinity (10, 5, 1)**	**Ionic makeup (10, 5, 1)**	**Other water quality (3, 2, 1)**	**Freshwater availability (10, 5, 0)**	**Land availability (10, 5, 0)**	**Soil type (10, 5, 0)**	**Environ-mental sensitivity (3, 2, 1)**	**Existing structures (10, 5, 3, 0)**	**Labour & services availability (3, 2, 1)**	**Electricity supply proximity (10, 5, 1)**	**Transport proximity (10, 5, 1)**	**Cost sharing opportunity (10, 5, 1)**	**Overall score (max 109)**
Amadeus Basin NT														
Unspecified aquifers	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Western Slopes and Plains fractured rock province, NSW	1	1	na	3	10	10	10	3	0	3	10	5	1	(57)
Eyre Peninsula fractured rock province, Pt Lincoln / Whyalla, SA	5	1	na	3	10	10	10	3	0	3	10	10	1	(66)
Western fractured rock province, WA	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)

Table 13: Ranking of Identified Saline Water Resource Interception and or Disposal Schemes for Grow-Out of Diadromous Fish Using Recirculation (A)

Saline water resource and nearest major location	**Resource availability (10, 5, 1)**	**Resource salinity (10, 5, 1)**	**Ionic makeup (10, 5, 1)**	**Other water quality (3, 2, 1)**	**Freshwater availability (10, 5, 0)**	**Land availability (10, 5, 0)**	**Soil type (10, 5, 0)**	**Environ-mental sensitivity (3, 2, 1)**	**Existing structures (10, 5, 3, 1)**	**Labour & services availability (3, 2, 1)**	**Electricity supply proximity (10, 5, 1)**	**Transport proximity (10, 5, 1)**	**Cost sharing opportunity (10, 5, 1)**	**Overall score (max 109)**
Woolpunda Goundwater Interception Scheme - Stockyard Plain Basin, Waikerie, SA	10	10	10	3	10	10	10	2	10	3	5	5	5	93
Waikerie Salt Interception Scheme - Stockyard Plain Basin, Waikerie, SA	10	10	10	3	10	10	10	2	10	3	5	5	5	93
Noora Drainage Diversion Scheme, Berri / Loxton, SA	5	10	10	2	5	10	10	2	10	3	5	5	5	82
Rufus River Goundwater Interception Scheme, Lake Victoria, NSW	10	10	10	3	5	10	10	3	10	1	5	1	5	83
Mildura-Merbein Goundwater Interception Scheme, Mildura, Vic	10	1	10	3	10	10	10	3	10	3	5	10	5	90
Buronga Salt Interception Scheme, Mildura, Vic	10	10	10	3	5	10	10	3	10	2	5	10	5	93
Mallee Cliffs Salt Interception Scheme, Mildura, Vic	10	10	10	3	10	10	10	2	10	2	5	10	5	97
Wakool Salinity Control Scheme, Wakool, NSW	10	10	10	2	10	10	10	3	10	2	10	1	10	98
Barr Creek Salinity Control Scheme, Kerang, Vic	10	10	na	2	10	10	10	1	10	3	10	5	5	(86)
Girgarre Basin Salinity Control Project, Stanhope, Vic	10	10	10	2	5	10	10	3	10	2	10	1	5	88
Pyramid Hill Groundwater Interception &Salt Harvesting Scheme, Kerang, Vic (private)	10	10	10	2	10	10	10	3	5	2	10	5	?	(87)

Table 13B: Ranking of proposed groundwater disposal schemes and potential resources for grow-out of diadromous fish using recirculation

Saline water resource and nearest major location	Resource availability (10, 5, 1)	Resource salinity (10, 5, 1)	Ionic makeup (10, 5, 1)	Other water quality (3, 2, 1)	Freshwater availability (10, 5, 0)	Land availability (10, 5, 0)	Soil type (10, 5, 0)	Environ-mental sensitivity (3, 2, 1)	Existing structures (10, 5, 3, 0)	Labour & services availability (3, 2, 1)	Electricity supply proximity (10, 5, 1)	Transport proximity (10, 5, 1)	Cost sharing opportunity (10, 5, 1)	Overall score (max 109)
Qualco-Sunlands Groundwater Interception & Salinity Control Scheme /Stockyard Basin, Waikerie, SA	10	10	10	2	10	10	10	2	5	3	5	5	10	92
Waikerie Stage II Salt Interception Scheme / Stockyard Basin, Waikerie, SA	10	10	10	3	10	10	10	2	5	3	5	5	10	93
Pyramid Creek Groundwater Interception Scheme, Kerang, Vic	10	10	10	3	10	10	10	3	3	3	5	5	10	92
Lindsay River Groundwater Interception Scheme, Mildura, Vic	10	10	10	3	5	10	10	1	3	1	5	1	10	79
Chowilla Groundwater Interception Scheme, Renmark, SA	10	10	10	3	5	10	10	1	3	3	5	5	10	85
Bookpurnong-Loxton Groundwater Interception & Drainage Scheme / Noora Basin, Berri / Loxton, SA	10	10	10	2	5	10	10	2	3	3	5	5	10	85
North Pike-Murtho Salt Interception Scheme, Paringa, SA	10	10	10	3	10	10	10	3	0	3	5	5	10	89
Yanda Creek Groundwater Interception Scheme, Louth (Darling River), NSW	10	10	10	3	5	10	10	2	0	1	1	1	10	73
Urban groundwater pumping schemes– various in MDB and WA e.g. Wagga, NSW	10	10	10	1	10	10	10	3	3	3	10	10	10	100
Ord River Irrigation Area groundwater pumping schemes, Kununurra, WA	10	10	10	2	10	10	10	3	3	2	5	5	10	90
Esperance-Kalgoorlie seawater pipeline, Esperance and Kalgoorlie, WA	10	10	10	3	10	10	10	3	3	3	10	10	10	102
On-farm Serial Biological-Concentration projects, Murray-Darling Basin and WA	5	10	5	2	0	10	10	3	0	1	5	1	10	62
Coal mine drainage water – various NSW and QLD	10	10	5	1	10	10	10	3	5	3	10	10	10	97

Table 13C: Ranking of Victorian permanent saline lakes for grow-out of diadromous fish using recirculation

Saline water resource and nearest major location	Resource availability (10, 5, 1)	Resource salinity (10, 5, 1)	Ionic makeup (10, 5, 1)	Other water quality (3, 2, 1)	Freshwater availability (10, 5, 0)	Land availability (10, 5, 0)	Soil type (10, 5, 0)	Environ-mental sensitivity (3, 2, 1)	Existing structures (10, 5, 3, 0)	Labour & services availability (3, 2, 1)	Electricity supply proximity (10, 5, 1)	Transport proximity (10, 5, 1)	Cost sharing opportunity (10, 5, 1)	Overall score (max 109)
Lake Corangamite, Colac, Vic	10	10	10	2	5	10	10	1	0	3	10	5	1	77
Lake Bullen Merri, Colac, Vic	10	10	10	2	5	10	10	2	0	3	10	5	1	78
Lake Purrumbete, Colac, Vic	10	10	10	2	5	10	10	2	0	3	10	5	1	78
Lake Martin, Colac, Vic	10	10	10	2	5	10	10	1	0	3	10	5	1	77
Lake Gnarpurt, Colac, Vic	10	10	10	2	5	10	10	1	0	3	10	5	1	77
Lake Colac, Colac, Vic	10	10	10	2	5	10	10	2	0	3	10	5	1	78
Lake Gnotuk, Colac, Vic	10	10	10	2	5	10	10	1	0	3	10	5	1	77
Lake Colongulac, Colac, Vic	10	10	10	2	5	10	10	1	0	3	10	5	1	77
East Basin Lake, Colac, Vic	10	na	na	2	5	10	10	1	0	3	10	5	1	(57)
West Basin Lake, Colac, Vic	10	na	na	2	5	10	10	1	0	3	10	5	1	(57)
Lake Tutchewop, Kerang, Vic	10	5	na	2	10	10	10	1	5	3	10	10	10	(86)
Cullens Lake, Kerang, Vic	10	10	na	2	10	10	10	1	5	3	10	10	5	(86)
Lake Kelly, Kerang, Vic	10	5	na	2	10	10	10	1	5	3	10	10	10	(86)
Lake William, Kerang, Vic	10	5	na	2	10	10	10	1	5	3	10	10	10	(86)
Lake Elizabeth, Kerang, Vic	10	10	na	2	10	10	10	2	5	3	10	10	5	(87)
Lake Wandella, Kerang, Vic	10	10	na	2	10	10	10	2	5	3	10	10	5	(87)
Little Lake Kelly, Kerang, Vic	10	5	na	2	10	10	10	2	5	3	10	10	10	(87)
Lake Charm, Kerang, Vic	10	10	na	2	10	10	10	1	5	3	10	10	10	(91)
Lookout Lake, Kerang, Vic	10	10	na	2	10	10	10	2	5	3	10	10	5	(87)

Table 13D: Ranking of deeper regional sedimentary and fractured-rock groundwaters for grow-out of diadromous fish using recirculation

Sedimentary basin and aquifer	**Resource availability (10, 5, 1)**	**Resource salinity (10, 5, 1)**	**Ionic makeup (10, 5, 1)**	**Other water quality (3, 2, 1)**	**Freshwater availability (10, 5, 0)**	**Land availability (10, 5, 0)**	**Soil type (10, 5, 0)**	**Environ-mental sensitivity (3, 2, 1)**	**Existing structures (10, 5, 3, 0)**	**Labour & services availability (3, 2, 1)**	**Electricity supply proximity (10, 5, 1)**	**Transport proximity (10, 5, 1)**	**Cost sharing opportunity (10, 5, 1)**	**Overall score (max 109)**
Murray Basin NSW, Vic & SA														
Parilla Sands	10	10	10	3	10	10	10	3	0	3	10	10	1	90
Calivil Fromation & Renmark Group	10	10	10	3	10	10	10	3	0	3	10	10	1	90
Lower Renmark Group	10	10	10	3	10	10	10	3	0	3	10	10	1	90
Otway Basin Vic														
Newer Volcanics	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Dylwin Formation	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Gippsland Basin Vic														
Gippsland Limestone	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Port Phillip Basin Vic														
Unspecified aquifers	10	10	na	2	10	10	10	3	0	3	10	10	1	(79)
Sydney Basin NSW														
Wianamatta Shales	10	10	10	3	10	10	10	3	0	3	10	10	1	90
Narrabeen Group	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Basal Permian sediments	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Clarence-Morton Basin NSW-QLD														
Walloon Coal Measures	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Basal Triassic coal measures	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Carnarvon Basin WA														
Tumbalagooda Sandstone	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Basal Birdrong Sandstone	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)

Table 13D (continued): Ranking of deeper regional sedimentary and fractured-rock groundwaters for grow-out of diadromous fish using recirculation

Sedimentary basin or aquifer	**Resource availability (10, 5, 1)**	**Resource salinity (10, 5, 1)**	**Ionic makeup (10, 5, 1)**	**Other water quality (3, 2, 1)**	**Freshwater availability (10, 5, 0)**	**Land availability (10, 5, 0)**	**Soil type (10, 5, 0)**	**Environ-mental sensitivity (3, 2, 1)**	**Existing structures (10, 5, 3, 0)**	**Labour & services availability (3, 2, 1)**	**Electricity supply proximity (10, 5, 1)**	**Transport proximity (10, 5, 1)**	**Cost sharing opportunity (10, 5, 1)**	**Overall score (max 109)**
Amadeus Basin NT														
Unspecified aquifers	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Western Slopes and Plains fractured rock province, NSW	10	10	na	3	10	10	10	3	0	3	10	5	1	(75)
Eyre Peninsula fractured rock province, Pt Lincoln / Whyalla, SA	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Western fractured rock province, WA	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)

Table 14: Ranking of Identified Saline Water Resource Interception and or Disposal Schemes for Grow-Out of Diadromous Fish Using Ponds (A)

Saline water resource and nearest major location	**Resource availability (10, 5, 1)**	**Resource salinity (10, 5, 1)**	**Ionic makeup (10, 5, 1)**	**Other water quality (3, 2, 1)**	**Freshwater availability (10, 5, 0)**	**Land availability (10, 5, 0)**	**Soil type (10, 5, 0)**	**Environ-mental sensitivity (3, 2, 1)**	**Existing structures (10, 5, 3, 1)**	**Labour & services availability (3, 2, 1)**	**Electricity supply proximity (10, 5, 1)**	**Transport proximity (10, 5, 1)**	**Cost sharing opportunity (10, 5, 1)**	**Overall score (max 109)**
Woolpunda Goundwater Interception Scheme - Stockyard Plain Basin, Waikerie, SA	10	10	10	3	10	10	5	2	10	3	5	5	5	88
Waikerie Salt Interception Scheme - Stockyard Plain Basin, Waikerie, SA	10	10	10	3	10	10	5	2	10	3	5	5	5	88
Noora Drainage Diversion Scheme, Berri / Loxton, SA	5	10	10	2	5	10	5	2	10	3	5	5	5	77
Rufus River Goundwater Interception Scheme, Lake Victoria, NSW	10	10	10	3	5	10	5	3	10	1	5	1	5	78
Mildura-Merbein Goundwater Interception Scheme, Mildura, Vic	10	1	10	3	10	10	5	3	10	3	5	10	5	85
Buronga Salt Interception Scheme, Mildura, Vic	10	10	10	3	5	10	5	3	10	2	5	10	5	88
Mallee Cliffs Salt Interception Scheme, Mildura, Vic	10	10	10	3	10	10	5	2	10	2	5	10	5	92
Wakool Salinity Control Scheme, Wakool, NSW	10	10	10	2	10	10	5	3	10	2	10	1	10	93
Barr Creek Salinity Control Scheme, Kerang, Vic	10	10	na	2	10	10	5	1	10	3	10	5	5	(81)
Girgarre Basin Salinity Control Project, Stanhope, Vic	10	10	10	2	5	10	5	3	10	2	10	1	5	83
Pyramid Hill Groundwater Interception &Salt Harvesting Scheme, Kerang, Vic (private)	1	10	10	2	10	5	0	3	5	2	10	5	?	(63)

Table 14B: Ranking of proposed groundwater disposal schemes and other potential resources for grow-out of diadromous fish using ponds

Saline water resource and nearest major location	**Resource availability (10, 5, 1)**	**Resource salinity (10, 5, 1)**	**Ionic makeup (10, 5, 1)**	**Other water quality (3, 2, 1)**	**Freshwater availability (10, 5, 0)**	**Land availability (10, 5, 0)**	**Soil type (10, 5, 0)**	**Environ-mental sensitivity (3, 2, 1)**	**Existing structures (10, 5, 3, 0)**	**Labour & services availability (3, 2, 1)**	**Electricity supply proximity (10, 5, 1)**	**Transport proximity (10, 5, 1)**	**Cost sharing opportunity (10, 5, 1)**	**Overall score (max 109)**
Qualco-Sunlands Groundwater Interception & Salinity Control Scheme /Stockyard Basin, Waikerie, SA	10	10	10	2	10	10	5	2	5	3	5	5	10	87
Waikerie Stage II Salt Interception Scheme / Stockyard Basin, Waikerie, SA	10	10	10	3	10	10	5	2	5	3	5	5	10	88
Pyramid Creek Groundwater Interception Scheme, Kerang, Vic	10	10	10	3	10	10	5	3	3	3	5	5	10	87
Lindsay River Groundwater Interception Scheme, Mildura, Vic	10	10	10	3	5	10	5	1	3	1	5	1	10	74
Chowilla Groundwater Interception Scheme, Renmark, SA	10	10	10	3	5	10	5	1	3	3	5	5	10	80
Bookpurnong-Loxton Groundwater Interception & Drainage Scheme / Noora Basin, Berri / Loxton, SA	10	10	10	2	5	10	5	2	3	3	5	5	10	80
North Pike-Murtho Salt Interception Scheme, Paringa, SA	10	10	10	3	10	10	5	3	0	3	5	5	10	84
Yanda Creek Groundwater Interception Scheme, Louth (Darling River), NSW	10	10	10	3	5	10	5	2	0	1	1	1	10	68
Urban groundwater pumping schemes– various in MDB and WA e.g. Wagga, NSW	10	10	10	1	10	10	5	3	3	3	10	10	10	95
Ord River Irrigation Area groundwater pumping schemes, Kununurra, WA	10	10	10	2	10	10	5	3	3	2	5	5	10	85
Esperance-Kalgoorlie seawater pipeline, Esperance and Kalgoorlie, WA	10	10	10	3	10	10	5	3	3	3	10	10	10	97
On-farm Serial Biological-Concentration projects, Murray-Darling Basin and WA	1	10	5	2	0	5	5	3	0	1	5	1	10	48
Coal mine drainage water – various NSW and QLD	10	10	5	1	10	10	5	3	5	3	10	10	10	92

Table 14C: Ranking of Victorian permanent saline lakes for grow-out of diadromous fish using ponds

Saline water resource and nearest major location	Resource availability (10, 5, 1)	Resource salinity (10, 5, 1)	Ionic makeup (10, 5, 1)	Other water quality (3, 2, 1)	Freshwater availability (10, 5, 0)	Land availability (10, 5, 0)	Soil type (10, 5, 0)	Environ-mental sensitivity (3, 2, 1)	Existing structures (10, 5, 3, 0)	Labour & services availability (3, 2, 1)	Electricity supply proximity (10, 5, 1)	Transport proximity (10, 5, 1)	Cost sharing opportunity (10, 5, 1)	Overall score (max 109)
Lake Corangamite, Colac, Vic	10	10	10	2	5	10	5	1	0	3	10	5	1	72
Lake Bullen Merri, Colac, Vic	10	10	10	2	5	10	5	2	0	3	10	5	1	73
Lake Purrumbete, Colac, Vic	10	10	10	2	5	10	5	2	0	3	10	5	1	73
Lake Martin, Colac, Vic	10	10	10	2	5	10	5	1	0	3	10	5	1	72
Lake Gnarpurt, Colac, Vic	10	10	10	2	5	10	5	1	0	3	10	5	1	72
Lake Colac, Colac, Vic	10	10	10	2	5	10	5	2	0	3	10	5	1	73
Lake Gnotuk, Colac, Vic	10	10	10	2	5	10	5	1	0	3	10	5	1	72
Lake Colongulac, Colac, Vic	10	10	10	2	5	10	5	1	0	3	10	5	1	72
East Basin Lake, Colac, Vic	10	na	na	2	5	10	5	1	0	3	10	5	1	(52)
West Basin Lake, Colac, Vic	10	na	na	2	5	10	5	1	0	3	10	5	1	(52)
Lake Tutchewop, Kerang, Vic	10	5	na	2	10	10	5	1	5	3	10	10	10	(81)
Cullens Lake, Kerang, Vic	10	10	na	2	10	10	5	1	5	3	10	10	5	(81)
Lake Kelly, Kerang, Vic	10	5	na	2	10	10	5	1	5	3	10	10	10	(81)
Lake William, Kerang, Vic	10	5	na	2	10	10	5	1	5	3	10	10	10	(81)
Lake Elizabeth, Kerang, Vic	10	10	na	2	10	10	5	2	5	3	10	10	5	(82)
Lake Wandella, Kerang, Vic	10	10	na	2	10	10	5	2	5	3	10	10	5	(82)
Little Lake Kelly, Kerang, Vic	10	5	na	2	10	10	5	2	5	3	10	10	10	(82)
Lake Charm, Kerang, Vic	10	10	na	2	10	10	5	1	5	3	10	10	10	(86)
Lookout Lake, Kerang, Vic	10	10	na	2	10	10	5	2	5	3	10	10	5	(82)

Table 14D: Ranking of deeper regional sedimentary and fractured-rock groundwater resources for grow-out of diadromous fish using ponds

Sedimentary basin and aquifer	Resource availability (10, 5, 1)	Resource salinity (10, 5, 1)	Ionic makeup (10, 5, 1)	Other water quality (3, 2, 1)	Freshwater availability (10, 5, 0)	Land availability (10, 5, 0)	Soil type (10, 5, 0)	Environ-mental sensitivity (3, 2, 1)	Existing structures (10, 5, 3, 0)	Labour & services availability (3, 2, 1)	Electricity supply proximity (10, 5, 1)	Transport proximity (10, 5, 1)	Cost sharing opportunity (10, 5, 1)	Overall score (max 109)
Murray Basin NSW, Vic & SA														
Parilla Sands	10	10	10	3	10	10	10	3	0	3	10	10	1	90
Calivil Fromation & Renmark Group	10	10	10	3	10	10	10	3	0	3	10	10	1	90
Lower Renmark Group	10	10	10	3	10	10	10	3	0	3	10	10	1	90
Otway Basin Vic														
Newer Volcanics	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Dylwin Formation	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Gippsland Basin Vic														
Gippsland Limestone	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Port Phillip Basin Vic														
Unspecified aquifers	10	10	na	2	10	10	10	3	0	3	10	10	1	(79)
Sydney Basin NSW														
Wianamatta Shales	10	10	10	3	10	10	10	3	0	3	10	10	1	90
Narrabeen Group	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Basal Permian sediments	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Clarence-Morton Basin NSW-QLD														
Walloon Coal Measures	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Basal Triassic coal measures	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Carnarvon Basin WA														
Tumbalagooda Sandstone	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Basal Birdrong Sandstone	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)

Table 14D (continued): Ranking of deeper regional sedimentary and fractured-rock groundwaters for grow-out of diadromous fish using ponds

Sedimentary basin or aquifer	Resource availability (10, 5, 1)	Resource salinity (10, 5, 1)	Ionic makeup (10, 5, 1)	Other water quality (3, 2, 1)	Freshwater availability (10, 5, 0)	Land availability (10, 5, 0)	Soil type (10, 5, 0)	Environ-mental sensitivity (3, 2, 1)	Existing structures (10, 5, 3, 0)	Labour & services availability (3, 2, 1)	Electricity supply proximity (10, 5, 1)	Transport proximity (10, 5, 1)	Cost sharing opportunity (10, 5, 1)	Overall score (max 109)
Amadeus Basin NT														
Unspecified aquifers	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Western Slopes and Plains fractured rock province, NSW	1	10	na	3	10	10	10	3	0	3	10	5	1	(66)
Eyre Peninsula fractured rock province, Pt Lincoln / Whyalla, SA	5	10	na	3	10	10	10	3	0	3	10	10	1	(75)
Western fractured rock province, WA	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)

Table 15: Ranking of Identified Saline Water Resource Interception and or Disposal Schemes for Native Fish Based on Recirculation (A)

Saline water resource and nearest major location	**Resource availability (10, 5, 1)**	**Resource salinity (10, 5, 1)**	**Ionic makeup (10, 5, 1)**	**Other water quality (3, 2, 1)**	**Freshwater availability (10, 5, 0)**	**Land availability (10, 5, 0)**	**Soil type (10, 5, 0)**	**Environ-mental sensitivity (3, 2, 1)**	**Existing structures (10, 5, 3, 1)**	**Labour & services availability (3, 2, 1)**	**Electricity supply proximity (10, 5, 1)**	**Transport proximity (10, 5, 1)**	**Cost sharing opportunity (10, 5, 1)**	**Overall score (max 109)**
Woolpunda Goundwater Interception Scheme - Stockyard Plain Basin, Waikerie, SA	10	1	10	3	10	10	10	2	10	3	5	5	5	84
Waikerie Salt Interception Scheme - Stockyard Plain Basin, Waikerie, SA	10	1	10	3	10	10	10	2	10	3	5	5	5	84
Noora Drainage Diversion Scheme, Berri / Loxton, SA	5	1	10	2	5	10	10	2	10	3	5	5	5	73
Rufus River Goundwater Interception Scheme, Lake Victoria, NSW	10	1	10	3	5	10	10	3	10	1	5	1	5	74
Mildura-Merbein Goundwater Interception Scheme, Mildura, Vic	10	1	10	3	10	10	10	3	10	3	5	10	5	90
Buronga Salt Interception Scheme, Mildura, Vic	10	1	10	3	5	10	10	3	10	2	5	10	5	84
Mallee Cliffs Salt Interception Scheme, Mildura, Vic	10	1	10	3	10	10	10	2	10	2	5	10	5	88
Wakool Salinity Control Scheme, Wakool, NSW	10	1	10	2	10	10	10	3	10	2	10	1	10	89
Barr Creek Salinity Control Scheme, Kerang, Vic	10	1	na	2	10	10	10	1	10	3	10	5	5	(77)
Girgarre Basin Salinity Control Project, Stanhope, Vic	10	1	10	2	5	10	10	3	10	2	10	1	5	79
Pyramid Hill Groundwater Interception &Salt Harvesting Scheme, Kerang, Vic (private)	10	1	10	2	10	10	10	3	5	2	10	5	?	(78)

Table 15B: Ranking of proposed groundwater disposal schemes and other potential saline water resources for native fish based on recirculation

Saline water resource and nearest major location	**Resource availability (10, 5, 1)**	**Resource salinity (10, 5, 1)**	**Ionic makeup (10, 5, 1)**	**Other water quality (3, 2, 1)**	**Freshwater availability (10, 5, 0)**	**Land availability (10, 5, 0)**	**Soil type (10, 5, 0)**	**Environ-mental sensitivity (3, 2, 1)**	**Existing structures (10, 5, 3, 0)**	**Labour & services availability (3, 2, 1)**	**Electricity supply proximity (10, 5, 1)**	**Transport proximity (10, 5, 1)**	**Cost sharing opportunity (10, 5, 1)**	**Overall score (max 109)**
Qualco-Sunlands Groundwater Interception & Salinity Control Scheme /Stockyard Basin, Waikerie, SA	10	1	10	2	10	10	10	2	5	3	5	5	10	83
Waikerie Stage II Salt Interception Scheme / Stockyard Basin, Waikerie, SA	10	1	10	3	10	10	10	2	5	3	5	5	10	84
Pyramid Creek Groundwater Interception Scheme, Kerang, Vic	10	1	10	3	10	10	10	3	3	3	5	5	10	83
Lindsay River Groundwater Interception Scheme, Mildura, Vic	10	1	10	3	5	10	10	1	3	1	5	1	10	70
Chowilla Groundwater Interception Scheme, Renmark, SA	10	1	10	3	5	10	10	1	3	3	5	5	10	76
Bookpurnong-Loxton Groundwater Interception & Drainage Scheme / Noora Basin, Berri / Loxton, SA	10	1	10	2	5	10	10	2	3	3	5	5	10	76
North Pike-Murtho Salt Interception Scheme, Paringa, SA	10	1	10	3	10	10	10	3	0	3	5	5	10	80
Yanda Creek Groundwater Interception Scheme, Louth (Darling River), NSW	10	1	10	3	5	10	10	2	0	1	1	1	10	64
Urban groundwater pumping schemes– various in MDB and WA e.g. Wagga, NSW	10	10	10	1	10	10	10	3	3	3	10	10	10	100
Ord River Irrigation Area groundwater pumping schemes, Kununurra, WA	10	10	10	2	10	10	10	3	3	2	5	5	10	90
Esperance-Kalgoorlie seawater pipeline, Esperance and Kalgoorlie, WA	10	1	10	3	10	10	10	3	3	3	10	10	10	93
On-farm Serial Biological-Concentration projects, Murray-Darling Basin and WA	5	10	10	2	0	10	10	3	0	1	5	1	10	67
Coal mine drainage water – various NSW and QLD	10	10	10	1	10	10	10	3	5	3	10	10	10	102

Table 15C: Ranking of Victorian permanent saline lakes for native fish based on recirculation

Saline water resource and nearest major location	Resource availability (10, 5, 1)	Resource salinity (10, 5, 1)	Ionic makeup (10, 5, 1)	Other water quality (3, 2, 1)	Freshwater availability (10, 5, 0)	Land availability (10, 5, 0)	Soil type (10, 5, 0)	Environ-mental sensitivity (3, 2, 1)	Existing structures (10, 5, 3, 0)	Labour & services availability (3, 2, 1)	Electricity supply proximity (10, 5, 1)	Transport proximity (10, 5, 1)	Cost sharing opportunity (10, 5, 1)	Overall score (max 109)
Lake Corangamite, Colac, Vic	10	1	10	2	5	10	10	1	0	3	10	5	1	68
Lake Bullen Merri, Colac, Vic	10	10	10	2	5	10	10	2	0	3	10	5	1	78
Lake Purrumbete, Colac, Vic	10	10	10	2	5	10	10	2	0	3	10	5	1	78
Lake Martin, Colac, Vic	10	10	10	2	5	10	10	1	0	3	10	5	1	77
Lake Gnarpurt, Colac, Vic	10	10	10	2	5	10	10	1	0	3	10	5	1	77
Lake Colac, Colac, Vic	10	10	10	2	5	10	10	2	0	3	10	5	1	78
Lake Gnotuk, Colac, Vic	10	1	10	2	5	10	10	1	0	3	10	5	1	68
Lake Colongulac, Colac, Vic	10	10	10	2	5	10	10	1	0	3	10	5	1	77
East Basin Lake, Colac, Vic	10	na	na	2	5	10	10	1	0	3	10	5	1	(57)
West Basin Lake, Colac, Vic	10	na	na	2	5	10	10	1	0	3	10	5	1	(57)
Lake Tutchewop, Kerang, Vic	10	1	na	2	10	10	10	1	5	3	10	10	10	(82)
Cullens Lake, Kerang, Vic	10	1	na	2	10	10	10	1	5	3	10	10	5	(77)
Lake Kelly, Kerang, Vic	10	1	na	2	10	10	10	1	5	3	10	10	10	(82)
Lake William, Kerang, Vic	10	1	na	2	10	10	10	1	5	3	10	10	10	(82)
Lake Elizabeth, Kerang, Vic	10	1	na	2	10	10	10	2	5	3	10	10	5	(78)
Lake Wandella, Kerang, Vic	10	1	na	2	10	10	10	2	5	3	10	10	5	(78)
Little Lake Kelly, Kerang, Vic	10	1	na	2	10	10	10	2	5	3	10	10	10	(83)
Lake Charm, Kerang, Victoria	10	10	na	2	10	10	10	1	5	3	10	10	10	(91)
Lookout Lake, Kerang, Vic	10	10	na	2	10	10	10	2	5	3	10	10	5	(87)

Table 15D: Ranking of deeper regional sedimentary and fractured-rock groundwater resources for native fish based on recirculation

Sedimentary basin and aquifer	**Resource availability (10, 5, 1)**	**Resource salinity (10, 5, 1)**	**Ionic makeup (10, 5, 1)**	**Other water quality (3, 2, 1)**	**Freshwater availability (10, 5, 0)**	**Land availability (10, 5, 0)**	**Soil type (10, 5, 0)**	**Environ-mental sensitivity (3, 2, 1)**	**Existing structures (10, 5, 3, 0)**	**Labour & services availability (3, 2, 1)**	**Electricity supply proximity (10, 5, 1)**	**Transport proximity (10, 5, 1)**	**Cost sharing opportunity (10, 5, 1)**	**Overall score (max 109)**
Murray Basin NSW, Vic & SA														
Parilla Sands	10	1	10	3	10	10	10	3	0	3	10	10	1	81
Calivil Fromation & Renmark Group	10	1	10	3	10	10	10	3	0	3	10	10	1	81
Lower Renmark Group	10	1	10	3	10	10	10	3	0	3	10	10	1	81
Otway Basin														
Newer Volcanics	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Dylwin Formation	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Gippsland Basin Vic														
Gippsland Limestone	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Port Phillip Basin Vic														
Unspecified aquifers	10	10	na	2	10	10	10	3	0	3	10	10	1	(79)
Sydney Basin NSW														
Wianamatta Shales	10	1	10	3	10	10	10	3	0	3	10	10	1	81
Narrabeen Group	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Basal Permian sediments	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Clarence-Morton Basin NSW-QLD														
Walloon Coal Measures	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Basal Triassic coal measures	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Carnarvon Basin WA														
Tumbalagooda Sandstone	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Basal Birdrong Sandstone	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)

Table 15D (continued): Ranking of deeper regional sedimentary and fractured-rock groundwater resources for native fish based on recirculation

Sedimentary basin or aquifer	Resource availability (10, 5, 1)	Resource salinity (10, 5, 1)	Ionic makeup (10, 5, 1)	Other water quality (3, 2, 1)	Freshwater availability (10, 5, 0)	Land availability (10, 5, 0)	Soil type (10, 5, 0)	Environ-mental sensitivity (3, 2, 1)	Existing structures (10, 5, 3, 0)	Labour & services availability (3, 2, 1)	Electricity supply proximity (10, 5, 1)	Transport proximity (10, 5, 1)	Cost sharing opportunity (10, 5, 1)	Overall score (max 109)
Amadeus Basin NT														
Unspecified aquifers	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Western Slopes and Plains fractured rock province, NSW	10	1	na	3	10	10	10	3	0	3	10	5	1	(66)
Eyre Peninsula fractured rock province, Pt Lincoln / Whyalla, SA	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Western fractured rock province, Canarvon, WA	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)

Table 16: Ranking of Identified Saline Water Resource Interception and or Disposal Schemes for Native Fish Based Ponds (A)

Saline water resource and nearest major location	**Resource availability (10, 5, 1)**	**Resource salinity (10, 5, 1)**	**Ionic makeup (10, 5, 1)**	**Other water quality (3, 2, 1)**	**Freshwater availability (10, 5, 0)**	**Land availability (10, 5, 0)**	**Soil type (10, 5, 0)**	**Environ-mental sensitivity (3, 2, 1)**	**Existing structures (10, 5, 3, 1)**	**Labour & services availability (3, 2, 1)**	**Electricity supply proximity (10, 5, 1)**	**Transport proximity (10, 5, 1)**	**Cost sharing opportunity (10, 5, 1)**	**Overall score (max 109)**
Woolpunda Goundwater Interception Scheme - Stockyard Plain Basin, Waikerie, SA	10	1	10	3	10	10	5	2	10	3	5	5	5	79
Waikerie Salt Interception Scheme - Stockyard Plain Basin, Waikerie, SA	10	1	10	3	10	10	5	2	10	3	5	5	5	79
Noora Drainage Diversion Scheme, Berri / Loxton, SA	5	1	10	2	5	10	5	2	10	3	5	5	5	68
Rufus River Goundwater Interception Scheme, Lake Victoria, NSW	10	1	10	3	5	10	5	3	10	1	5	1	5	69
Mildura-Merbein Goundwater Interception Scheme, Mildura, Vic	10	1	10	3	10	10	5	3	10	3	5	10	5	85
Buronga Salt Interception Scheme, Mildura, Vic	10	1	10	3	5	10	5	3	10	2	5	10	5	79
Mallee Cliffs Salt Interception Scheme, Mildura, Vic	10	1	10	3	10	10	5	2	10	2	5	10	5	83
Wakool Salinity Control Scheme, Wakool, NSW	10	1	5	2	10	10	5	3	10	2	10	1	10	79
Barr Creek Salinity Control Scheme, Kerang, Vic	10	1	na	2	10	10	5	1	10	3	10	5	5	(72)
Girgarre Basin Salinity Control Project, Stanhope, Vic	10	1	10	2	5	10	5	3	10	2	10	1	5	74
Pyramid Hill Groundwater Interception &Salt Harvesting Scheme, Kerang, Vic (private)	1	1	10	2	10	5	0	3	5	2	10	5	?	(54)

Table 16B: Ranking of proposed groundwater disposal schemes and other potential saline water resources for native fish based ponds

Saline water resource and nearest major location	**Resource availability (10, 5, 1)**	**Resource salinity (10, 5, 1)**	**Ionic makeup (10, 5, 1)**	**Other water quality (3, 2, 1)**	**Freshwater availability (10, 5, 0)**	**Land availability (10, 5, 0)**	**Soil type (10, 5, 0)**	**Environ-mental sensitivity (3, 2, 1)**	**Existing structures (10, 5, 3, 0)**	**Labour & services availability (3, 2, 1)**	**Electricity supply proximity (10, 5, 1)**	**Transport proximity (10, 5, 1)**	**Cost sharing opportunity (10, 5, 1)**	**Overall score (max 109)**
Qualco-Sunlands Groundwater Interception & Salinity Control Scheme /Stockyard Basin, Waikerie, SA	10	1	10	2	10	10	5	2	5	3	5	5	10	78
Waikerie Stage II Salt Interception Scheme / Stockyard Basin, Waikerie, SA	10	1	10	3	10	10	5	2	5	3	5	5	10	79
Pyramid Creek Groundwater Interception Scheme, Kerang, Vic	10	1	10	3	10	10	5	3	3	3	5	5	10	78
Lindsay River Groundwater Interception Scheme, Mildura, Vic	10	1	10	3	5	10	5	1	3	1	5	1	10	65
Chowilla Groundwater Interception Scheme, Renmark, SA	10	1	10	3	5	10	5	1	3	3	5	5	10	71
Bookpurnong-Loxton Groundwater Interception & Drainage Scheme / Noora Basin, Berri / Loxton, SA	10	1	10	2	5	10	5	2	3	3	5	5	10	71
North Pike-Murtho Salt Interception Scheme, Paringa, SA	10	1	10	3	10	10	5	3	0	3	5	5	10	75
Yanda Creek Groundwater Interception Scheme, Louth (Darling River), NSW	10	1	10	3	5	10	5	2	0	1	1	1	10	59
Urban groundwater pumping schemes– various in MDB and WA e.g. Wagga, NSW	5	10	10	1	10	10	5	3	3	3	10	10	10	90
Ord River Irrigation Area groundwater pumping schemes, Kununurra, WA	10	10	10	2	10	10	5	3	3	2	5	5	10	85
Esperance-Kalgoorlie seawater pipeline, Esperance and Kalgoorlie, WA	10	1	10	3	10	10	5	3	3	3	10	10	10	88
On-farm Serial Biological-Concentration projects, Murray-Darling Basin and WA	1	10	10	2	0	10	5	3	0	1	5	1	10	58
Coal mine drainage water – various NSW and QLD	10	10	10	1	10	10	5	3	5	3	10	10	10	97

Table 16C: Ranking of Victorian permanent saline lakes for native fish based ponds

Saline water resource and nearest major location	Resource availability (10, 5, 1)	Resource salinity (10, 5, 1)	Ionic makeup (10, 5, 1)	Other water quality (3, 2, 1)	Freshwater availability (10, 5, 0)	Land availability (10, 5, 0)	Soil type (10, 5, 0)	Environ-mental sensitivity (3, 2, 1)	Existing structures (10, 5, 3, 0)	Labour & services availability (3, 2, 1)	Electricity supply proximity (10, 5, 1)	Transport proximity (10, 5, 1)	Cost sharing opportunity (10, 5, 1)	Overall score (max 109)
Lake Corangamite, Colac, Vic	10	1	10	2	5	10	5	1	0	3	10	5	1	63
Lake Bullen Merri, Colac, Vic	10	10	10	2	5	10	5	2	0	3	10	5	1	73
Lake Purrumbete, Colac, Vic	10	10	10	2	5	10	5	2	0	3	10	5	1	73
Lake Martin, Colac, Vic	10	10	10	2	5	10	5	1	0	3	10	5	1	72
Lake Gnarpurt, Colac, Vic	10	10	10	2	5	10	5	1	0	3	10	5	1	72
Lake Colac, Colac, Vic	10	10	10	2	5	10	5	2	0	3	10	5	1	73
Lake Gnotuk, Colac, Vic	10	1	10	2	5	10	5	1	0	3	10	5	1	63
Lake Colongulac, Colac, Vic	10	10	10	2	5	10	5	1	0	3	10	5	1	72
East Basin Lake, Colac, Vic	10	na	na	2	5	10	5	1	0	3	10	5	1	(52)
West Basin Lake, Colac, Vic	10	na	na	2	5	10	5	1	0	3	10	5	1	(52)
Lake Tutchewop, Kerang, Vic	10	1	na	2	10	10	5	1	5	3	10	10	10	(77)
Cullens Lake, Kerang, Vic	10	1	na	2	10	10	5	1	5	3	10	10	5	(72)
Lake Kelly, Kerang, Vic	10	1	na	2	10	10	5	1	5	3	10	10	10	(77)
Lake William, Kerang, Vic	10	1	na	2	10	10	5	1	5	3	10	10	10	(77)
Lake Elizabeth, Kerang, Vic	10	1	na	2	10	10	5	2	5	3	10	10	5	(73)
Lake Wandella, Kerang, Vic	10	1	na	2	10	10	5	2	5	3	10	10	5	(73)
Little Lake Kelly, Kerang, Vic	10	1	na	2	10	10	5	2	5	3	10	10	10	(78)
Lake Charm, Kerang, Victoria	10	10	na	2	10	10	5	1	5	3	10	10	10	(86)
Lookout Lake, Kerang, Vic	10	10	na	2	10	10	5	2	5	3	10	10	5	(82)

Table 16D: Ranking of deeper regional sedimentary and fractured-rock groundwater resources for native fish based ponds

Sedimentary basin and aquifer	Resource availability (10, 5, 1)	Resource salinity (10, 5, 1)	Ionic makeup (10, 5, 1)	Other water quality (3, 2, 1)	Freshwater availability (10, 5, 0)	Land availability (10, 5, 0)	Soil type (10, 5, 0)	Environ-mental sensitivity (3, 2, 1)	Existing structures (10, 5, 3, 0)	Labour & services availability (3, 2, 1)	Electricity supply proximity (10, 5, 1)	Transport proximity (10, 5, 1)	Cost sharing opportunity (10, 5, 1)	Overall score (max 109)
Murray Basin NSW, Vic & SA														
Parilla Sands	10	1	10	3	10	10	10	3	0	3	10	10	1	81
Calivil Fromation & Renmark Group	10	1	10	3	10	10	10	3	0	3	10	10	1	81
Lower Renmark Group	10	1	10	3	10	10	10	3	0	3	10	10	1	81
Otway Basin														
Newer Volcanics	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Dylwin Formation	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Gippsland Basin Vic														
Gippsland Limestone	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Port Phillip Basin Vic														
Unspecified aquifers	10	10	na	2	10	10	10	3	0	3	10	10	1	(79)
Sydney Basin NSW														
Wianamatta Shales	10	1	10	3	10	10	10	3	0	3	10	10	1	81
Narrabeen Group	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Basal Permian sediments	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)
Clarence-Morton Basin NSW-QLD														
Walloon Coal Measures	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Basal Triassic coal measures	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Carnarvon Basin WA														
Tumbalagooda Sandstone	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Basal Birdrong Sandstone	10	10	na	3	10	10	10	3	0	3	10	10	1	(80)

Table 16D (continued): Ranking of deeper regional sedimentary and fractured-rock groundwater resources for native fish based ponds

Sedimentary basin or aquifer	Resource availability (10, 5, 1)	Resource salinity (10, 5, 1)	Ionic makeup (10, 5, 1)	Other water quality (3, 2, 1)	Freshwater availability (10, 5, 0)	Land availability (10, 5, 0)	Soil type (10, 5, 0)	Environ-mental sensitivity (3, 2, 1)	Existing structures (10, 5, 3, 0)	Labour & services availability (3, 2, 1)	Electricity supply proximity (10, 5, 1)	Transport proximity (10, 5, 1)	Cost sharing opportunity (10, 5, 1)	Overall score (max 109)
Amadeus Basin NT														
Unspecified aquifers	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)
Western Slopes and Plains fractured rock province, NSW	1	1	na	3	10	10	10	3	0	3	10	5	1	(57)
Eyre Peninsula fractured rock province, Pt Lincoln / Whyalla, SA	5	1	na	3	10	10	10	3	0	3	10	10	1	(66)
Western fractured rock province, Canarvon, WA	10	1	na	3	10	10	10	3	0	3	10	10	1	(71)

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9. BENEFITS

The R&D Plan and Resource Inventory and Assessment will assist existing and potential aquaculturists, R&D funding agencies, research providers, planners and managers involved with saline groundwater control and rural communities.

Existing aquaculturists will benefit from having major constraints to commercial development identified and brought to the attention of potential research funding agencies and research providers. This should improve funding opportunities to address these constraints. The Project will also benefit this group by focusing attention on the merit of utilising degraded resources (saline groundwater and saline affected land) for a commercial business. Aquaculture is one of the few business opportunities with saline groundwater. This recognition should generate increased government and community support for aquaculture using saline groundwater.

Potential aquaculturists will benefit for reasons given above and also because planners and managers involved with saline groundwater control will be aware of opportunities to integrate aquaculture with new saline groundwater control schemes. This integration could help defray capital and operating costs (for water supply and disposal) for the new aquaculture operation and make obtaining government approvals much easier.

R&D funding agencies and research providers will benefit by having genuine commercial opportunities identified and research issues listed.

Planners and managers involved with saline groundwater control will benefit by having access to information on aquaculture opportunities which will help them plan for integration of aquaculture in new saline groundwater control schemes. As these opportunities are realised, and commercial inland saline aquaculture develops, the costs of saline groundwater control schemes will be considerably reduced. Aquaculture ponds are just as effective for evaporation as purpose built evaporation ponds. New control schemes might include high-capacity groundwater pumps (maybe from many bores) and relatively small evaporation ponds. The operators of the schemes could "sell" saline water to aquaculturists and then "sell" the right for them to dispose of their effluent in the schemes' evaporation ponds.

Rural communities should benefit from the Project as it will speed up commercial development of commercial inland saline aquaculture. New business opportunities from this new industry will provide economic development and employment.

10. FURTHER DEVELOPMENTS

The enormous problem with rising saline groundwater is achieving increased national recognition. The National Dryland Salinity Program (NDSP) that was established in 1993, entered a second phase in 1998/99. The NDSP was established as a means of improving research, development and extension coordination to better manage dryland salinity across Australia. The threat to productive agriculture from salinity has long been recognised but it is only since the establishment of the NDSP that the extent of the salinity problem has become apparent. In particular, the threat to rural and even some metropolitan infrastructure (including roads, buildings and properties), environmental resources and access to quality drinking water supplies have recently become apparent. Research, development and extension to make better use of degraded land and saline water is a key objective of the Phase 2 NDSP.

The Dryland Salinity Program has established a new unit called “Options for the Productive Use of Salinity (OPUS)”. This unit has recognised aquaculture as having potential in saline affected areas.

At the launch of the Murray-Darling Basin Commission’s 1999 salinity audit, the Federal Minister for the Environment described rising salinity as “the worst environmental problem Australia faces”.

In Dubbo, NSW on 16-17 Mach 2000, the Premier convened a Salinity Summit to address problems, causes and opportunities in a coordinated approach. Over two hundred people attended this Summit including eight government ministers, twelve Department heads and senior officials and representatives of community groups across NSW. Aquaculture was identified as having real potential in saline affected areas. The recommendations from the working group established to identify ways of encouraging business initiative included the following:

- ❖ Encourage farmers to diversify into new salinity compatible products, such as aquaculture in saline ponds (4 other products were also listed);
- ❖ Support research to develop or validate business initiatives in aquaculture research and development, including the need for demonstration farms and effective extension services, in inland saline affected areas.

11. CONCLUSION

This project had two planned outcomes. These were the preparation of an R&D Plan for inland saline aquaculture and a resource inventory and assessment of inland saline resources for aquaculture.

The R&D Plan developed the following mission statement: "To foster the establishment of commercial aquaculture activities in Australia based on the use of inland saline water through relevant applied research to remove identified impediments". The status of inland saline aquaculture in 1999 was described and a vision for 2004 developed to help guide the R&D Plan.

An R&D planning workshop of managers, researchers and industry representatives was convened to review emerging findings and to agree on priorities for future R&D. The group identified seven project areas that would explore specific commercial development opportunities for inland saline aquaculture or address emerging constraints. Preliminary research parameters were then developed for each of these project areas. These project areas were:

1. Grow-out of Marine Species Using Shallow Aquifers.
2. Aquaculture from Deep Artesian Water.
3. Winter Culture of Salmonids Using Shallow Aquifers.
4. Artemia from Existing Facilities.
5. High Health Prawn Hatchery.
6. Environmental Guidelines for Inland Saline Aquaculture.
7. Research and Extension Networking.

The inland saline aquaculture opportunities with the highest potential for commercial development, which were identified in the R&D Plan were used to help guide the preparation of the Resource Inventory and Assessment. To prepare the resource inventory, information was identified and collated from a wide range of sources, including the Internet, abstracting and subject-specific databases, agency libraries, unpublished reports, the scientific literature, as well as discussions with agency staff. Broad screening criteria were used to avoid collecting detailed information and assessing resources that are clearly unsuitable for the establishment of a saline aquaculture industry.

A diverse range of saline water resources was identified as having potential for inland saline aquaculture. These resources included:

1. Existing large-scale groundwater interception schemes and associated disposal basins located in three main areas of the southern Murray-Darling Basin. In total, the pond area in existing groundwater interception schemes and associated disposal basins, identified as having aquaculture potential, exceeds 6,300 ha in 11 schemes. These schemes were constructed at a cost of more than $108 million and cost more than $3 million per year to operate. They are used to dispose of more than 50,000 ML/yr.
2. A number of new proposed and planned saline groundwater interception schemes in these same regions. There are another 8 schemes being constructed or planned which could also have aquaculture potential. These new schemes will cost more than $50 million to build and more than $2 million per year to operate. They will dispose of a further more than 13 100 ML/yr.
3. Permanent natural saline lakes in Victoria.

4. Saline and brackish groundwaters from sedimentary basins and fractured rock aquifers around Australia. These were found in all states except Tasmania. A number of brackish geothermal groundwaters were also identified.
5. Urban groundwater pumping to protect urban infrastructure and property in areas affected by dryland or irrigation-derived salinity. These opportunities for cost-sharing were located in the Murray-Darling Basin and the wheatbelt area of southwest Western Australia. There are some 74 rural towns (24 in Victoria, 21 in NSW, 1 in South Australia and 28 in Western Australia) which are experiencing or threatened by rising saline groundwater tables.
6. Proposed shallow groundwater pumping in the Ord River Irrigation Area around Kununurra in northern WA.
7. Two other unusual saline water resources with exceptional aquaculture potential were also identified. These were the proposed Esperance-Kalgoorlie seawater pipeline and saline drainage water associated with coal mines in NSW and Queensland.

Thirteen criteria were developed for a preliminary assessment of the potential of these identified saline water resources for the establishment of different aquaculture types (eg hatcheries, growout of euryhaline or stenohaline fish in ponds or recirculation units, etc). These criteria included the availability of land and freshwater, the nature of the surrounding environment, existing infrastructure and services and opportunities for cost sharing. The application of the developed criteria to potentially suitable saline water resources provided an indicative assessment of the suitability in relation to the various aquaculture types. A number of saline resources were identified as being attractive for a range of aquaculture types. (This is based on a preliminary and indicative assessment using tentative scoring criteria, and often with limited resource information.) These were in particular:

- The Esperance-Kalgoorlie seawater pipeline.
- Most groundwater interception schemes.
- Most of the Kerang Lakes.
- Urban groundwater pumping.
- The aquifers of the Murray Hydrogeological Basin.
- Coal mine drainage water.

12. APPENDICES

Appendix 1: Ambient Air Temperatures in Representative Irrigation Areas

		High		Low	
		Average	**Max**	**Average**	**Max**
QLD	Toowoomba	27.6	39.3	5.3	-4.4
	St George	34.5	45.0	5.4	-2.2
	Goondiwindi	33.8	43.7	5.1	-3.3
NSW	Moree	33.4	44.4	3.8	-5.3
	Narrabri	33.6	43.4	3.7	-5.6
	Gunnedah	31.7	41.9	4.0	-5.6
	Bourke	36.4	51.7	4.6	-2.4
	Warren	33.9	45.2	2.4	-6.4
	Narromine	32.0	43.4	2.6	-5.4
	Forbes	32.7	43.0	2.8	-5.6
	Lake Cargelligo	34.0	47.0	3.3	-6.1
	Griffith	31.5	43.4	2.9	-5.4
	Hay	32.9	47.2	3.4	-3.6
	Balranald	33.0	47.7	3.4	-4.8
	Deniliquin	32.6	46.9	3.4	-4.8
	Mildura	31.9	46.9	4.3	-4.0
Vic	Shepparton	31.1	44.4	3.0	-3.2
	Bendigo	28.9	41.7	3.5	-3.5
	Swan Hill	31.4	46.1	4.1	-3.6
SA	Renmark	32.4	47.4	5.1	-3.8
	Waikerie	32.7	46.5	5.0	-3.1
	Murray Bridge	28.7	45.6	5.4	-5.0
WA	Morawa	36.8	47.2	6.1	-1.6
	Southern Cross	34.6	45.6	4.4	-3.8
	Narregin	31.4	43.4	5.8	-2.7

Appendix 2: Representative Water Chemistry of Selected Salt Interception Schemes

Scheme	Salinity mg/L	Cations and Anions (as mg/L, and % mille-equivalents of cations or anions) Ca	Mg	Na	K	HCO_3	Cl	SO_4	Cation/ Anion balance#	pH	Silica as mg/L	TP as ug/L	TN as ug/L	Fe mg/L
Waikerie (Salt Interception Scheme)[1]	16,700	281	388	5,410	72	600	8,780	1,500		7.5	22	110	1,450	4.2
19/11/91		**5.0%**	**11.3%**	**83.1%**	**0.6%**	**3.4%**	**85.8%**	**10.8%**	**0.981**					
Woolpunda (bore-25)[1]	21,600	502	624	6,620	81	475	11,500	2,000		6.9	35	-	-	2.9
10/7/90		**6.8%**	**14.0%**	**78.6%**	**0.6%**	**2.1%**	**86.8%**	**11.1%**	**0.980**					
Woolpunda (bore-24)[1]	14,400	250	289	4,750	94	519	8,050	730		7.2	20	-	-	0.6
27/7/90		**5.1%**	**9.7%**	**84.3%**	**1.0%**	**3.4%**	**90.5%**	**6.1%**	**0.975**					
Mildura-Merbein (Lake Ranfurly west)[2]	~90,000	1,200	7,000	50,000	300	220?	81,000	14,000		7.6	46			1
23/5/94		**2.1%**	**20.4%**	**77.2%**	**0.3%**	**0.1%**	**88.6%**	**11.3%**	**1.092**					
Mildura-Merbein (Lake Ranfurly east)[2]	~20,400	260	870	7,300	76	150	12,000	2,700		8.8	12			0.3
23/5/94		**3.2%**	**17.7%**	**78.6%**	**0.5%**	**0.6%**	**85.2%**	**14.2%**	**1.017**					
Lake Hawthorn[2] 23/5/94	~4,200	110	110	690	14	280	890	640		8.5	17			0.1
(		**12.2%**	**20.2%**	**66.8%**	**0.8%**	**10.7%**	**58.4%**	**31.0%**	**1.044**					
Buronga (bore #36947)[3]	22,000	329	1,220	7,350	51	243	13,720	2,380		6. 8	12			43$
?date		**3.8%**	**22.9%**	**73.0%**	**0.3%**	**0.9%**	**87.8%**	**11.2%**	**0.994**					
Mallee Cliffs (bore #36878)[3]	33,000	561	1,597	10,260	104	116	19,564	3,370		6.5	13.4			27.6$
15/9/90		**4.6%**	**21.6%**	**73.4%**	**0.4%**	**0.3%**	**88.5%**	**11.2%**	**0.975**					
Wakool[4]	19,600	504	820	4,210	9.2	238	11,000	1,100		7.9		<100**		<0.05
?date		**9.1%**	**24.4%**	**66.4%**	**0.1%**	**1.2%**	**92.1%**	**6.8%**	**0.819**					
Pyramid Hill (bore 115175)[2]	~29,300	1,080	1,700	10,600	20	nd	18,020	3900		6.6	42			low
Aug 1996 (see also Pyramid Ck. Sect. 6.4)	(48,900 EC)	**8.2%**	**21.3%**	**70.4%**	**0.1%**	nd	**86.2%**	**13.9%**	**1.11##**					
Girgarre [5]	11,900	350	670	3,200	17	320	6,400	1,300		6.7	31*	14*	890	0.05
27/10/99		**8.2%**	**26.0%**	**65.6%**	**0.2%**	**2.5%**	**84.8%**	**12.7%**	**0.997**					
Standard seawater[6]		410	1,350	10,500	390	142	19,000	2,700			6.4	90	670	
		3.4%	**18.6%**	**76.3%**	**1.7%**	**0.4%**	**90.2%**	**9.5%**	**1.006**					

*[1]supplied by Peter Forward, SA Water; [2]supplied by John Ginnivan, Goulburn-Murray Water; [3]supplied by Mike Ernie, DLWC; [4]supplied by Geoff Allan, NSW Fisheries; [5]supplied by Peter Dickinson, Goulburn-Murray Water; [6]Goldberg et al.,. (1971) reported in Hem 1985; # = Σcations/Σanions as mille-equivalents; ## =excluding bicarbonate; * = average from other analyses;*
*** = total phosphate-phosphorus; $ = total iron*

Appendix 3: Representative Water Chemistry of Permanent Saline Lakes and Groundwater Resources

Location	Salinity mg/L	Cations and Anions (as mg/L, and % mille-equivalents of cations or anions) Ca	Mg	Na	K	HCO_3	Cl	SO_4	Cation/ Anion balance	PH range	Silica as mg/L	TP as ug/L	TN as ug/L	Fe as mg/L
Lake Corangamite[1]	32,500	55	968	11,100	141	850	18,800	645		7.9 - 9.1		110 - 150	1.02 - 7.35	
		0.5%	**14.0%**	**84.9%**	**0.6%**	**2.5%**	**95.1%**	**2.4%**	**1.020**					
Lake Bullen Merri[1]	8,100	16	248	2,615	88	650	4,500	<1		8.4 - 9.3		27 - 57	0.23 - 1.11	
		0.6%	**14.9%**	**82.9%**	**1.6%**	**7.7%**	**92.3%**	**0.0%**	**0.997**					
Lake Purrumbete[1]	430	17	31	86	5	150	121	17		6.8 - 9.1		41 - 110	0.20 - 0.69	
		12.7%	**38.3%**	**56.1%**	**1.9%**	**39.5%**	**54.8%**	**5.7%**	**1.167**					
Lake Martin[1]	3,580	42	106	1,107	17	292	1,950	60		7.0 - 8.8		97 - 170	0.34 - 1.99	
		3.5%	**14.7%**	**81.1%**	**0.7%**	**7.8%**	**90.1%**	**2.1%**	**0.973**					
Lake Gnarpurt[1]	10,500	74	407	3,600	47	488	5,530	328		7.1 - 8.9		170 - 220	0.55 - 3.63	
		1.9%	**17.2%**	**80.3%**	**0.6%**	**4.7%**	**91.3%**	**4.0%**	**1.141**					
Lake Colac[1]	1,890	60	71	55	nd	313	927	12		6.8 - 8.6		1,400	0.7 - 2.8	
		9.1%	**17.8%**	**73.1%**	nd	**16.3%**	**82.8%**	**0.8%**	**1.043**					
Lake Gnotuk[1]	53,700	124	2,210	15,740	400	740	34,390	59		7.9 - 8.7		390 - 470	0.61 - 5.69	
		0.7%	**20.6%**	**77.5%**	**1.2%**	**1.2%**	**98.6%**	**0.1%**	**0.898**					
Lake Colongulac[1]	10,500	45	194	3,690	100	760	5,600	108		8.2 - 9.3		4500 - 5400	0.62 - 3.75	
		1.2%	**8.8%**	**88.5%**	**1.4%**	**7.2%**	**91.5%**	**1.3%**	**1.050**					
Wianamatta Shale (Sydney Basin)[2]	nd	469	340	3,542	nd	851	6,802	9		6.9				
		11.4%	**13.6%**	**75.0%**	nd	**6.8%**	**93.1%**	**0.1%**	**0.997#**					
Merredin WA MDO1[3]	?23,800	124	528	8,390	201	1	12,500	2,020		?3				
		1.5%	**10.4%**	**86.9%**	**1.2%**	**<0.1%**	**89.3%**	**10.7%**	**1.063**					
Merredin WA MD2C[3]		318	542	6,060	161	119	10,500	1,390		5.8				
		4.8%	**13.6%**	**80.3%**	**1.3%**	**0.3%**	**90.6%**	**8.8%**	**1.003**					
Standard seawater[4]	35,500	410	1,350	10,500	390	142	19,000	2,700			6.4	90	670	
		3.4%	**18.6%**	**76.3%**	**1.7%**	**0.4%**	**90.2%**	**9.5%**	**1.006**					

[1]variously derived from Timms (1976 & 1983), De Decker & Williams (1988), Williams (1981); [2]WRC (1984); [3]Matta (1999); [4]Goldberg et al.,. (1971) reported in Hem (1985);
nd = no data; # = without potassium; * = total phosphate-phosphorus

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