Catchment Management Planning and Landcare in the Little River Catchment

Little River Big Picture

Little River Landcare Group Inc.

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Management for Change and Priorities for the Future

The Stage 2 report identified **20 Best Management Options** (BMOs) for the catchment—influenced by Land Management Units (LMUs). The Land Management Unit section, including tables 18 and 19, expands on the LMU concept. Some issues raised (and BMOs) will not apply to all parts of the catchment and specific application of the BMOs will depend on current management, goals for the future and financial and social limitations. Each BMO, recommended as part of the CMP, is covered in a separate paragraph below.

Land Management

- **Land use** should be **matched to land capability**. Land degradation happens when land is used beyond its capability, which normally means over-intensive use such as cropping for too long or clearing some poor quality timber country for agricultural use. The first step for landholders is to identify land capability and then maybe to complete a property management plan in line with this, all with the goal of long-term sustainability in mind.

- Most of the catchment is prone to acidification, and **applying ameliorants** (such as lime) is the main management option. At the moment, many farmers in the catchment do not see liming as standard farming practice. Soils should be tested regularly and ameliorants and fertilisers applied as necessary. Acidity contributes to salinity because the poor plant growth that it causes means that water use falls and more water leaks to the watertable. This is the same for other toxicities and deficiencies. Another ameliorant, gypsum, can be used to improve soil structure of sodic soils.

- **Soil conservation earthworks** are one answer to erosion, which is the main cause of lost production in the catchment. Even with other practices such as conservation farming, some landscapes also need earthworks to repair or prevent erosion. This may involve contour banks (to reduce run-off), contour ripping on compacted or scald areas, repairing and preventing gully damage, fencing, revegetation or diverting water away from salty areas. It is important not to divert flows away from natural drainage patterns or increase flooding risk.

- **Engineering solutions for salinity** are a ‘last resort’ management option to be used when vegetative management methods are not suitable and where saline water can be safely disposed of. Groundwater pumping can be used to lower water tables but this requires detailed knowledge of the Groundwater Flow Systems and normally each situation must be assessed individually. If the groundwater is fresh it can be used for irrigation or pumped into a river. Many subsoils affected by rising watertables in the catchment are high in clay, which makes water extraction difficult. An alternative is drainage (tile, mole or spear point) but is only worthwhile if it provides significant off-site benefits or is used in areas of valuable infrastructure. There are some possibilities for the use of saline water, for example salt-water aquaculture. This creates dangers of seepage from dams.

Native Vegetation

- **Encouraging high levels of diversity** in all perennial systems improves the functioning of the ecosystem. Typically, agricultural systems have low diversity levels, especially in crops or improved pastures, and woodlands tend to be the same as the understorey has often been grazed out. Diversity in a tree stand will provide different rooting depths—useful in reducing recharge—or, in agricultural systems, will provide better pest and disease resistance and may reduce climatic impacts.

- **Agroforestry and plantation forestry** are enterprises that may reverse rising groundwater levels and the onset of dryland salinity caused by clearing trees and perennial grasses. They provide faster growth than a stand of native species and, therefore, a better short-term impact on rising watertables. Forestry can deliver both environmental and economic benefits. Generally, larger blocks are better and other factors, such as position and species selection, will depend on location, suitable sites, reason for planting and other plantings in the area. Species selection is important and too many pine plantations may cause acidity problems.

Yellow Box – Blakely's Red Gum Woodland, Little River Catchment. CSIRO (Julian Seddon)

- **Strategic tree planting** will achieve many natural resource management objectives including reducing recharge and dryland salinity, restoring the original land and water equilibrium, providing shade, shelter and wind protection and improving biodiversity. A single plantation could have multiple benefits, such as reducing recharge, being a wildlife corridor, restoring river environments, providing timber or fodder and even being used in alley farming. Native species, grown from local seed, should be used wherever possible.

"In human medicine…the loss of more than 70 percent of the skin by burning is usually fatal. To denude the Earth of its forests and other natural ecosystems and of its soils is like burning the skin of a human. And we shall soon have destroyed or replaced with inefficient farmlands 70 percent of the Earth's natural land surface."

James Lovelock,
Originator, Gaia Hypothesis.

- **Remnant vegetation conservation** is less labour intensive than revegetation. It has the benefits of being cheaper and also being a natural, diverse area of timber as it does not involve artificial planting. As so much of the catchment has already been cleared, it is important that there is no more clearing and that existing riverside vegetation is also conserved. Managing remnants is necessary including fencing to exclude stock, weed and pest control, linking remnants with wildlife corridors and planting buffers around remnants to reduce edge effects and agricultural impacts.

Water

- **Buffer zones**, such as riverside areas, wetlands and floodplain sinks, **between rivers and human activity** protect the river system. They filter chemicals, nutrients, sediment, animal waste and urban pollution before they enter as run-off. These buffers are very important for water quality and should be carefully managed. Riverside areas and wetlands should not be cropped and to reduce pollution from livestock, creeks can be fenced off, strategically grazed and alternative watering points provided. Groundwater can become contaminated from nitrate and heavy metal leaching or chemical contamination directly into bore heads. Salt still remains the most common groundwater contaminant.

- Even though over-allocation of groundwater is not a problem in the catchment, it is important that **water use** in the catchment does **not exceed long-term sustainable levels**. This practice will preserve water quality, yield and river (bank, bed, aquatic) health.

- Many landholders do not see **in-stream management** as being a relevant issue requiring action. The state of the river, presence of weeds and debris, bank stability, extent of aquatic vegetation and presence of introduced fish species all impact on river health. Landholders can take action—along with the community and agencies—by revegetating banks, removing weeds (including willows) and improving native fish habitats so they can compete with carp.

Pest Animals

- Native and feral animals are a problem (foxes, rabbits, pigs and, especially, kangaroos) in the west of the catchment around the National Park and other timbered areas but outside these areas there is insufficient habitat to support large numbers of pests. Some of the impacts from pests are erosion, vegetation and habitat loss and species decline. **Cooperative action to control pests and weeds** is necessary between all affected landholders, otherwise control programs will only temporarily reduce numbers. The weed situation is worst in the river environment where weeds are spread downstream by water, so a collaborative effort is also required by all landholders along the river.

Farming Systems

- It is important to **reduce fallow length** to achieve a number of environmental objectives. Existing cropping systems in the catchment are based on winter cropping, with mainly cereals and some farmers using canola as a break crop. This is a problem because these systems do not use all available rainfall, leaving the remainder to drain to the water table, worsening the salinity problem. Some ways to prevent this are intercropping and companion farming which involves sowing crops into existing pastures so that plants are growing (and using water) year-round. Another option is to practice response or opportunity cropping, which involves sowing a crop once a certain soil moisture level is reached. This helps to reduce recharge to the watertable during fallow periods with high rainfall. This system is best combined with reduced tillage. A third option is to delay removing lucerne—or other sown pastures—before a cropping phase until the summer, so there is a shorter fallow period.

- **Crop-pasture rotations** have the benefits of improving water use, nutrient cycling and soil health. Another name for this is phase cropping, which uses perennial pastures and lucerne to dry up soil moisture and then limit the length of cropping in the rotation to reduce recharge (during fallows). Improving crop and pasture management will improve plant growth and, therefore, water use (not to mention profitability). For example, better crop rotations can be introduced using cereals, canola, legumes and possibly summer crops for response cropping (as in the previous paragraph).

- **Conservation farming**, which includes reduced and zero tillage, direct drill, controlled traffic, contour farming and stubble retention, is another farming system with a number of advantages. It improves ground cover, litter retention, infiltration, improves soil biota and reduces soil erosion. These systems reduce compaction and improve root growth and soil structure, which improve water use. Adoption of this system may be limited, as it requires new or modified machinery. In the early years, the nitrogen requirement increases as stubble retains nitrogen.

- **Strategic grazing** includes various forms of time-controlled grazing and rotational grazing and does not include set stocking. Strategic grazing involves pasture management to alter species composition, increase perennial species and diversity, and managing grazing to get the most beneficial seed-set of desirable species. This all requires some knowledge of plant physiology and the ability to assess ground cover and not overgraze a paddock. Keeping high ground cover levels, including litter, is the key and will lead to many benefits. As strategic grazing is most effective with small paddocks and large mobs, changes may be necessary such as more fencing, additional watering points and herd management changes.

- **Perennial mixed pastures** are an option to increase water use and reduce erosion, which existing annual grass and weed pastures are ineffective at doing. Perennial mixed pastures, which means a combination of grasses and legumes with less than 30% annuals, are valuable because they are deeper-rooting, provide year-round growth and ground cover, which makes good use of water and reduces recharge. Better ground cover means increased litter, which improves organic matter levels and general soil health. Although lucerne is an effective water user it also increases acidity and has poor ground cover, but this can be remedied by growing it with other species to create a perennial mixed pasture. The climatic variation in the catchment (from north to south) means that the preferred pasture species will vary, depending on locality.

- **Using native pastures** is valuable, particularly on country suited to low input systems. There are significant areas of native pastures in the catchment, concentrated in the country with low fertility, nutrient imbalances and lower rainfall. Although native pastures are less productive and use less water, they are better adapted to poorer country and, when managed well, will provide good year-round ground cover and growth. Native species enhance biodiversity and provide animal habitats. They are also the best grasses for buffer zones alongside streams, as use of fertilisers is discouraged and the decomposed litter is not harmful to the river environment.

- **Saltland agronomy** involves the use of salt tolerant species such as saltbush, puccinellia or tall wheat grass on land that has become too salty for growth of regular pasture and crop species. Problem areas should be fenced, appropriate species established and then strategically grazed. Saltbush will not establish on the acid soils of the catchment.

Urban Waste Management

- The **urban population** has the same **responsibility to the environment** as the rural population. Urban pollution includes rubbish, oil, detergents, garden refuse, pet waste and sewerage and they can enter the river or groundwater through runoff, leaching under rubbish tips or Sewerage Treatment Plant (STP) releases. To maintain clean water for drinking, recreation and production purposes, there needs to be increased awareness and changed practices like reducing home and garden water use, detergent selection and participation in maintaining the environment.

Monitoring & Evaluation

There are no specific BMOs that apply directly here but Objective 8 (in the CMP Overview section) is relevant. It intends that "the plan and associated processes and arrangements are relevant, effective and reflect the current conditions". This will involve ensuring that the Plan has effective recommendations, is appropriate with current resources, is coordinated with other plans, is promoted to all stakeholder groups and that the costs of implementing the Plan are shared by the community, government and industry.

A recurring priority amongst the Stage 2 targets is to **appoint an Executive Officer** who, among other things, would oversee implementation of the Plan and assist the constant review, evaluation and updating of the Plan over the ten year period. The Executive Officer position is closely tied with nearly all monitoring and evaluation targets. Regularly updating the Geographic Information System (GIS)—both with new data and with on-ground feedback from the community—will help with evaluating changes in the condition of the catchment so the Plan can be revised periodically.

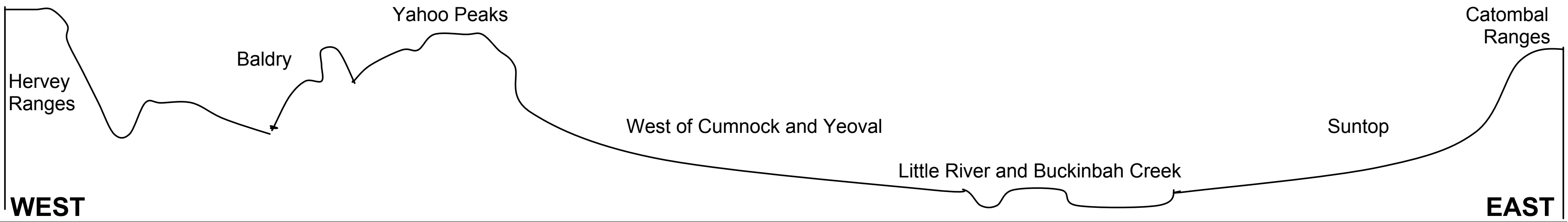
Communication will play a large part, using media such as articles in local newspapers, Landcare newsletters, catchment surveys and community meetings, seminars and workshops. The goal is not only publicity and education but also feedback on how well the Plan is being used, the success stories and where improvements can be made. If communication is effective and innovative it will reach a wide audience.

Land Management Units

Given the strong influence soils have on determining land use, land management and catchment health, soils are the foundation for defining LMUs. The characteristics of each LMU provide the basis for recommending the most appropriate mix of land uses and management practices. For people interested in the detail of this important concept we recommend that you read the comprehensive report on LMUs in Stage 2 of the CMP, Chapters 5, 6 and 7.

Table 18 shows a cross section of the catchment with an accompanying table providing an overview of LMUs across the catchment (and their land capability classes). Table 19 covers the key issues facing each LMU to aid in management decisions.

Table 18: Cross Section of Land Management Units in the Little River Catchment [Source: Donaldson (2001)]



LMU	Shallow (Fine–sediments)	NCBS	Red Solodic	Shallow (Coarse grained–granites)	Siliceous Sand	Non-Calcic Brown (Granites)	Euchrozem	Riparian	Alluvial	Red Brown Earth	Non-Calcic Brown (Sediments)	Red Podzolic (incl Terra Rossa)
Capability	6–7	3–4	3–5	6–7 (rocky outcrops–8)	3–6	3–5	2–3	5	1–2 (lower) 2–3 (upper catchment)	2–3	2–3	3–5

Table 19: Key Issues facing the nine Land Management Units of the Little River Catchment

LMU	Shallow	Red Solodic	Siliceous Sand	Euchrozem	Riparian	Alluvial	Red Brown Earth	Non-Calcic Brown	Red Podzolic
Key issues	Deep drainage Acidity Erosion Very low fertility Steep & rocky Pests	Sodicity Acidity Erosion, esp. gully Low fertility	Deep drainage Gully Erosion Acidity Tree decline Very low fertility Waterlogging	Salinity Erosion Tree decline	Salinity Tree decline Sheet erosion Streambank erosion Flooding Weeds	Salinity Erosion Flooding Tree decline Weeds	Salinity Erosion Structure & fertility decline Acidity Tree decline	Salinity Erosion Tree decline Deep drainage Acidity Structure & fertility decline	Deep drainage Gully erosion Tree decline Acidity Low fertility
Dominant Ground-Water Processes-Recharge or Discharge	Recharge - shallow soils with exposed rock fractures	Recharge due to elevation - but also affected by discharge from other ground-water systems e.g. from the granites/ siliceous sands	Recharge Very permeable soils. Local ground water system, but contributes to surrounding areas	Discharge	Discharge	Discharge (some recharge to alluvial gravels)	Discharge, some recharge May be affected by intermediate groundwater system. (Limestone aquifers)	Recharge, some discharge Recharge through elevated, exposed rocks	Mostly recharge, which occurs in higher landscape; Found in higher rainfall areas

Source: Donaldson (2001)

Cost Benefit Analysis

The Landcare group recognised the importance of putting financial costs and benefits to the Best Management Options (BMOs). This information will allow the Landcare group and landholders **to prioritise the allocation of funds and to work out how to share costs** between landholders and the broader community (government).

An economic analysis was done on the 14 highest priority BMOs and across the five major soil groups of the catchment (covering 75% of the area).

The financial values in table 20 are Net Present Values (NPVs), which account for future and past costs, returns and inflation over the 10 year period of the Catchment Management Plan (CMP).

"If a high-growth economy is needed to fight the battle against pollution, which itself appears to be the result of high growth, what hope is there of ever breaking out of this extraordinary circle?"
E. F. Schumacher, Economist.

River Red Gum Woodland, Little River Catchment CSIRO (Julian Seddon)

Table 20: Total costs and benefits (where available) of implementing each BMO over 10 years to achieve the outcomes targeted in the Little River CMP.

Best Management Option	NPV costs ($ million)	NPV benefits ($ million)	Non-financial benefits
1. Match land use to land capability	41.2	2.8	Improved water quality Reduced salinity. Improved biodiversity
2. Reduce fallow length	1.4	*	Reduced recharge Improved water quality
3. Crop-pasture rotations	1.3	*	Reduced recharge Improved water quality
4. Conservation farming	0.5	*	Improved biodiversity Improved water quality
5. Strategic / rotational grazing	2.2	*	Reduced recharge Reduced salinity Improved water quality
6. Perennial mixed pastures	0	*	Reduced recharge Reduced erosion Improved water quality
7. Native pastures	0	*	Reduced recharge Improved biodiversity
8. Diversity – nature conservation and habitat enhancement	0.2	0.2	Improved biodiversity
9. Farm forestry / agroforestry	7.5	*	Salinity mitigation Improved biodiversity Improved water quality
10. Strategic tree planting	20.7	*	Salinity mitigation Improved biodiversity Improved water quality
11. Vegetation conservation	2.5	2.4	Improved biodiversity
12. Ameliorants (e.g. liming)	17.5	57.0	Reduced recharge Reduced erosion Improved water quality
13. Buffer strips for riparian zones	2.7	*	Improved water quality Improved biodiversity Aesthetic beauty In-stream habitat
14. In stream management	0.8	*	Improved water quality Improved biodiversity Aesthetic beauty In-stream habitat

Source: Hassall & Associates (2002)

* financial value of benefits not calculated

The total NPV costs for putting into practice the priority BMOs over 10 years are around $100 million, which is $380 per hectare over the whole catchment. The tangible, financial benefits, mainly from liming on acid soils, are valued around $60 million, leaving a **net total cost of $40 million**. Over the whole catchment, this still amounts to $150 per hectare, which is considerably higher than the average whole farm business profit of

$14 per hectare for the catchment. A recent survey in the catchment found that the main reason for not taking action against natural resource problems is that it is not thought to sufficiently improve profit or production.

These actions will have many benefits to downstream Macquarie River water users and the Murray-Darling Basin as well as the benefits to the community. The next challenge for Little River Landcare is to select which actions are to be prioritised. To establish the priorities, the Stage 3 report asked whether each BMO was achievable (to the targeted level), affordable, whether the benefits were tangible and whether it was consistent with the Central West Catchment Blueprint priorities.

Table 21: Analysis of BMOs against four criteria

Best Management Option	Achievable	Affordable	Tangible Benefits	Consistency with CMB Priorities
1. Match land use to land capability	✓	✓	✓	✓✓
2. Reduce fallow length	✓✓	✓✓	✓	✓
3. Crop-pasture rotations	✓	✓	✓	✓✓
4. Conservation farming	✓✓	✓✓	✓	✓✓✓
5. Strategic / rotational grazing	✓✓	✓✓	✓✓	✓✓
6. Perennial mixed pastures	✓	✓✓	✓✓	✓✓✓
7. Native pastures	✓	✓✓	✓	✓
8. Diversity – nature conservation and habitat enhancement	✓	✓	✓	✓✓
9. Farm forestry / agroforestry	✓	✓	✓	✓
10. Strategic tree planting	✓✓	✓	✓✓	✓✓
11. Vegetation conservation	✓✓	✓✓	✓✓	✓✓
12. Ameliorants (e.g. liming)	✓✓	✓	✓✓✓	✓✓
13. Buffer strips for riparian zones	✓✓	✓✓	✓	✓✓
14. In-stream management	✓	✓	✓	✓✓

Source: Hassall & Associates (2002)

According to this analysis, the following BMOs are likely to be the most suitable, in terms of the four criteria:

- Use of soil ameliorants
- Strategic / rotational grazing
- Native vegetation conservation
- Conservation farming
- Perennial Mixed Pastures
- Strategic tree planting
- Buffer strips for riverside zones

The cost of implementing these BMOs is estimated at $46 million over the 10 year period. With the estimated benefits of $59 million, this will return an **estimated 10 year profit of $13 million**, excluding less tangible environmental benefits.

OVERCOMING BARRIERS TO CHANGE

Economic

As mentioned in the Cost Benefit Analysis section, a recent survey in the catchment found that money issues are one of the major barriers to overcome. There is the view that many natural resource management actions do not significantly improve profits and also the cash flow problems associated with the delayed returns of investing in lime, even though the returns are significant.

> *"I have never pondered such matters…nor do I ever intend to."*
> Enoch Powell, late senior British politician, on environmental issues.

Following are some schemes that may help overcome economic hurdles:
- No interest / low interest loans or subsidies for lime or gypsum
- Funds for machinery conversions to encourage change to reduced tillage systems
- State agencies to supply salinity advisory staff (to advise, educate and coordinate)
- Funds for extra fencing and watering points to encourage change to strategic grazing
- Funds for trees, fencing and labour (on priority areas) to encourage tree planting
- Availability of technical advice on what trees to plant, where and to coordinate plantings
- Install additional water quality monitoring stations
- Funds for pest control in vegetation conservation areas
- Fund an Executive Officer position (to educate, coordinate and implement projects)
- Continue to deliver FarmBi$ programs in the catchment

Some of these recommendations also meet social, education and research needs.

Social

Social barriers are closely tied with the following two headings in this section, especially education. The education needs highlight some social barriers.

Education

Education is important, both to increase awareness of problems and also to help people know what to do about the problems.

Some points made in the Economic section (above) also provide for education issues including the availability of advisory staff and technical advice. Education in the following areas will be valuable:

- Deliver grazing management strategy courses
- Increase awareness—among the whole community—of the impacts of dryland salinity
- Form groups (possibly around each BMO) for support and joint learning
- Education for landholders, local government and others about hydrological processes in the catchment
- Promote each BMO, focussing on the 7 highest priority ones
- Educate agribusiness advisors and agronomists to encourage landholders in sustainable practices

Packages could be developed to aid landholders in:
- Identifying the major soil groups and their characteristics (see the Soils section)
- Understanding land capability (including soils, geology and slope)

- Biodiversity principles and native vegetation management
- Establishment and management of native grasses
- Understanding the value and management of riverside zones and river systems and awareness about good practice in fertiliser and chemical application

Research

The research needs listed below cover both 'traditional' scientific experiments done by research organisations and less formal—but still well organised—experiments or trials of different practices that may be done by local landholders. The results and lessons learned can be shared with the community to help find the best and most sustainable agricultural practices for the catchment.

Some research needs in the catchment are:

- To compare the water use of trees, understorey, pastures and crops
- To develop management practices to reduce soil acidification in grazing systems (rather than rely on using lime)
- Surveys and investigations to establish salinity hazard areas and associated issues
- Investigation into feasibility of groundwater pumping options
- Trees and understorey—direct seeding, suitable species, economics of agroforestry, social implications
- To tailor standard riverside zone management recommendations to the catchment
- To trial ways of providing incentives to landholders to take up new practices

Getting these research programs under way will require collaboration with both public and private sector organisations.

"The grass is rich and matted. It holds the rain and the mist and they seep into the ground feeding the streams. …It is well tended, and not too many cattle feed upon it; not too many fires burn it, laying bare the soil. Stand unshod upon it, for the ground is holy, being as it came from the Creator. Keep it, guard it, care for it, for it keeps men, cares for men. Destroy it and man is destroyed…"

Alan Paton,
Cry, the Beloved
Country.

References

At the end of each reference is the section of the report that it is credited to.

Acid Soil Action (1998). *Acid Soil Action for Agriculture in NSW*. NSW Agriculture. Acidity section.

Baker, P.A. and Evans, W.R. (2003). *Mid-Macquarie Community Salinity Prioritisation and Strategic Direction Project: Final Report*. Bureau of Rural Sciences. Water and Hydrogeology sections.

Baker, T. (1999). *An Assessment of Riverine Health in the Macquarie, Bogan and Castlereagh Rivers* [DRAFT]. River Environment section.

Bureau of Meteorology (2003). Online: *http://www.bom.gov.au/climate/averages/tables/cw_065023.shtml* and *http://www.bom.gov.au/climate/averages/tables/cw_065035.shtml* 1 July 2003. Climate section.

Bureau of Rural Sciences (2002). *National Vegetation Information System (NVIS) Database*. Vegetation section.

Campbell, M. (2003). *Personal Communication—17 July 2003*. DIPNR Hydrogeologist. Land Use section.

Department of Conservation and Land Management (1994). *Macquarie River Catchment – Land degradation report*. Land Capability and Dryland Salinity sections.

Department of Conservation and Land Management (1997). *Namoi River Catchment – Land degradation report*. Land Capability section.

Department of Infrastructure, Planning and Natural Resources (2003). *Landuse Eastern NSW*. Land Information Systems Unit. Land Use section.

Department of Land and Water Conservation (1999). *GIS Maps and Statistics* – erosion, salinity. Dryland Salinity and Soil Degradation sections.

Department of Land and Water Conservation (1999). *Little River GIS*. Soils and Acidity sections.

Donaldson Planning & Management Consultants (2000). *Little River Catchment Management Plan Stage 1 Report*. Little River Landcare Group. Many sections.

Donaldson Planning & Management Consultants (2001). *Little River Catchment Management Plan Stage 2 Report*. Little River Landcare Group. Many sections.

Haridharan, H.S. (2003). *Personal Communication—6 July 2003*. DIPNR Hydrogeologist. Land Use section.

Hassall & Associates (2003). *Little River Landcare Group GIS*. Catchment Description section.

Hassall & Associates (2002). *Little River Catchment Best Management Options: Cost Benefit Analysis – Summary*. Little River Landcare Group. Cost Benefit Analysis section.

Humphries, E.J. (2000). *Salinity Risk Assessment of the Central West Catchment (Macquarie, Castlereagh and Bogan Catchments)*. Central West Catchment Management Committee. Dryland Salinity section.

Ivey ATP (1998). *Costs of Dryland Salinity – Phase Two Dryland Salinity Survey of the Talbragar and Little River Catchments, Central West NSW – Costs to the Little River Catchment*. Murray Darling Basin Commission. Dryland Salinity section.

Kazemi, G.A. (1999). *Groundwater Factors in the Management of Dryland Salinity and Stream Salinity in the Upper Macquarie Valley*. Dryland Salinity section.

Langfield, K. (2003). *Personal Communication—15 July 2003*. DIPNR. Background, History & Planning Process section.

Murray-Darling Basin Commission (1999). *The Salinity Audit of the Murray-Darling Basin – a 100 year perspective*. MDBC. Surface Water section.

Nancarrow, S. (1998). *CNWRWQP – 1997/98 Report on Nutrients and General Water Quality Monitoring*. River Environment section.

Seddon, J., Briggs, S. and Doyle, S. (2002). *Little River Catchment Biodiversity Assessment*. A report for the TARGET project. CSIRO Sustainable Ecosystems. Biodiversity section.

Taylor, S. (1994). *Macquarie River Catchment – Land Management Proposals for the Integrated Treatment and Prevention of Land Degradation*. Department of Conservation and Land Management. Dryland Salinity section.

Watson, W., Evans, R., Powell, J., Oliver, M. and Hall, M. (2002). *Sustainability Profile for the Little River Catchment*. Integrated Catchment Assessment and Management (iCAM) Centre report prepared for the TARGET project, Australian National University, Canberra. Many sections.

Wellington Shire Council (1999). *Noxious Weeds Guide*. Pasture Degradation and Weeds section.

APPENDIX

The Little River GIS contains the following information:

Name of theme	Description	Date	Scale	Source
1. Geographic Data				
Study Boundary	Boundary of the Study Area		1:100000	DLWC
Study Boundary	Sub-catchment boundaries		1:100000	DLWC
Infrastructure	Towns, villages, roads, rail etc.			DLWC
Shire Boundaries	Local Government boundaries			DLWC
2. Natural Resource Data				
Hydrography	Rivers, creeks, surface water			DLWC
Relief (Drainage)	Contours		1:100000	DLWC
Geology	Geological Provinces – lithology, complexity	1999	1:250000	DLWC / AGSO
Soils	Soils landscape units, topsoil acidity	1990-1999	1:250000	DLWC
3. Land Use & Erosion Data				
Land Use	Land use	1988	1:100000	DLWC
Land Capability	Land capability	1988	1:100000	DLWC
Erosion I	Land and water degradation (Sheet & Rill)	1988	1:100000	DLWC
Erosion II	Land and water degradation (Gully)	1988	1:100000	DLWC
Dryland Salinity	Known saline sites	1992 & 1998-9	1:100000	DLWC
4. Vegetation Data				
Woody Vegetation	Woody vegetation (trees of significant size) – Raster Data			DLWC
Vegetation Types	Eastern Bushlands Data	1989-1991	1:250000	NPWS

Source: Donaldson (2000)