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Economic impacts of salinity on townsite infrastructure

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Economic impacts of salinity on townsite infrastructure

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RURAL TOWNS MANAGEMENT COMMITTEE
DEPARTMENT OF AGRICULTURE

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EXECUTIVE SUMMARY

This report summarises the findings from the investigation of the predicted economic impact of rising saline groundwater in six rural towns representing the range of situations found in the agricultural areas of WA. The six towns are Brookton, Corrigin, Cranbrook, Katanning, Merredin and Morawa, and separate reports have been published for each. An electronic Decision Support Tool called the *Urban Salinity Economic Analysis Package (USEAP)* and associated Operating Manual were also produced.

The Rural Towns Program Management Committee commissioned a consultancy to **investigate the economic costs of salinity and the benefits to abatement on rural infrastructure in Western Australia**. This consultancy was completed by Dames & Moore – NRM (now URS Australia) and The Resource Economics Unit from February 2000 to June 2001. The requirements for the project were:

- Quantification of the costs of salinity and rising groundwater tables in six towns in the agricultural areas of WA - by estimating the level of additional costs to public organisations, commerce, industry and households that could result from unchecked rising groundwater beneath these townsites;
- Assessment of the benefit-cost ratio for a range of groundwater/surface water strategies that will ameliorate the impact of rising groundwater and salinity within the townsites; and
- Development of decision aid(s) that can be transferred and applied in other WA towns.

Modelling of groundwater movement in each of the six case study towns indicated that in the absence of measures taken to slow groundwater rise, the groundwater table is:

- already in equilibrium and close to the ground surface over a large part of the Katanning townsite;
- rising beneath the Brookton, Corrigin, Cranbrook and Merredin townsites; and
- perched on shallow bedrock in Morawa.

The infrastructure observably affected by this rise in watertable level and salinity includes roads; public, commercial, retail and residential buildings; parks, gardens and sporting fields.

In all cases, there are three general options to control groundwater rise:

- Reducing the amount of imported water available to enter the groundwater table (more efficient use of water within the town);
- Intercepting the water before it is able to recharge the groundwater (use of improved stormwater drainage and trees); and
- Removal of water from the groundwater below the areas of town most endangered over the next four to twelve years (pumping).

Table 1 summarises the situation for the six towns. The scenarios are very different, which emphasises the needs for site-specific investigation and development of options. However, there are actions that can commence now that will have a favourable impact on water management in all towns:

- Provide advice to householders, businesses and builders on all aspects of urban water balance management, including conservation, domestic drainage, urban stormwater control and effects of trees.
- Progressively improve town drainage schemes to prevent run-off from within town entering the watertable beneath the town.
- Aim to ensure complete coverage with sewerage systems.

Table 1: Damage and control costs for the six towns

Town (timescale of estimates)	Damage costs (7%)	Timing of onset of major costs (years)	Total cost of potential options to control rising groundwater (7%)	Cost of abandoning land and infrastructure (7%)
Brookton **(60 yrs)**	$0.618m	4	$0.275m[1]	$0.678m
Corrigin **(60 yrs)**	$0.210m	2	-$0.105m[2]	$0.09m
Cranbrook **(60 yrs)**	$0.611m	22	$5.742m evap $1.554m ($2.251m[3])	$0.889m
Katanning **(30 yrs)**	$6.865m	1	$7.609m evap $3.422m	$13.8m
Merredin **(60 yrs)**	$0.384m	26	$4.565m evap $0.922m ($1.827m[4])	$0.698m
Morawa **(30 yrs)**	$0.248m	1	$0.900m	N/A

1. assumes reduced need to purchase scheme water.
2. shown as a negative cost because of benefit due to reduced need to purchase scheme water.
3. if pumping and drainage implemented in Year 16.
4. if pumping and drainage implemented in Year 20.

All towns need to address issues associated with salinity and water impacts on private and public infrastructure. In most cases, these issues will require significant investment decisions over coming years. Key stakeholders will be local government, State and Federal Governments, and private and corporate infrastructure owners.

Other towns that have completed detailed hydrological investigations and modelling studies of groundwater in the townsites should be encouraged to apply the USEAP economic analysis.

1 Introduction

This report collates and summarises the findings and conclusions from the investigation of the predicted economic impact of rising saline groundwater in six representative rural towns in the agricultural areas of WA. The six towns are Brookton, Corrigin, Cranbrook, Katanning, Merredin and Morawa, and separate reports have been prepared for each town. An electronic Decision Support Tool called the *Urban Salinity Economic Analysis Package (USEAP)* and associated Operating Manual were also produced.

1.1 Background

The Western Australian Government is investing funds in the prevention of damage to rural town infrastructure resulting from rising saline groundwater levels. In the 1998 update of the State Salinity Action Plan (now Salinity Strategy 2000), annual expenditure of $4 million per annum from State and Commonwealth sources was targeted for protection of rural infrastructure assets. The Rural Towns Program is directed by a Management Committee and is managed by Agriculture Western Australia.

1.2 The requirement

The State Government and rural communities need analysis of the private and public financial consequences of increased salinisation and watertable levels on infrastructure within rural townsites and the likely return on the investment in protection of these assets through groundwater control. These parties require this information to provide a basis for rational decision making about the level of intervention required.

In response to this need, the Rural Towns Program Management Committee through Agriculture Western Australia commissioned a consultancy to **investigate the economic costs of salinity and the benefits to abatement on rural infrastructure in Western Australia**. This consultancy was completed by Dames & Moore – NRM (now URS Australia) and The Resource Economics Unit over the period February 2000 to June 2001. The requirements for the project were:

- A quantification of the costs of salinity and rising groundwater in six case study towns in the agricultural areas of WA - by estimating the level of additional costs to public organisations, commerce, industry and households that could result from unchecked rising groundwater beneath these townsites;
- An assessment of the benefit-cost ratio for a range of groundwater/surface water strategies that will ameliorate the impact of rising groundwater and salinity within the townsites; and
- Development of a decision aid(s) that can be transferred and applied in other WA towns.

2 Findings

2.1 Damage costs – impacts of groundwater and salinity on different classes of infrastructure

Towns in the Western Australian wheatbelt are affected by rising groundwater and salinity in a variety of ways. This report deals with the effects of rising water and salinity on fixed physical infrastructure such as roads, drainage, water supply, public buildings and major facilities. The extent to which a town's infrastructure is affected has been determined by identifying those items that are subject to rising water and salinity and correlating the degradation with estimates of water level and salinity concentration. The economic impact has been quantified by estimating the additional cost of the remedial work needed to be undertaken on the degraded items of infrastructure, and the expenditure required to maintain the infrastructure – termed the 'damage costs'.

2.1.1 Groundwater trends in the case study towns

The movement of groundwater in each of the six towns was modelled by Agriculture Western Australia. Modelling indicated that in the absence of measures taken to slow groundwater rise, the groundwater table is:

- already in equilibrium and close to the ground surface over a large part of the Katanning townsite;
- rising beneath the Brookton, Corrigin, Cranbrook and Merredin townsites; and
- perched on shallow bedrock in Morawa.

The causes of soil saturation are complex, and vary between towns, but include:

- leakage from drainage lines that enter the towns from their wider catchments;
- recharge from roofs, roads and other sealed surfaces within the towns;
- recharge from water that is imported to the towns via piped water supplies;
- reduction of total evapo-transpirational demand within townsites.

The clearing of natural vegetation in the wider catchments containing these towns is considered to be a minor influence on the depth to groundwater table in the townsites, but it does promote higher surface run-off during peak rainfall events.

2.1.2 General observations for all six towns

Inspections of all six towns were made by the engineer and architect-builder, and discussions were held with shire officials. A list of generic findings and observations made during these visits shows that the six towns have many issues related to water management in common including the following points:

- All receive surface water flows from their wider catchments, via drainage lines, surface rocks, or from major roads running into the town from higher in the landscape;

- Groundwater within some of the towns was used as a fresh water supply prior to the 1960s;
- Reticulated water from external sources, was supplied to many of the towns for the first time in the 1950s and 1960s;
- Sewerage collection and disposal was previously by pan and then septic tank;
- Reticulated sewerage collection and disposal has been implemented in recent years, but is not yet completed in some towns;
- The volume of domestic water used to maintain ornamental plants in some situations is high;
- Stormwater drainage predominantly uses unsealed and unlined open drains and road surfaces;
- The road pavements are relatively wide sealed pavements with kerbs;
- Building-roof rainwater run-off is very commonly discharged to ground next to buildings in the towns;
- Treated sewage is used, when rainfall is low, to water parks and ovals;
- Collected stormwater is stored and returned for use to water public areas;
- Natural drainage lines are generally unsealed and often contain vegetation or debris that restricts natural flow, increases retention and increases local recharge to groundwater from the drainage line;
- High watertables occur at specific locations within the towns; and
- Salt crusting on the ground surface can be seen in some towns, but the incidence is generally localised.

The infrastructure observably affected by this rise in watertable level and salinity includes:

- Roads;
- Public, commercial, retail and residential buildings; and
- Parks, gardens and sporting fields.

2.1.3 Distinguishing between damage due to rising groundwater and surface water

Damage to masonry and brickwork of many buildings is evident in all towns. In discussions with local people, it appears that this is most normally ascribed to impacts from rising groundwater. But very wet (even intermittently saturated) soil at the ground surface does not *necessarily* indicate a shallow or rising groundwater table. The alternative cause, which is often not considered, is poor drainage around the building itself and inadequate disposal of stormwater run-off from roofs and other hard surfaces. Where the groundwater table is currently deeper than 1.5 metres at a given location, damage to buildings will be the result of poor surface drainage on the site and *not* the result of interaction with the groundwater table.

Given this situation, it is clear that the impact of rising groundwater tables is being over-estimated by many people who are wrongly interpreting the evidence of infrastructure damage. Therefore, it is very important that this distinction is recognised in making policy and developing strategies for groundwater management.

This study was confined to investigating and costing the impact of rising groundwater alone. For those areas exposed to shallow watertables, improved surface drainage has been included as a defensive measure to prevent damage to infrastructure due to chronic dampness. However, this need for improved surface water management around buildings applies also to areas without rising groundwater tables. More general conclusions and recommendations about the management of surface water are given in Sections 3 and 4.

2.2 The options for controlling groundwater rise

In all cases, there are three general options to control groundwater rise in a rural town. In general, it is unlikely that any single measure will be sufficient in the long-term to offset the problems associated with a rising watertable.

2.2.1 Intercepting all excess water before it is able to recharge

Improved drainage

Inspection of buildings and facilities in all towns revealed that a considerable amount of stormwater drainage is discharged to ground adjacent to the source. This has two compounding impacts. First, damage associated with damp surface soil layers near to point of discharge was noted in several instances. While not a problem associated with a groundwater table *per se*, it is an impact caused by excessive water near buildings. Advice with management of this source damage could be provided. The objective will be to assist owners of infrastructure with drainage around their properties that is causing damage, which it has been suggested may be wrongly attributed to the impact of rising groundwater tables.

Second, discharge to ground within a townsite is a major source of groundwater recharge. The surface water discharged from sites within the township should be directed to sealed drainage systems to prevent localised recharge. The cost for design and installation of a comprehensive sealed and lined stormwater and sub-surface drainage system is estimated to be approximately $50,000 per hectare.

Tree establishment within a townsite

Trees grown in plantation format are effective at lowering local groundwater tables. Based on existing published research, on a site where the watertable was rising at 0.25 m/yr, trees lowered the groundwater table by 2 m over a six-year period. However, the research also showed that most of the water was not being drawn from the watertable direct, but the trees were removing water from the soil profile above the watertable. Hence the action of the trees amounts to a reduction of recharge, which is a similar approach to that described in the previous section.

Although not exclusively the case, research indicates that the effect of trees on groundwater tables is very localised – to within 10 to 30 m of the edge of the plantings. Nevertheless, there will be value in planting trees and/or shrubs on vacant land within the area where the symptoms of rising groundwater will be experienced over the next 10 years. This approach will complement other measures.

The use of trees along road reserves is suggested because road damage represents the single largest cost arising from shallow groundwater. Trees planted near roads can be an effective method of preventing the ground beneath the road pavement from becoming saturated.

2.2.2 Reducing the amount of imported water available to enter the groundwater table

The use of imported water to maintain gardens that are unsuitable for the climate needs to be reviewed. A reduction in domestic water use could be encouraged using domestic irrigation control equipment (e.g. trickle systems) associated with the use of indigenous plants and a reduced lawn area. Water use minimisation programs can be implemented. Reduced imported water use will yield another public benefit, in terms of a lower total cost for providing domestic water to a town community. Savings are shared by the local and wider communities, which subsidise water costs in rural areas.

Where a rising groundwater table is fresh near its surface (as often occurs as the fresh water is less dense) the use of household bores will help to stabilise it, because only a small proportion of the pumped water will be returned to the ground as recharge. Most will be lost to the atmosphere through evaporation and use by plants.

The recycling of waste water and excess stormwater to public areas needs to be managed carefully to ensure that this does not become a significant contributor to recharge. Completion of sewerage networks and monitoring of water use and irrigation using tensiometers will improve the efficiency of water use and limit the movement of water past the root zone into the groundwater table.

2.2.3 Removal of water from the groundwater table below the areas of town most endangered

Groundwater abstraction within a townsite is the most costly option. Because of the localised effect of individual bores, a network of bores is usually needed to achieve sufficient drawdown of the groundwater level. This control option should be limited to the area of a town where the symptoms will be experienced within the next 10 years. However, because the drawdown will create a substantial hydraulic gradient with the surrounding groundwater table, it is anticipated that the pumping will need to be long-term, continuous and accompanied by other measures (e.g. drainage) that reduce recharge across the townsite. It will be possible to place bores strategically, in areas not suitable or feasible for tree planting. At the same time, bores would need to be kept at some distance from buildings, to avoid differential foundation movements from de-watering.

Disposal of the pumped water is an important issue. If potable, it can be used to replace more expensive imported water. If saline, it can be evaporated off. However, evaporation is an expensive option, and additional work to develop economic uses for the saline water is required – including recovery of potable water through desalination, and use of the water for aquaculture, salt harvesting and to generate electricity.

2.3 Findings in the six towns

Locations of the towns are shown in Figure 1. Average damage costs for different types of infrastructure are summarised in Figure 2. The findings for damage costs and recommended control costs are presented under individual towns and summarised in Table 2.1. The information presented is for the two possible extremes, namely:

- *The level of damage costs* that is likely to be experienced in the absence of any effort being made to control groundwater rise; and
- *The level of control costs* that will go a long way to averting all damage.

Intermediate solutions, that would involve accepting some continuing damage, and concentrating controls only on the most affected areas, are also discussed. The Decision Support System (USEAP) produced as part of this study emphasises trade-offs between control costs and damage costs.

2.3.1 Brookton

Brookton was established in 1899 and has been a service centre for the railway and local farming community. It is 138 kilometres from Perth, and is located on the intersection of the Brookton Highway and the Great Southern railway line. It supports a modest range of service facilities, and has a total of 500 buildings including 244 private dwellings (counted from the town map and street survey), a percentage of which are owned by government agencies for housing employees resident in Brookton.

Hydrology

The main hydrological influence below Brookton is a shallow unconfined near-fresh to saline groundwater aquifer which experiences seasonal fluctuations in depth below ground level.

Conclusions from the analysis

- The hydrological modelling predicts that groundwater tables will rise to the surface over a significant area of town over the next four years and then reach equilibrium. The area most affected will be between the railway reserve and the Avon River, with an extension across the railway reserve in the southern area of town. This area includes a substantial proportion of the housing stock in Brookton.
- The present value of the total damage cost of that management into the long-term (i.e. the cost of living with the problem) will be approximately $618,000.
- If conditions in the worst affected areas become too severe for continued management of the damage, abandonment will impose a cost of $678,000 to be borne by infrastructure owners.

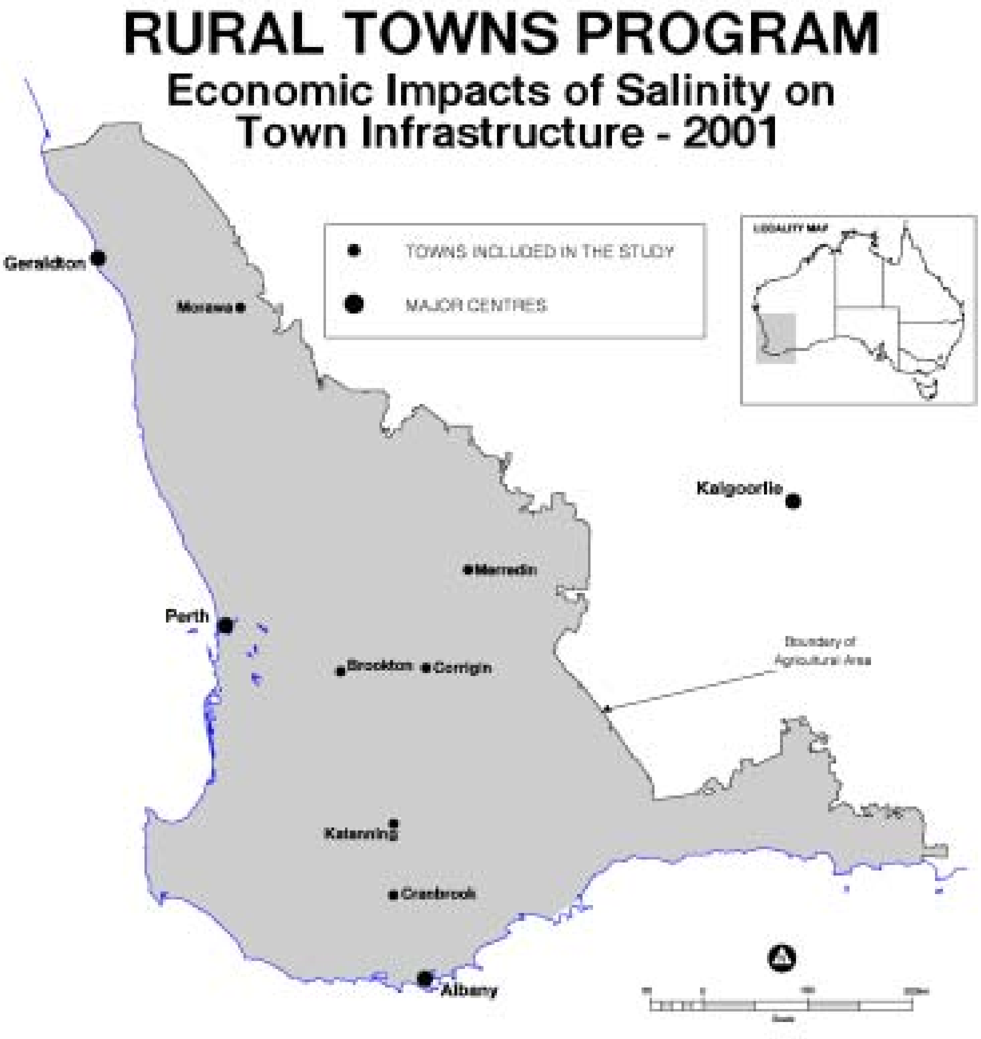

Figure 1. Location of towns involved in economic impact study

- Options to prevent further rise in the groundwater table and induce eventual lowering of groundwater include a combination of reduced domestic water discharge to the groundwater, improved surface water management and direct abstraction by pumping from the watertable.
- Captured surface water and recovered groundwater can be stored and mixed to produce a water resource for commercial use on ovals and parks.
- Implementation of the complete program over the next five years will have a capital cost of $575,000, with annual operating and maintenance costs of $27,000. Based on the current commercial purchase price for water, being able to use the stored surface and groundwater will generate savings of $69,000 per annum. Overall, the cost of the program if implemented over the next two to five years will be $275,000 (discounted at 7 per cent) over the next 60 years.

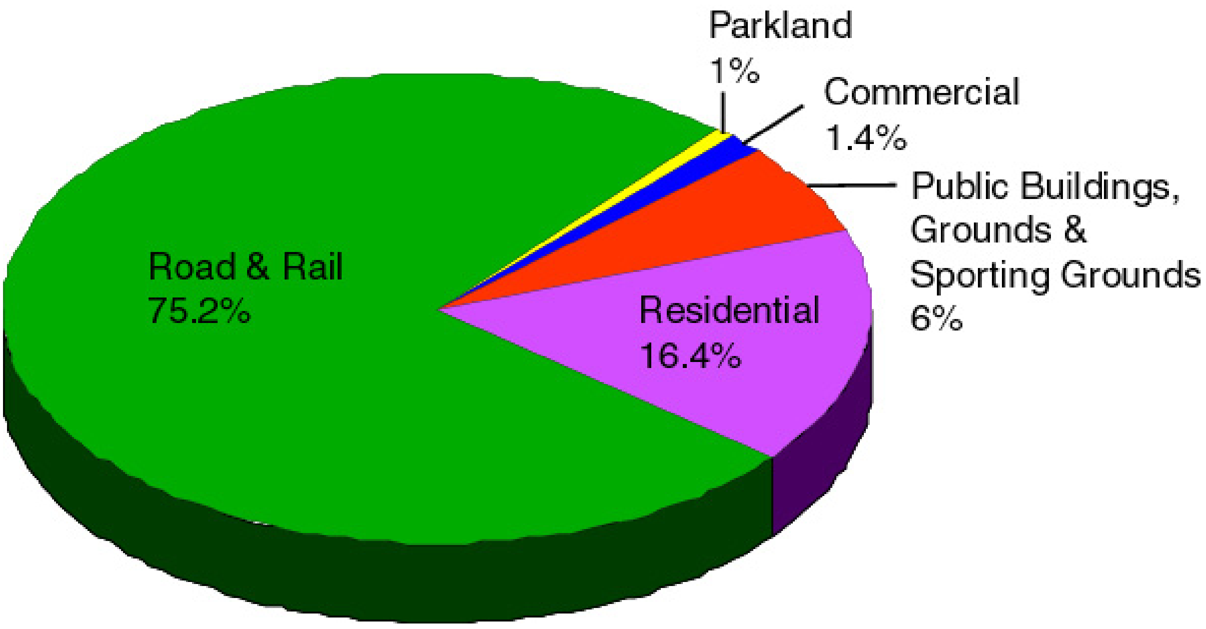

Figure 2. Average damage costs to different infrastructure categories found in towns

Recommendations for Brookton

- Introduce an Integrated Water Management Program as soon as possible, including a commitment to advise on domestic and commercial water use efficiency and stormwater management around domestic and commercial infrastructure.
- Ensure the sewerage system is complete and is not able to discharge water to the groundwater table.
- Use the next two years to monitor available bores to confirm that the rate of groundwater rise is similar to that predicted by the model. Confirm the technical viability and the estimated costs and returns of the integrated pumping and stormwater management system with a feasibility study.
- Determine and secure the market for harvested and recovered water within the town.
- Assuming the feasibility study confirms the general thrust of the conclusions in this report, commence implementation of the integrated water management program and the pumping and stormwater management system over the four-year period, to be completed in Year 5.

2.3.2 Corrigin

Corrigin is located 234 km east-south-east of Perth and has a population of about 1,300 people. The town is a service centre for the local agricultural community and also supports a small steel fabrication industry, machinery dealers and manufacturers, upholstery business and a flourmill. It has 314 private dwellings (counted from town map and street survey) some which are owned by government agencies for employees resident in Corrigin.

Hydrology

Hydrogeological description of Corrigin is based to a large extent on supposition. This is due mainly to a lack of long-term groundwater monitoring data. The main groundwater systems exist within the fractured and weathered zones of the bedrock and within a regolith (which has been identified using geophysical images). Depth to groundwater varies throughout the townsite. Shallow depths to groundwater are only found in the low-lying areas of the town in the vicinity of the creek. In these areas, depth to groundwater varies but is generally 1.5 m to 0.5 m from the soil surface.

Conclusions from the analysis

The position of the town on the western slopes of Corrigin Rock has resulted in:

- relatively simple surface drainage within the town;
- a small area that is predicted to have shallow groundwater at 0.5 m or less; and
- a responsive, relatively fresh groundwater table.

In recent years, because areas within the town have shown some evidence of the impacts of rising groundwater, the shire has initiated a project to both assess the situation and overcome it through groundwater pumping. Damage costs in the absence of groundwater pumping are predicted to be low, with a present value of the total cost for the community of $210,000 (discounted at 7 per cent over the next 60 years). The shire embarked on a program of groundwater pumping two years ago. The analysis indicates that these efforts have been well founded, and are in fact likely to make savings for the town through the replacement of scheme water by water from the town’s aquifer. The present value of benefit for the town over the next 60 years is estimated at $314,000 using a 7 per cent discount rate. This figure includes the damage avoided ($210,000) and the net present value of the water obtained from the pumping scheme.

Given current and planned pumping activities, Corrigin is unlikely to suffer significant problems of infrastructure decline as a result of rising saline groundwater. Any additional activity beyond that already been planned is unlikely to yield further benefits to the town.

Recommendations for Corrigin

The existing strategy is supported and the planned extension of the pumping scheme is endorsed assuming that the predicted sustainable level of extraction can be maintained and that the water can be used to offset imported supplies.

2.3.3 Cranbrook

Cranbrook is located 85 km north-north-west of Albany and has a population of approximately 320 people. The town is at the centre of the Shire of Cranbrook and is a small service centre for the local agricultural community and is a thoroughfare for tourists travelling to the nearby Stirling Ranges. The town covers approximately 485 hectares and has 105 private dwellings (counted from town map and street survey), a percentage of which are owned by government agencies for employees resident in Cranbrook.

Hydrology

The town is located on the relatively flat, lower slopes of the Cranbrook Catchment with the main tributary of Pinjalup creek passing through it and discharging into the Gordon River 11 kilometres downstream. The depth to saline groundwater varies throughout the townsite, but is generally already within 3.0 m of the surface and rising. This is a serious future problem.

Cranbrook's problem with water management is a consequence of its position in the valley floor of a relatively flat catchment. The town experiences seasonal waterlogging due to the low relief and the poorly drained duplex soils. While damage due to saline groundwater is currently low, the groundwater model predictions suggest that significant damage due to rising groundwater tables will occur after 2020.

Conclusions from the analysis

Overall, the town faces a damage bill with a present value of $611,000 (i.e. discounted at 7 per cent). This is the present cost of living with the problem over the next 60 years.

The alternative approach is to invest in groundwater control. To ensure groundwater levels are kept below 1.5 m below the surface long-term may require a combination of sealed sub-surface drainage, tree planting and groundwater pumping. However, the economics are problematic – implementation of all these programs will have a net present cost of $5.74 million (discounted at 7 per cent over 60 years). Even with staged implementation so that the most expensive programs – pumping and sealed drainage are not implemented until 2016, the total control cost will still be $2.25 million, or three times the estimated total damage cost.

A third approach not explored in this analysis will be to undertake some control works to limit the amount of damage that will occur. A possible compromise position that may minimise the overall public and private outlays will be to keep the groundwater table below the level where it will impact significantly on private domestic structures, while accepting some damage to the publicly owned road pavements within the town. Additional analysis will be required to determine the optimum mixture of damage and control costs for the town.

Recommendations for Cranbrook

While a strictly commercial view would suggest that deciding to accept the damage costs as they occur will be the preferred option, social costs need to be considered and the possibility that incorporation of desalination and salt harvesting into the pumping program as the technology develops may alter the control costs in their favour. This suggests three possible decisions:

- Develop a strategy focused on accepting and meeting the estimated present value of the damage costs ($611,000) in a way that minimises social difficulties for the town;
- Adopt a strategy of controlling groundwater rise irrespective of the higher cost – this will require a consideration of funding options; or
- Assume that groundwater control is the chosen strategy, and implement low cost measures now (e.g. tree-planting) while closely monitoring actual groundwater behaviour compared to the predicted rate of rise.

Because it will be 20 years before major costs are incurred, the recommended approach is the third one – an approach that plans for eventual control but with limited action in the immediate future. The attraction of this approach is that the ‘breathing space’ available before major impacts occur allows for more cost-effective technologies to be developed. It will also enable analysis of the best mixture of damage and control strategies to be determined. The decision to adopt this third option will require frequent review over coming years so that current owners and potential investors in Cranbrook will have access to current thinking about the preferred scenario for the town.

2.3.4 Katanning

Katanning is located approximately 295 km south-east of Perth in the Great Southern region. It is a major town with a population of over 4,000 people and supports significant regional service facilities. Local industries include farming, stock selling, brickworks, engineering, stock foods and wholesaling. It has 1866 private dwellings (WA Municipal Directory 1999-2000), a percentage of which are owned by government agencies for housing employees.

Hydrology

The town is situated within the Katanning Creek catchment that flows south and east into Lake Ewlyamartup via a series of pools. The drainage system is capable of containing run-off in average years and flooding only occurs in extreme events, such as the cyclone events of 1982. The catchment is largely cleared with about 1,000 hectares or 10 per cent of the original woodlands remaining.

Within the townsite, the depth to bedrock varies from approximately 14 to 40 metres. The clay-rich profile above this bedrock allows only sluggish movement of groundwater and so in many places water levels have risen near the surface and salinity is well-developed. The saline watertable is frequently within 0.5 m of the soil surface along the narrow valley floor of the Katanning Creek and is greater than 8 m in elevated mid-slope to upper-slope positions. Groundwater data monitoring has only been conducted for a short period, but it is expected that further rises will be in the vicinity of 0.1 to 0.2 metres per year.

Conclusions from the analysis

Of the towns reviewed, Katanning clearly has the most significant difficulties with current and predicted damage due to rising groundwater. Nearly two-thirds of the townsite is currently experiencing the effects of ground water less than 1.5 m from the soil surface.

For a town of this size, the economic and social implications are large. The predicted damage bill for this town is $6.865 million, which equates to approximately $1,800 per resident, although the distribution of the costs will be very uneven across the town.

The major reason for the high predicted damage cost is that the watertable is very near the surface over a large area of the town. Soil profiles within the town are already saturated in many areas, and the situation has reached the critical 0.5 m depth. Combined with the range and quantity of infrastructure within the townsite, this has generated a damage cost budget, the scale of which is not likely to be seen in many other wheatbelt towns.

Katanning faces substantial costs to manage the groundwater table problem, irrespective of which options are pursued. To simply meet the damage costs without controlling and lowering the groundwater tables will cost the town approximately $6.865 million (discounted at 7 per cent). In contrast, the estimated control cost to prevent further rise and lower existing groundwater levels will be approximately $7.609 million (discounted at 7 per cent).

Recommendations for Katanning

While the difference between the two scenarios is significant, it would appear that the social implications of failing to control the saline groundwater table are likely to be significant. On this basis, the following recommendations are offered:

- A groundwater pumping program be designed and implemented immediately.
- Investigation of alternatives to evaporative water disposal.
- Strategic additions to, and upgrading of the existing stormwater drainage system to complement the pumping program.
- Determination of the effects of lining major drainage lines within the townsite, and implementation of a program to implement such work on the basis of positive results from the investigation.
- Immediate implementation of a program that addresses water use in the town and domestic stormwater management and disposal.

2.3.5 Merredin

Merredin was established as a Town adjacent to the Goldfields railway line 230 km east of Perth in 1893. It is now the most significant town in the eastern wheatbelt, with a population of about 3,000. It is strategically located at the centre of a major grain growing area, and supports significant service facilities. It has 1,100 private dwellings (counted from town map and street survey), a percentage of which are owned by government agencies for housing employees resident in Merredin.

Hydrology

The Merredin catchment covers 400 square kilometres, with Merredin located about mid-way down the catchment. Surface drainage flows through the town from east to west via a series of intermittent creeks. These creeks flow towards the salt lake chains of the Yilgarn River. The Shire of Merredin has approximately 11 per cent of its original remnant vegetation.

The town, and consequently most of its high value assets, is located in a valley floor and like most eastern wheatbelt catchments, the town of Merredin is situated in a landscape with little hydrological relief. Rising groundwater is a problem and has been a focus of community activity since the mid-1980s. The depth to groundwater varies throughout the townsite, and is estimated to be rising by an annual average of 0.1 to 0.2 m.

Conclusions from the analysis

From the analyses provided, the present value of damage costs due to predicted rising groundwater levels is approximately $384,100. Although a moderate impost on the community as a whole, the impact will be distributed very unevenly across the town. Most damage costs are predicted to occur in two small areas, one centred on the showgrounds and another near the shire offices. Current levels of damage due to rising groundwater are low. Most costs will be incurred after 2025, which provides the community with a substantial ‘breathing space’ during which to consider how to address the problem in a way that generates the most benefits.

Early implementation of the full array of technologies to control groundwater rise has a present value of $4.565 million. This investment clearly cannot be justified given the much lower damage costs that would be prevented. Given current technologies, the actions warranted for immediate implementation include advice with water management to reduce recharge and damage to infrastructure, continual improvement in drainage systems and tree-planting within the town to reduce recharge.

A third approach not explored in this analysis would be to undertake some control works to limit the amount of damage. In this approach, the cost of rising saline groundwater levels will be met in part through some investment in control measures and by continuing to treat some of the symptoms in the form of damage to infrastructure.

Recommendations for Merredin

- Implementation of the low cost actions to address the causes are warranted, and should include a program to encourage more efficient water use, improved water management on town ovals, and tree-planting in the area of town most vulnerable over the next 10 years.
- Groundwater pumping is sufficiently sound for planning purposes, but is expensive to implement and difficult to justify when compared to the total damage cost. At this stage, the pumping option should not be considered as an option in its current form. The need for pumping to lower groundwater tables should be reviewed in 10 years time.
- Major improvements to stormwater drainage is also a sound option in terms of long-term planning, although it is also difficult to justify major investment at present given the comparison with the total damage cost. However, normal investment in best practice drainage management should be pursued by the Shire, with a review in 10 years of the need for a substantially increased level of investment.
- The interim time before deciding if pumping and evaporative disposal options are needed to eliminate damage costs can be used in developing uses for the water that either reduce the net present cost of pumping and disposal, or preferably make the pumping option an economic benefit in its own right. Technologies that will have some influence include salt recovery, desalination to produce potable water and aquaculture.

2.3.6 Morawa

Morawa is a small town 310 km north of Perth that supports a modest number of service facilities. It has 242 private dwellings (counted from town map and street survey), a percentage of which are owned by government agencies for housing employees resident in Morawa.

Hydrology

Morawa lies over shallow rock. Borehole geological profiles indicate that the regolith depth varies between 0.5 and 7 m under the majority of the townsite. The undulating nature of the bedrock under the townsite has led to small saturated basins separated by subtle bedrock highs which as a consequence prevent lateral flow of groundwater. Instead of lateral flow, the ‘retained’ groundwater rises to the surface after recharge events. Repeated recharge and rises at this local scale cause small isolated scalds seen within the townsite.

Groundwater tables are shallow and disconnected on the townsite scale. As a consequence, groundwater modelling, as undertaken in the other five towns, is not beneficial in identifying potential future risk areas. For the purpose of this study it has been assumed that the system has reached a quasi steady-state condition with the extent of the townsite which could be potentially affected remaining the same into the future. This justified the choice of the 30 year planning horizon.

Conclusions from the analysis

Unlike other towns in this study, Morawa does not have a problem with persistently rising local groundwater. The town's positioning over shallow granitic bedrock, and its location midway down the catchment ensures that throughout most of the town, water damage to infrastructure is not a problem.

However, some sections of the town are subjected to seasonal waterlogging and surface water ponding, as a result of inadequate stormwater drainage allowing water to pond in basins. These areas are in the centre and south-western sections of town. In these areas, seasonal waterlogging and ponding does occur, and some residential, commercial and public buildings are showing signs of deterioration due to frequent exposure to damp soils. The impacts of this waterlogging and surface water ponding are minor in comparison to other towns within the study group. Subsequently, the likely financial burden of meeting the damage costs is relatively low at $248,000 (at a 7 percent rate of discount).

While it would be ideal for the town to implement a comprehensive surface water drainage strategy, this analysis suggests that it cannot be justified on economic grounds. The estimated cost of implementing a major sealed sub-surface drainage project within the affected areas of town is $900,000 — $652,000 more than the estimated damage costs.

A third approach not explored will be to undertake some new drainage works to limit the amount of damage that will occur. In this approach, the cost of damage will be met in part through investment in control measures and by continuing to treat some of the symptoms in the form of damage to infrastructure. Additional analysis will be required to determine the optimum mixture of damage and control costs for the town.

Recommendations for Morawa

- Consider a strategy of addressing the damage costs as the town's major option. While this may not necessarily be the optimum solution in terms of controlling the impacts of shallow groundwater, it is the most economically feasible. Given that the benefits will be received by both public and private owners of infrastructure, cost-sharing mechanisms developed and managed by the local authority could help with implementing the necessary improved drainage around buildings.
- Continue with improvements to drainage in the areas of town most affected, to be linked and coordinated with the actions taken by owners of affected infrastructure. Again, shared funding by shire and landholder can be used to meet the costs.
- Continue with the revegetation program where feasible as a means of using annual 'retained' water in the town before it is able to affect infrastructure.

2.3.7 Generic recommendations applying to all towns

Table 2.1 summarises the situation for the six towns. The most important feature is that the scenarios facing the towns are very different, which emphasises the needs for site-specific investigation and development of options. However, it is clear from the analyses that there are actions across all situations that can commence now that will have a favourable impact on water management in all of the towns.

- Improve water use efficiency within towns and provide advice to householders, businesses and builders on all aspects of urban water balance management, including water conservation, domestic drainage, urban stormwater control and effects of trees.
- Improve surface water management within the townsite to reduce water entry from the surrounding catchment and ensure removal from townsites as soon as possible.
- Aim for complete coverage with sewerage systems.

Table 2.1: Damage and control costs for the six towns

Town (timescale of estimates)	Damage costs (7%)	Timing of onset of major costs (years)	Total cost of potential options to control rising groundwater (7%)	Cost of abandoning land and infrastructure (7%)	Recommendations
Brookton (60 yrs)	$0.618 m	4	$0.275 m*	$0.678 m	Improve water use efficiency, surface drainage and storage associated with groundwater pumping – re-use recovered and captured water (* assumes reduced need to purchase scheme water).
Corrigin (60 yrs)	$0.210 m	2	-$0.105 m*	$0.09 m	Continue to recover and reuse potable groundwater (* shown as a ‘negative cost’ because this is a benefit due to reduced need to purchase scheme water).
Cranbrook (60 yrs)	$0.611 m	22	$5.742 m evap $1.554 m ($2.251 m*)	$0.889 m	Implement tree planting. Relocate oval. Review need for sealed drainage and pumping in Year 10, based on groundwater trends (* if pumping and drainage implemented in Year 16)
Katanning (30 yrs)	$6.865 m	1	$7.609 m evap $3.422 m	$13.8 m	Improve water use efficiency, sealed drainage on the creeks and pumping now.
Merredin (60 yrs)	$0.384 m	26	$4.565 m evap $0.922 m ($1.827 m*)	$0.698 m	Improve water use efficiency and tree planting. Review need for sealed drainage and pumping in Year 10, based on groundwater trends (* if pumping and drainage implemented in Year 20).
Morawa (30 yrs)	$0.248 m	1	$0.900 m	N/A	Improve in-town surface drainage, additional tree-planting.

3 Conclusions

The findings from investigations in the six towns reveal that all will need to address issues associated with salinity and water impacts on private and public infrastructure. In most cases, dealing with these issues will require significant investment decisions to be made by the owners of public and private infrastructure over coming years. Key stakeholders in these decisions will be Local Governments, State and Federal Governments, and private and corporate infrastructure owners.

Beyond the specific issues to be addressed in the six towns, the study revealed a number of generic conclusions which are presented below as items for further consideration by the Rural Towns Program Management Committee.

3.1 The importance of locally-based recharge

In four of the six towns, local recharge within the townsite is a major source of groundwater rise. In these low-lying towns, groundwater beneath the towns has low rates of lateral flow through material of low transmissivity. The implication is that actions taken to reduce groundwater recharge higher in the catchment will have very little impact on groundwater behaviour below the town within time scales required to prevent damage. The corollary is that actions to prevent groundwater rise or to lower existing levels need to occur within or immediately adjacent to the townsite. These actions must include completion of sewerage systems, sealed drainage to remove surplus rainfall before it can enter the groundwater table, and promotion of wise use of imported water.

The exceptions are Corrigin, which lies above a fast-moving aquifer which recharges to the north-east of the town; and Morawa where damage to infrastructure is not caused by persistently rising groundwater. In both cases, preventing rainfall accumulation around infrastructure and infiltration within the town using improved drainage will help reduce damage.

3.2 Surface water management issues are significant in all towns

This study focused only on the predicted economic impacts of groundwater rise. However, expert observations revealed that management of surface water in all six towns is not sufficient to prevent damage to infrastructure. It is likely that some of the damage being experienced is being attributed erroneously to rising groundwater, when it is a result of poor domestic water management and a lack of sealed drainage. Examples include:

- discharge of roof run-off directly to ground adjacent to buildings; and
- run-off from hard surfaces being allowed to accumulate beneath and adjacent to buildings.

In all towns, improvements to surface water management at household and town scales must accompany any other actions taken to lower groundwater levels. This should occur as part of normal ‘best practice’ water management, independent of its relationship to local recharge.

3.3 Damage to public infrastructure represents the major cost to town communities

The study revealed that damage to public infrastructure, in particular to road pavements will represent about 60 per cent of the damage cost in towns subject to persistently rising groundwater tables. Where these costs are being experienced now (e.g. in Katanning), shires are required to spend funds in maintaining affected roads in serviceable condition. Conversely, householders, particularly those living in stumped houses, can repair and prevent damage with relatively modest investments.

The difference in cost burden between private and public infrastructure owners becomes significant in planning response to rising saline groundwater tables. Accepting continued damage as a strategy will impact largely on local government (for roads), with less impact on affected householders. Implementation of major infrastructure works to prevent groundwater rise, particularly integrated sealed drainage and pumping can only realistically be done by governments. The benefits to government will be in the prevention of damage to public infrastructure. In this case, householders will be ‘free riders’ unless they contribute to the investment costs, through differential rating schemes, for example. Shires in particular will need to develop rational and feasible ways of funding programs that either address or prevent damage.

3.4 The large variability experienced in the six towns

The groundwater and economic scenarios presented in the six towns vary greatly. In Katanning, the damage due to saline groundwater is immediate, covers a large area of the town and is imposing significant costs. Morawa is experiencing significant damage, but due to very different hydrological circumstances. In the case of Corrigin, the recommended actions being implemented – groundwater recovery and use, are simply re-establishing water management practices that stopped when scheme water reached the town in 1960.

The extension of this conclusion is that generalisations about situation and options are dangerous. Towns will need individual investigation and advice in determining the most appropriate course of action. Without specialist professional input, affected towns are unlikely to grasp the necessary integrated approach to urban water management that is needed. In addition, the issue of social impacts has arisen several times but it was outside the scope of this study – yet it is likely that the social implications of decisions made about resource allocations will be of great importance to elected shire officials and responsible government agencies.

3.5 The need for accepted 'best practice' in managing the impacts of rising groundwater

Various approaches are used currently by private and public sector owners and organisations to manage water damage. These include:

- 'do-nothing', thereby allowing infrastructure to depreciate, sometimes in line with property values;
- short-term patching and repair of masonry and road surface, and replacement of stumps as required;
- major re-building of road surfaces and land build-up on 'wet' blocks; to enable building on the site;
- drainage around buildings, including use of reverse leach drains in wet areas;
- accelerated installation of sewerage systems;
- drainage within towns, sometimes using the roads as shallow drains; and
- trial pumping schemes, as in Merredin and Katanning.

Overall, there is no consistency of approach, or consideration of salinity and water impacts as an identified separate cost. Decisions on damage management appear to be mainly driven by personal preference, traditional behaviour and budgetary considerations. This made determination of realistic damage management strategies for use as standards in the costing difficult, with the information shown in Annexes 5 and 6 being a combination of engineering best practice (determined by the Team's Engineer and Architect-Builder) and current behaviour. It is apparent that if damage management is to be used as an on-going strategy, additional work should be done in defining the best approaches.

3.6 The importance of integrated water management

Although this project focused on the economic impacts of rising saline groundwater, it became clear during the course of the study that it is difficult to investigate this issue in isolation from all other aspects of water management in rural towns. This is evident in the some conclusions presented above and in the recommendations for the individual towns in Section 2. To address the totality of water management requires attention to a very wide range of technical, economic and socio-political issues, with examples as follows:

- The cost of imported water, although more expensive in country towns than in the metropolitan area, is still charged at less than the cost of delivery. The balance is contributed as a cross-subsidy by metropolitan consumers.
- Balanced against the cost of water provision, is the social and political value of water in rural towns in creating a living environment that is more attractive to residents. This needs further exploration.
- A focus on water management for domestic and commercial purposes that reduces local recharge through the elimination of septic systems, connection of household and public hard surface run-off to sealed drainage systems, modifications to artificial wetlands within towns, and more sensible garden and park watering.

- The development of a rational basis for sharing the cost of improved surface and ground water management between public and private sectors.
- Increased research and development into the use of saline groundwater for industrial and commercial purposes. Suggestions include recovery of potable water via desalinisation, aquaculture, commercial salt harvesting, and electricity generation.

4 Recommendations

Individual recommendations for actions in the six towns are presented in Section 2.

Other towns in the Rural Towns Program that have completed detailed hydrological investigations and modelling should be encouraged to apply the USEAP economic analysis to their local situations.

5 Bibliography and acknowledgments

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Annex 1

Definitions used in the study

This report includes a number of terms that have a particular meaning in the context of this study and the economic assessments undertaken. The important terms are defined below.

Infrastructure

Infrastructure as described in this report refers to all classes of buildings and constructions within and immediately adjacent to a townsite. It includes all classes of privately owned infrastructure, such as houses, motels and hotels, offices, churches, factories, storage facilities and service stations. It also includes all publicly-owned facilities such as Local, State and Commonwealth Government buildings and facilities; roads, railways lines, communication and power networks, water and sewerage lines and sport and recreation facilities. Finally, the analysis also considers the value of vacant land that may have its potential uses altered by rising groundwater tables.

Groundwater model

The data for predicted shifts in groundwater levels is generated from a Groundwater Model. The Model uses data inputs such as catchment size and slope, rainfall, known geology, known depths to groundwater and information on the permeability of the soils and then computes the most likely trends in groundwater behaviour in the future. The output from models, often called ‘simulated data’ is compared to actual information to confirm the validity of the simulations.

In this situation, there is a good match between recent trends in groundwater levels and the predictions made by the Model. On this basis, the Model has been used to predict where groundwater levels will be in a townsite over the next 30 years. Output from the Model **predicts** where the groundwater table will be for all parts of the town for each year up to 2030 under a ‘do nothing differently’ scenario.

While the Model represents the best prediction that can be made at the current time and with current knowledge, it must be STRONGLY emphasised that it is ONLY a prediction. As with any prediction, there is inherent uncertainty in determining where groundwater levels may be over the coming years. Interpretation of the maps showing groundwater contours over the coming years must recognise this uncertainty. This qualification extends through to the interpretation of the economic costs of rising groundwater, in particular the individual costs for maintenance shown in Annexes 5 and 6.

Damage costs

The damage caused by rising groundwater and observed salinity are the impacts upon the infrastructure as it comes in contact with these phenomena.

'Damage costs' is the term used in economic studies and in this Report for the costs associated with maintaining the condition and functioning of these infrastructure items in the face of damage caused by water and salinity factors. These costs are referred to in places under the 'do nothing differently scenario' being the maximum level of the costs if nothing is done in a coordinated way to prevent the predicted rise in groundwater. Most importantly, investment to address the damage caused by saline groundwater symptoms does not attempt to slow or prevent the rise of groundwater rise and is thus equivalent to the 'do nothing differently' cases presented in the hydrological modelling (Jay Matta *pers. comm*.).

These costs are presented in two ways in this study.

- The normal approach assumes that as groundwater rises towards the surface, an increasing array of costs are incurred to maintain the infrastructure in a useable state. The groundwater will continue to rise until it reaches an equilibrium point where it is less than 0.5 m of the surface over parts of the town. Although this area will then be subject to 'chronic dampness', owners of infrastructure located in this area can choose to continue *to meet the costs of maintaining the infrastructure into the long-term*. This approach has been observed in a number of towns and methods to cope with chronic dampness are used by owners of both private and public land and infrastructure.
- The alternative, more radical approach, is to elect to *abandon the infrastructure* at some point after the watertable is at or near the surface – or at the point of 'chronic dampness'. Abandonment may be prompted by increased observable surface salinity as a consequence of evaporation of the saline groundwater as it discharges, or by a judgement that the costs of staying are higher that the costs of relocating. In this study, the cost of abandonment is presented as an option at a point in time 10 years after the site becomes chronically damp (groundwater less than 0.5 m). The reasoning is that if surface salinity is an issue at the site, then at this point, it can be argued that normal salt-susceptible gardens will no longer be viable and the site will be increasingly unattractive. Calculating the cost of abandonment uses the '*terminal values*' of the infrastructure and land being abandoned. These costs are calculated as the current market value of those assets and hence reflect demand for land and buildings in the town.

The analysis in this study addressed both types of cost, but with a focus on the former, given that there is no evidence from towns that already have chronically damp areas that abandonment has been considered seriously as an option. For instance, the Ministry for Housing will continue to undertake normal maintenance on existing houses, doing modification to drainage and sewerage to handle the continual waterlogging of the site. It will also build on damp sites by increasing block height to RL600 mm for the concrete pad for new buildings. This suggests that the problem of chronic dampness can be tolerated.

Given this situation and the absence of any obvious formal concern by either State or local governments about the prospect of wide-scale abandonment, it is considered that the total abandonment cost, being the loss of all land and building asset values, represents a cost that is unlikely to be incurred in full. Thus the figures for terminal values are presented mainly for comparative purposes and to support the conclusions and recommendations. It is not recommended that they be used alone to justify actions to address the causes.

Control costs

The cause of the damage is the rise in the saline groundwater table beneath a townsite – a rise measured typically measured at approximately 0.1 to 0.2 m per year.

'Control costs' is the term used in economic studies and in this Report for the costs associated with preventing the rise of the groundwater table, so that the symptoms themselves do not occur. Preventing groundwater table rise can be done by reducing imported water use in the town; reducing the amount of water leakage from pipes; completing sewerage connections; removing surplus water before it can recharge the system through sealed and lined drainage; and direct abstraction of water from the soil profile and groundwater table.

The analyses presented in this report consider the two scenarios of 'damage costs' and 'control costs' separately. It does not investigate formally the trade off between the two in a quantified sense. However, trade-offs are discussed qualitatively in the individual town reports and in the summaries in Section 2.

Zones

As presented in the hydrological models, the first symptoms of rising groundwater will be seen at different times over coming years for different parts of the town. Similarly as shown in Annexes 5 and 6, the impacts of groundwater tables will be different for different classes of infrastructure. To handle this complexity and to ensure a clear analysis of the cost of coping with the symptoms, the towns in this study have been subdivided into between 100 and 300 zones, as described in Annex 3.

In this report, a **'zone'** is described as:

- a discrete piece of land supporting one type of infrastructure;
- with a single set of actions to address the symptoms; and
- a unique timetable for the rise of groundwater to critical depths when the symptoms will be first observed.

Each spatial zone must:

- be sufficiently small that all the items it contains are likely to experience the *same trajectory of groundwater rise over time*; and
- contain land, buildings or infrastructure that will incur the *same types of damage cost over time*: in practice this mean that the contents of the zone must be homogeneous in terms of (a) physical characteristics and importantly (b) property values.

Details of the methodology for establishing zones is given in Annex 3, and a visual example is provided in **Figure 3**.

Thus, zones may be as small as individual properties such as a hotel or service station, or as large as several blocks containing up to 100 houses. Some infrastructure items such as a major road may be segmented into a number of zones, in recognition of different groundwater depths along the length of the road. Examples of zones include:

- A block of 10 houses on stumps where the watertable will be at 3.0 metres in 10 years, 1.5 metres in 20 years and 0.5 metres in 30 years; and
- A brick and tile church where the watertable will be at 3.0 metres in 20 years; 1.5 metres in 30 years; but where the groundwater table will not rise to 0.5 metre.

Benefit-cost analysis

This technique is widely used in business and government to assist in choosing between different options for investment. Benefit cost analysis considers the impacts of action or inaction on all sections of society in terms of the difference made to their incomes or outlays.

Benefit cost analysis is well suited to comparing different scenarios where the income and cost streams are different and occur over many years. For this reason it is a common tool used in helping decision makers in the management of natural resources where there may be long time lags between making an investment and receiving a return.

Essentially the approach taken is to ‘discount’ the future flows of incoming and outgoing dollars to their ‘present value’. Present value is the amount that would need to be set aside now to provide the future income or to cover the future cost. This applies even in an inflation-free economy, because investments yield income (see below for further notes on discounting). Options can therefore be compared using their net flow of current dollars. This is a simple way of seeing whether a proposal has a net positive benefit, or a net negative benefit.

The **benefit-cost ratio**, is simply the ratio of the benefits to the costs. This is a useful way of comparing alternative management actions that have similar levels of cost outlays. In this study the discounted costs of damage due to groundwater and salinity impacts are compared with the discounted costs of alternative approaches for ground and surface water management in each town. The benefits of the various water management plans are the averted damage costs (and ‘defensive’ costs) resulting from shallow groundwater if nothing is done to control groundwater tables. The analysis assumes that if the prescribed groundwater control actions are implemented, then all of the costs associated with damage from saline groundwater rise will be eliminated.

Figure 3: Example of a typical zone –residential housing on stumps

Other criteria may be used to supplement the benefit cost analysis: for example there may be an unequal distribution of benefits and costs (equity criterion), or there may be social and environmental impacts that have not been expressed in dollar terms in the benefit cost analysis. In this study equity, social and environmental consequences are noted where relevant, but are not costed within the benefit cost analysis.

Discount rates

Under normal circumstances, a person or institution has a preference for receiving a dollar today as compared to receiving a dollar at some time in the future. In this sense, the person is 'discounting' the value of that dollar in the future. Similarly, a person who has to spend funds in repairing infrastructure affected by rising groundwater will prefer that requirement to occur later rather than sooner (assuming that the delay does not create extra costs). In that situation the 'cost' of the investment is more significant now than if it can be delayed to a later time.

The term used to indicate this time preference for income is the **discount rate**, which is expressed as a percentage by which a dollar is discounted each year into the future. The full title for this term is the *'nominal discount rate'* which does not include any adjustment for actual or predicted cost inflation. Nominal discount rates are the preferred way of making a comparison between two flows of costs that extend into the future for several years – as in the situation where groundwater will reach certain levels at different points in time in different parts of the town.

The so-called 'real discount rate' includes the factor for time preference adjusted for the inflation rate. However, because the inflation rate is unpredictable into the future, it is impossible to define a real discount rate for this type of analysis.

Deciding on the nominal discount rate to be used can be difficult. In this analysis two discount rates have been used - 7 per cent, which means that the cost/value of one dollar in 2000 is equivalent to a cost/value of 93 cents in 2001 and 4 per cent, which means that the cost/value of one dollar in 2000 is equivalent to a cost/value of 96 cents in 2001 and so on. To determine the effect of the discount rate on an analysis of future costs, 'sensitivity analyses' can be used to compare the effect of using different discount rates. An alternative approach is to compare projects on the 'internal rate of return' – calculated as the discount rate that would apply to make a future stream of income exactly equal the stream of projects costs.

On advice from the Rural Towns Program Management Committee, the analysis in this report focuses on a ***discount rate of 7 per cent*** as being the normal rate used by government in making decisions about investment in public infrastructure.

Discounted costs

Applying the discount rate to an investment that consists of a stream of future costs can be used to convert that stream to '**discounted costs'**, showing how the impact of those costs declines over time. These discounted costs can be aggregated into a single term, being the 'present value of cost' of the investment. Similarly a flow of benefits that is anticipated over many years can be discounted and aggregated into a 'present value of benefits'. A simple example of two discounted streams of costs is shown in Table A1.1.

Table A1.1: Example of discounted costs (with a discount rate of 7 per cent)

Example	Cost type	Present value of costs	Year cost incurred			
			1	2	3	4
1	Current $	$100	$10	$10	$40	$40
	Discounted $	**$86.07**	$10	$9.30	$34.60	$32.17
2	Current $	$100	$40	$40	$10	$10
	Discounted $	**$93.89**	$40	$37.20	$8.65	$8.04

As shown above, the effect of using discounted costs is to show that costs that can be delayed (as in Example 1) have a lower present value than where those costs are incurred sooner.

Calculating the present value of the costs shows how much money has to be put away in an interest bearing deposit now and withdrawn when the expenditure is actually made. In Example 1 in Table A1.1, the cost of the four-year program will be met by investing $86.07 at 7 per cent compound interest now, with withdrawals made over the coming four years. Additional information on the economic principles underlying the study is given in Annex 4.

The level and timing of damage costs

Because future costs are discounted as described above, delayed onset of damage will reduce the present value of costs and the amount of investment warranted in controlling groundwater rise. Therefore, the two critical issues in deciding the nature of intervention necessary to control the rising groundwater tables are the level and timing of the damage costs incurred in the absence of action.

For instance, where damage costs are high, but do not 'kick in' until 15 years into the future, decision-makers can afford to delay expensive intervention until closer to the time when most of the costs begin to be incurred. Being able to delay taking action to limit groundwater rise will reduce the present value of control costs. Conversely, in towns where damage costs will be incurred over the next few years, an early decision is required about the best means of addressing them.

Annex 2

Summary of the methodology

The conceptual approach

The conceptual approach to the analysis involved estimating the economic cost of **damage** alone, without any consideration given to actions that would control the cause of the damage – that is, actions that will lower the groundwater table. The total discounted **damage cost** was then compared to the total discounted costs of groundwater **control** methods, using the 7 per cent discount rate. Using the total damage cost as a benchmark, and given the amelioration objective, the most cost-effective mixture of control methods was determined in removing completely the impact of saline groundwater on infrastructure.

An overview of the methodology

An investigation of the economic costs of salinity and rising groundwater tables and the benefits of abatement on rural infrastructure in the six towns was undertaken using the following methodology:

- development of groundwater models for each town by Agriculture Western Australia, which map estimated groundwater depth within a town (at 0.5 m, 1.5 m and 3.0 m contours) and predict changes in groundwater depth over a 30-year period, under current (or 'do nothing differently') water management practices, across the townsite;
- mapping the townsite, by dividing the townsite into zones of similar groundwater depth and infrastructure characteristics, and quantifying the infrastructure, buildings and grounds within each zone, including sub-surface items such as storage tanks, swimming pools, cellars, water and sewer pipes, and telecommunications cables;
- estimating general infrastructure, land and property damage costs as a function of salinity and rising groundwater;
- identifying the critical groundwater depth for the different types of infrastructure;
- identifying the times at which zones will fall within critical groundwater depths, by superimposing the groundwater depth maps onto the townsite map;
- applying benefit-cost analysis (BCA) to estimate the discounted costs of addressing salinity and rising groundwater tables for each zone within the townsite over a thirty-year period;
- summing the discounted costs for each zone, to identify the total **damage costs** of salinity and rising groundwater tables for the town;
- Separately calculating abandonment costs for infrastructure items and land 10 years after the time when the groundwater table reaches 0.5 m below the surface;
- quantifying the costs of a groundwater/surface water management plan that prevents groundwater tables and salinity from impacting infrastructure within the townsite – the **control costs**;
- using the damage costs as a benchmark in determining the most cost-effective method of removing the impact of rising groundwater and salinity on the infrastructure, and

- drawing conclusions and making recommendations for action by the Rural Towns Program and the community.

Figure 4 describes the sequence of steps required to conduct the analysis. The following section gives a summary of the key points that arose in implementing the methodology. Further discussion of zoning and valuation principles can be found in Annexes 3 and 4.

Groundwater modelling

Hydrogeological analysis and modelling of the catchment for each town was necessary to test various scenarios that could help to predict the impacts of salinity and rising groundwater tables upon the town. While these predictions are the best available, they must be interpreted with caution.

Local steady state and transient models were developed for each town, using the following data: borehole and piezometric levels for the townsite and within the catchment; borehole and piezometric coordinates and elevations; topography; climatic data; geology; and aquifer properties.

Establishing the inventory of infrastructure in each town

Establishing a comprehensive inventory of the infrastructure within the townsite boundary required the following actions:

- The cadastre for the townsite was obtained from each Shire and from the Ministry for Planning;
- Aerial photography (1:25,000 scale) was obtained from the Department of Land Administration; and
- On-ground inspection noted the type of infrastructure located on every individual land tenure location within each townsite.

Categorising infrastructure

To enable infrastructure to be allocated into discrete zones, it has been categorised according to the investment required to address the symptoms. These categories are:

- residential (two categories – on stumps, or located on a concrete pad on the ground);
- industrial (two categories – on stumps and on a concrete pad on the ground);
- automotive service/repair structures with underground tanks;
- wholesale including gas distribution depots;
- shops and commercial buildings (two categories, on stumps, or located on a concrete pad on the ground);
- Public buildings (unique zone for each one - town hall, swimming pool, theatre, churches etc.);

Figure 4: Methodology used in the study

- hotels/motels (with and without cellars);
- roads (two categories – sealed main roads and sealed roads within the townsite);
- water supply infrastructure;
- sewerage infrastructure;

- electricity distribution lines;
- railways;
- parks, recreation and sporting areas; and
- vacant land.

Valuing infrastructure

Infrastructure was valued using documentary sources, discussion with Local Government and State Government officers and direct inspection.

Documentary sources

Information on private property sales in the six case study towns was obtained from the Valuer General's Office: this includes data on sale price, land area and structures placed on the land. Statistical analysis was used to develop reliable estimates of (i) vacant land and (ii) buildings of different types. This information was then used to develop a total dollar value of the stock of land and buildings within each zone in the townsite (see below).

Discussions with the owners of significant infrastructure items

Interviews were held with officers from each Shire, the Water Corporation, Westrail, Main Roads Department, Western Power, Telstra, Cooperative Bulk Handling Pty Ltd, Ministry for Housing and local machinery dealers.

On-ground inspection

The six towns were inspected by an engineer with experience in flood management and mitigation, and an architect-builder with experience in property repair and maintenance issues in a variety of WA locations. They determined the extent and causes of observed damage and need for repair and maintenance.

Establishing zones

The data obtained as described in previous sections was used to establish zones across the townsite using the definition given in Annex 1.

All townsites were divided into zones of similar groundwater depth (in year 1) and infrastructure, building or surface characteristics (e.g. residential housing on stumps, vacant land, church site, school, parkland, highway, railway etc.).

Between 100 and 300 zones were defined for each of six towns, with the variation in number depending on the size of the town and the complexity of the predicted groundwater scenario. Linear features such as roads and the railway reserve were divided into segments and each segment became a separate zone. Isolated commercial buildings and social infrastructure such as churches, sporting clubs, hospital, schools etc were identified as individual zones.

Critical groundwater depths

Depth to groundwater is the parameter used to identify the onset of damage to infrastructure (including buildings) and costs resulting from groundwater inundation of land surfaces within the townsite. Consequently, the number of years predicted for groundwater to reach 0.5, 1.5 and 3.0 m below natural surface (BNS) has been estimated for each zone. For example, in Zone 40 (residential housing on stumps) it is predicted that the groundwater is already within 3.0 m of the ground surface, and it will be within 1.5 m in one year, and within 0.5 m in two years. In zones where it is predicted that the groundwater will not reach a specified groundwater depth (e.g. 0.5 m) within the time period of the analysis, 1000 years has been specified.

The impact of the rising water and salinity is determined by estimating the cost required fix any damage caused by exposure to the rising water and by salinity. This has been done for three identifiable levels of the saline watertable, which are linked in this case.

In general, when the groundwater depth is greater than 3.0 m BNS, damage to most infrastructure will be zero or minimal. When groundwater depth is 1.5 m BNS, costs will be incurred for repair to some damaged infrastructure. These costs may differ, depending on the type of infrastructure or site damaged. And when the groundwater is within 0.5 m of the ground surface, high costs to treat damage are likely to result, with eventual abandonment and relocation costs a possibility.

These critical groundwater depths to the onset of costs will differ depending on the type of infrastructure. For example, sub-surface structures such as underground petrol storage tanks, below ground pools, and cemeteries will be affected by rising groundwater tables sooner than structures that are on- or above-ground such as commercial buildings, playing fields, and railway lines.

Estimating the damage costs of rising groundwater

Three ways of valuing the costs of coping with the symptoms of rising groundwater tables were utilised, depending on the particular item. Full details on all the per item costs are given in Annexes 5 and 6.

Controlling groundwater rise

It is clear from the hydrological information that the cause of the rising groundwater is principally generated within the boundaries of the townsite. Put simply, excessive recharge of the groundwater table beneath the townsite is being caused by stormwater infiltration from surrounding farmland, from roads and buildings and perhaps from water imported for domestic gardens and public parks. Therefore the focus on reducing groundwater table rise must be on actions taken within the townsite and particularly within those areas that will experience symptoms of rising watertables within the next four years.

There are three general options to control groundwater rise within a townsite:

- Reducing the amount of imported water available to enter the groundwater table (more efficient use of water within the town);

- Intercepting the water before it is able to recharge the groundwater (use of improved stormwater drainage and trees); and
- Removal of water from the groundwater table below the areas of town most endangered over the next four to twelve years (pumping).

A summary of underlying assumptions in the methodology

The methodology used is based on a number of fundamental assumptions, some of which are presented in earlier sections. Others are implicit in the methodology and are not spelled out in the preceding sections. To help with interpretation of the findings presented in subsequent sections, these implicit assumptions are summarised in the following points.

- Damage and control costs remain constant in real terms over the life of the assessment (30 to 60 years).
- Damage costs are equal at all places within an individual zone. This ignores likely differences between the damage to separate infrastructure items within a zone due to variations in the micro-relief across the zone. The exception is in estimating road damage costs, where damage is assumed to affect only one third of the road pavement in any zone.
- Damage costs are uniform within the various categories of infrastructure across all towns. Thus the cost of maintaining a sporting ground in one town is the same as in all the others.
- The control costs assume existing technology, particularly in the area of use and disposal of abstracted saline water. Investigating the possibilities of reducing the costs associated with saline water management through desalination, aquaculture and salt harvesting is recommended where relevant.
- The only comparison made between damage and control costs is between the two extremes – acceptance of full damage costs in the ‘do nothing differently’ scenario on the one hand, and control of all groundwater impacts on the other. The assumption is that the control technologies proposed are fully effective in preventing any damage.
- In undertaking sensitivity analysis, the advice from the Agency hydro-geologist was that it was not valid to use the groundwater model to demonstrate spatial sensitivities in groundwater behaviour. Instead, sensitivity was demonstrated using variations on rates of groundwater rise.
- Tax implications of costs and investments are ignored.

Annex 3

Definition and characteristics of zones in the townsites

Conceptual basis

In the economic model spatial zones are used to identify each item that is likely to experience similar cost impacts over time. An item is any piece of land, building or infrastructure in a townsite, or a spatial grouping of any of these. Spatial zones are used for both below-ground and above-ground assets.

Each spatial zone must:

- be sufficiently small that all the items it contains are likely to experience the *same trajectory of groundwater rise over time*; and
- contain land, buildings or infrastructure that will incur the *same types of damage cost over time*: in practice this mean that the contents of the zone must be homogeneous in terms of (a) physical characteristics and importantly (b) property values (for example two adjacent areas of similar brick houses might be put into two separate zones if one faced a busy highway and had low property values, while the other was located further away and had higher property values).

Thus, zones may be as small as individual properties such as a hotel or service station, or as large as several blocks containing up to 30 houses. Some infrastructure items such as a major road may be segmented into a number of zones, in recognition of different groundwater depths along the length of the road.

Provided that the whole townsite is zoned, the total area of surface zones equals the townsite area. However, additional zones may be created to account for items such as sub-surface utility services or local roads: the area of these zones is additional to the townsite area.

Practical guidelines for zoning

It is difficult to set out precise rules for zoning, beyond the two requirements noted above, as judgement is required in many cases. As a general rule it is safer to err on the side of having a large number of small zones, than to risk having zones with too wide a spread of expected groundwater depths, or assets which vary in nature or value.

It is recommended that the town planning scheme map should be used as the starting point. A street-by-street survey should then be conducted to identify the contents of each block. The list of land uses should be used by the surveyor to mark the contents of each block, down to the nearest lot. It was found that between a day and half a day was required to complete the street-by-street survey for each town.

Once the town planning scheme map has been marked up, zones should be delineated using the two criteria given above. At this stage it is useful to draw onto the map the 1.5 m groundwater contours expected at five-yearly intervals. This is useful for identifying zones which should be further sub-divided or re-aligned if the first-pass zones based solely on their property values, buildings and infrastructure were not homogeneous with respect to expected rates of rise of groundwater. An alternative approach is to use GIS technology to match zones to groundwater depths.

Quantifying the contents of zones

Different units of measurement are recommended for different types of zones. The three main units used are:

- *number of properties*: used for residential housing, groups of similar shops or offices, individual properties such as service stations, motels, sporting clubs;
- *length*: used for linear features such as roads, rail reserves, concrete drains, underground cables; and
- *area*: used for vacant land, parks, sporting grounds etc.

The cost budgets (see Annexes 5 and 6) are expressed in terms of dollars per unit of the zone's contents. For example, the costs of re-stumping houses are expressed as dollars per house, which when multiplied by the number of houses in a zone gives expected total costs in that zone. Similarly, road repair and maintenance costs are expressed as dollars per kilometre, which yields total costs when multiplied by the length of road affected. If the zone contains just one item, e.g. a service station, then the cost budget equals total costs for that item.

Annex 4

Valuation principles

Conceptual framework

Overview

In its simplest application, the economic model developed for this assessment compares:

a) the 'damage costs' which might be expected to be incurred if nothing new is done to slow the rate of rise of groundwater beneath a town, with

b) the costs of alternative groundwater management plans, termed 'control costs'.

In further applications different levels of damage cost that are associated with different control plans may be compared, and a trade-off struck between the levels of control costs to be incurred and the possible level of damage costs averted.

Damage costs

Damage costs are the capital and operating costs incurred by industries, public organisations, utilities or private households as a result of rising groundwater. Put another way they are the costs of dealing with (or imposed by) the impacts of shallow groundwater. They include:

- costs of coping with intrusion of shallow groundwater into facilities: for example pumping out of cellars, replacement of septic tanks or additional sewage treatment costs if there is intrusion of saline groundwater into sewers;
- costs of coping with physical displacement or de-stabilisation of assets, for example lifting underground tanks or swimming pools, by provision of additional weight to the structure e.g. concreting the retaining ground surface;
- costs of coping with waterlogging such as construction of on-site drains around buildings;
- additional costs of repair or replacement of physical assets: for example more frequent and higher-cost road stabilisation, more frequent renewal of saddle tappings on water supply pipes, replacement of rotting wooden poles and stumps, repair of distorted floor boards, repair of cracking masonry or deteriorating mortar, more frequent re-painting of house interiors;
- loss of amenity, such as waterlogged vegetation, parks or sporting ovals;
- loss of land from urban use if inundation occurs.

Control costs

For the purpose of this project, only those actions which change the underlying groundwater state are classified as 'control' actions. Put another way, they are the costs of directly addressing the *causes* of shallow groundwater. These include actions such as physical groundwater pumping, tree planting (another form of pumping), recharge reduction through better management of surface water, and combinations of these actions.

Valuation principles

Capital and operating costs of combative measures

Market values of the required equipment, materials, fuel and labour for repairs, maintenance, replacements, pumping, and surface water management described above are an accepted measure of economic cost. Market values generally reflect the opportunity costs of these economic resources. Exceptions may occur where there are market distortions: for example fuel subsidies or wage levels that are artificially high in the presence of unemployment. However, in comparison to other types of error associated with the study estimates it is judged that it is not necessary to modify market values for these items.

Loss of land and buildings

Valuation issues may arise with respect to the possible loss of land as a result of site waterlogging, if owners of infrastructure choose not to remain on the location. Assuming that the land would no longer be suitable for any use there are a number of ways of valuing the loss:

- *market value of the land that has been lost*; this can be taken as a measure of society's willingness to pay for the services provided by the land;
- *cost of replacing the lost land with alternative equivalent urban land*: this would include the market value (i.e. opportunity cost) of the replacement land in its alternative use such as agriculture plus the costs of land servicing, if required, and
- in the case of public land e.g. parks or reserves, the cost of waterlogging can be measured by a survey of *the community's willingness to pay* for use of the land in its current state.

For the purposes of this study, market values of land have been used, because there is both theoretical justification and because data on land sales values are available from the WA Valuer General's Office.

A similar set of choices about valuation method apples in the case of buildings that may become untenable because of site waterlogging if nothing is done to manage groundwater. The alternative approaches to valuation are:

- *market value of the building that has been lost*: this measures society's willingness to pay for the asset in question. Market value includes land value, but it is unlikely that a building would be completely lost without the land on which it stands also becoming untenable. This appears reasonable for residential properties. However, in the case of commercial sites such as, for example, shops, showrooms, warehouses or service stations, market value will often include an element of goodwill for the business that is being acquired along with the real estate. It is arguable that site waterlogging would not eliminate the goodwill of a business that could be re-established in new premises somewhere else in the town. Therefore, market value of the site would overestimate the economic cost of waterlogging.

- *replacement value*: this is the cost of providing alternative newly-constructed accommodation. The problem here is that the building that is being replaced may be old or sub-standard, whereas the replacement building would be new, so in practice the replacement value would differ from the market value of the property that had been waterlogged. However, it can be argued that in the absence of rising groundwater the economic resources needed for building replacement would have been freed for other purposes, and that there are not any additional, obvious benefits to the owners from the replacement premises.
- The chosen valuation method makes no allowance for future depreciation in the values of infrastructure during the thirty year projection period. The rationale for this is that while physical depreciation is likely, it is also probable that owners will make good the depreciation. Therefore, the best assumption that can be made for the projection period is that the physical condition and value of infrastructure in terms of year 2000 dollars will be maintained unless damaged by shallow groundwater.
- In the case of waterlogging of land with buildings on stumps, for example houses or offices, it is often feasible to transport the building to another location. In this case the market value of the replacement land plus all costs of relocating the building may more accurately reflect the economic costs.

For the purposes of this initial study, market values have been used for all residential buildings. For commercial buildings, replacement cost plus market value of an alternative site has been used as the basis for costing.

Discounting

All costs are discounted by the number of years from the present that they are expected to be incurred. The rationale for this is that (a) if the real rate of return to investment in the economy is positive then investment of a *smaller* amount now will create an income stream which will provide the required resources to cover the *full* costs in future and (b) independently of investment yields, society has a preference for receiving benefits earlier rather than later, costs later rather than earlier.

The formula for discounting costs is:

$$C^* = C_t / (1 + r)^t$$

where:

C* = discounted, or 'present' value of the cost

Ct = cost at the time it is incurred

r = percentage rate of discount divided by 100 (e.g. .07 for 7% discount rate)

t = time, in years from the present, when the cost will be incurred

While there has been general agreement about the theoretical correctness of discounting future costs and benefits, there has been much debate in the economics literature about the selection of an appropriate rate of discount. One school of thought suggests that in evaluating the net benefits of public investment (in this case the costs of implementing a groundwater management plan) it should be assumed that the resources used in a project could have been given to private investment and earned a real rate of return that is obtainable in the private sector. At the time of writing this would suggest a real rate of return, allowing for the inflationary effects on market interest rates, of around 7 per cent.

Another school advocates the use of a 'social' rate of discount, which is based on government or community rates of trade-off between the present and future. This rate of return is generally lower than the private market rate: around 4 per cent at the time of writing.

The Rural Towns Program Management Committee prefers the higher discount rate, which has been used in drawing conclusions and making recommendations for all six towns.

Annex 5

Costs of construction, maintenance and repair of roads located above shallow groundwater

This note is based on Wallace's advice to the Murray-Darling Basin Commission (MDBC, 1994), and other findings of a consultancy undertaken on road costs in irrigation areas. Wallace provides a summary of the principles involved in Australian road design, with particular reference to the control of moisture conditions.

General principles

It has been possible to construct roads in Australia at a fraction of the cost of equivalent roads in Western Europe and North America, by controlling water entry into the pavement and the underlying sub-grade soil, and taking advantage of deep groundwater tables and often infrequent rainfall, which limits the problem of infiltration of the road surface. According to Wallace, water is the single factor that has the greatest influence on the strength and stiffness of soils and road-making materials. If Australia's low-cost pavements wet up above their design moisture condition they deteriorate rapidly under continuing traffic.

Wetting processes and their effects on pavements depend on complex relationships between hydrology, soil type and pavement materials. Wallace suggests the following limiting values shown in Tables A5.1 and A5.2.

Table A5.1: Indicative depths to groundwater at which the permanent watertable begins to affect sub-grade moisture condition (rising groundwater), depending on soil type

Soil Type	Depth (m)
High plasticity clay	6
Low plasticity clay	3
Clean sand	1

Queensland Department of Transport (1992) indicates the following values of capillary rise of water above the watertable.

Table A5.2: Indicative heights of capillary rise for different soil types

Soil type	Capillary rise (m)
Clay	2.0 to 4.0
Silt	0.7 to 1.5
Fine sand	0.35 to 0.7

Hysteresis, (the asymmetric response of moisture in the sub-grade and pavement to falling groundwater table versus rising groundwater table), means that lowering the watertable may have a lagged effect on moisture within the road pavement and sub-grade soil. After lowering the watertable it is necessary to rely on evaporation from the capillary zone to ensure a return to drier conditions within the pavement and sub-grade soil. This can take 3 to 5 years for a sealed pavement on a plastic clay sub-grade. The process is assisted by vegetation planted near the roadside.

Where the watertable is 1.0 m or less from the surface the Queensland Department of Transport (1990) recommends that the sub-grade be assumed to be 'soaked'. The 'CBR' value may then drop to a third of the unsoaked condition in high-plasticity clay and to about two-thirds for silty sand. (The CBR value measures the bearing strength of the sub-grade or pavement material.)

Pavement Condition and Remedial Actions

The condition of a pavement is described in terms of various types of distress. These include:

- Roughness (riding quality)
- Rutting
- Patching
- Potholing
- Cracking
- Edge breakage
- Flushed or stripped surface texture.

When any of these reaches a critical level the following actions may be undertaken:

- Repairs or patching for potholes and edges;
- Re-sealing for roughness;
- Asphaltic concrete overlay for cracking or surface texture deterioration;
- Stabilisation of the sub-grade, usually with cement or lime; and
- Reconstruction usually with raising of the level of the road formation and sometimes with addition of a geotextile, which allows the road to 'float' on moist and swelling clay.

Due to great variability of soils at a local scale the response of a road to a shallow groundwater will be patchy: some sections will degrade more rapidly than others, and the rate of decay is uneven over time, with marked changes in road performance occurring suddenly.

Thus, only a proportion of the total road length will need to be repaired or re-constructed at any time, and it becomes a matter for judgement whether to reconstruct over a long distance, probably with formation raising, or to bear higher intermittent repair costs. Often, the limited availability of funds dictates that the higher intermittent repair strategy is adopted

The average length of service life of sealed roads in Victorian irrigation areas with watertables of 2.0 m or less was reported to be around 20 years compared with 40 years for equivalent roads in dryland areas over deep groundwater tables.

Cost Estimates

Table A5.3 contains a number of estimates of roads costs, which were presented in MDBC (1994).

Major State Highway

New road construction in 1994 was estimated to cost $390,000/km for a major highway, the Riverina Highway. This figure is comparable to an estimate of around $400,000/km quoted in a consultancy report to the WA Main Roads Department by the Australian Road Research Laboratory. Such a road would be expected to have a lifetime of around 40 years under normal conditions (i.e. with design loads and a continually dry sub-grade).

The additional construction cost for such a road, where there were difficulties with shallow groundwater of less than 2.0 m, was estimated to be from $71,000/km to $115,000/km. It was not made clear what the life expectancy of such a road would be, though it was mentioned that the smaller sealed roads in NSW and Victorian irrigation districts have a life expectancy of 20 years rather than 40 years.

Repair costs for a major highway, due to shallow groundwater, were estimated to be $10,000/km/year.

Standard Sealed Country Road

Estimates given in MDBC (1994) suggest a figure of around $100,000/km for the cost of new construction of a major sealed country road, with an additional $25,000/km to $35,000/km in additional construction cost under conditions of shallow groundwater tables.

Such a road would normally have a maintenance cost of around $2,500/km/year, which would be increased by $400 to $2,900/km/year where there was a shallow groundwater table. For minor sealed country road the additional maintenance cost due to shallow groundwater would be $300 on a normal base of $1,500/km/year.

Gravelled Roads

A construction cost as low as $7,000/km is quoted, with an additional $3,000/km for shallow groundwater conditions. The normal maintenance cost for gravel roads was estimated to be $800/km/year, increasing to $1,000/km/year for shallow groundwater.

Table A5.3: Cost estimates quoted in Murray-Darling Basin Commission (1994)

Source	Location	Type of cost	Groundwater depth	Additional Cost/km
MDBC (1994)	Murray-Darling Basin irrigation areas	New construction of Riverina Highway	<2.0m	$71,000 to $115,000 on $390,000
Shire of Kerang (1992)	Kerang, Victoria	New construction	<2.0m	$25,000 on $100,000
Conargo Shire, NSW	Conargo	New construction (formation raised 300 to 500 mm, plus geotextile)	< 2.0m	$35,000 on unknown base cost
Shire of Kerang	Kerang, Victoria	Gravel road construction	< 2.0m	$3,000 on $7,000
Wallace (1994)	NSW Municipalities in Murray-Darling Basin	New construction, standard sealed road	<2.0m	$20,000 on $60,000
Gray (1992)	Riverina Highway, Berriquin, NSW (80km)	Repair costs	75% <2m	$10,000/yr
Gordon Shire	Gordon, Victoria	Maintenance of major sealed roads	<2.00	$400 on $2,500/yr
Gordon Shire	Gordon, Victoria	Maintenance of minor sealed roads	<2.00	$300 on $1,500/yr
Gordon Shire	Gordon, Victoria	Maintenance of gravelled roads	<2.00	$200 on $800/yr

Discussion

This Section compares the damage cost functions used in the study of wheat belt towns to date, with the estimates from MDBC (1994) study. This comparison is done using discount rates of 4 per cent and 7 per cent over a 42-year period. The 42-year period was chosen to allow for three highway construction events (at years 1, 21 and 41), assuming a road service life of 20 years for shallow groundwater conditions.

For highways, it can be seen that the cost of $195,000/km every three years, which was assumed for highway stabilisation when groundwater table is <0.5 m, is actually more expensive than complete reconstruction every 20 years, if it costs around $500,000/km to reconstruct (including an allowance of $100,000 for raising the road and geo-textile placement). However, the stabilisation cost of $145,000 every seven years, which was assumed for highway stabilisation when the groundwater was between 1.5 and 0.5 m would be less expensive than complete reconstruction. A similar picture emerges for local roads.

Finally, Table A5.4 shows the discounted value of the annual average cost of road repairs attributable to shallow groundwater in Katanning. This is $10,000/km/year, which was calculated as the average annual expenditure on road repairs in the 0.5 m groundwater zone in Katanning, of $80,000, divided by the total length of local roads in the 0.5 m zone (approximately 8 km). At both of the selected discount rates the present values of this annual cost over the 42-year period are (a) slightly larger than the stabilisation cost every seven years we have assumed for the 1.5 to 0.5 m groundwater depth, and (b) slightly smaller than the cost of complete re-construction every 20 years.

Table A5.4: Comparison of NPVs of different road cost scenarios

Type of Road	Source	Cost description	NPV @ 4% $000s	NPV @ 7% $000s
Major Highway	MDBC (1994)	$400,000/km plus $100,000/km for shallow groundwater, construction every 20 years	809	628
	H'cstle Richards	$195,000/km for stabilisation every 3 years for groundwater table <0.5 m	1271	816
	H'cstle Richards	$145,000/km for stabilisation every 7 years for groundwater table <1.5 m	371	225
Local Roads	MDBC (1994)	$100,000/km plus $35,000/km for shallow groundwater, construction every 20 years	218	169
	H'cstle Richards	$100,000/km for stabilisation every 3 years for groundwater table <0.5 m	647	418
	H'cstle Richards	$70,000/km for stabilisation every 7 years for groundwater table <1.5 m	179	109
	Katanning Shire	$10,000/km additional annual repair and maintenance costs due to groundwater table <2.0 m	202	135

Annex 6

Damage cost factors (protection and repair of buildings and other items)

Conceptual framework

Market prices were used for all combative measures due to groundwater rise such as repair, maintenance, property-level pumping, property-level drainage for removal of rising groundwater and road and rail repair.

This Annex outlines the assumptions and cost factors for addressing damage costs caused shallow groundwater as it affects buildings, amenities such as parks and linear infrastructure such as roads and rail. These were applied to all six case study towns..

Basis of the estimates

Expenditures to cope with symptoms of shallow groundwater were estimated on the basis of (a) discussions with affected organisations, such as the owners of grain silos, local government and Ministry for Housing, (b) advice from an engineer with experience in civil construction in damp environments and (b) architect/builder estimates/advice.

A key point to be made is that unlike agricultural situations, where salinity or waterlogging may render the land unsuitable for any conventional use, there are ways of coping with the onset of a shallow groundwater table in an urban area in order to protect buildings and other items. Parks and gardens are not so easily protected, and this has been taken into account in developing the estimates.

Tables A6.2 and A6.3 give the assumed costs per property (or per unit area) for all property types at 0.5 and 1.5 m depth to watertable respectively. It is seen that most of the costs for buildings, public parks and gardens and roads are incurred when the groundwater reaches 0.5 m depth. This is necessarily a judgement on the part of the consultants, but in qualitative terms it is fair to say that costs are likely to be relatively minor until the groundwater becomes quite shallow (i.e. 0.5 to 1.5 m).

The following section comments on the items that were of most significance to the overall damage estimates.

Defensive expenditures to address damage costs

Houses on stumps

Wood-framed houses built on stumps make up the greater part of the total housing stock in Western Australian wheatbelt towns. As these houses also tend to be older than brick houses, they particularly dominate in the older parts of towns, and often occupy lower parts of the landscape. They also have lower values than more recent houses constructed of brick.

The stumped houses are generally well-adapted to cope with shallow groundwater tables, provided that adequate ventilation is maintained beneath the floor. They also cope reasonably well with any structural distortions caused by ground shifting, though re-lining of walls or ceilings, or re-fitting of doors is needed occasionally.

The main impact of wet soil is on the stumps. These are removed where necessary by jacking up the house and removing rotten stumps, and installing wood, steel or concrete replacements. It is only those stumps which are rotten that are replaced. An average cost per property of $1,000 every five years after the groundwater reaches 0.5 m has been assumed. This takes account of the likelihood that some houses will bear higher, and some lower, costs.

Brick housing on the ground

Brick housing built on the ground is potentially more vulnerable to shallow groundwater than stumped housing. Common problems are fretting brickwork or crumbling and cracking mortar. Brick houses with wooden floors may experience cupping floorboards, which are dealt with by heavy re-sanding. However, there is wide variability in the susceptibility of brick houses even within a small locality that has shallow groundwater, so the experience of problems is by no means uniform.

One mitigating factor is that unlike the practice in Perth, which is to put a concrete slab at ground level, brick houses in the wheatbelt towns usually have four or five courses of brick filled with granular material on which the concrete floor is placed. This provides a significant measure of protection from damp soil conditions. Advice from Ministry for Housing is that about 600 mm of coarse sand will be placed on damp soil before laying the concrete slab.

A widespread problem with brick houses built on swelling clay soils is the cracking of walls. However, this occurs in most locations as a result of surface infiltration, not groundwater rise. If a brick house has been constructed on swelling clay soils without adequate structural provisions it will experience cracking independently of the depth of groundwater.

Discussion with a builder/house repairer who has extensive experience in the wheatbelt towns suggest that some house owners may face repair bills of as much as $20,000 in severe cases of problems caused by shallow groundwater. These houses might require re-plastering, excavation of fallen eroded material from brick cavity walls, removal and replacement of mortar or whole walls, demolition and reconstruction of verandahs, provision of on-site drainage, attention to floorboards, creation of additional ventilation and so on. But this would certainly not apply to every house within a zone affected by shallow groundwater, and cannot be taken as an indicative average value.

An alternative approach to protect brick houses from these problems is to construct simple shallow drains around the perimeter of the house block, for localised groundwater discharge, with disposal via natural channels or exiting kerb-side drains. A local sump and pumps may be installed where necessary. This localised drainage solution can be done most economically if small clusters of houses, say 10 to 20, are treated at the same time, at an indicative cost of around $6,000/house. This requires coordination and cooperation from the local authority and possibly the Water Corporation.

Whether or not damage is avoided in advance by such localised drainage provision, the amount of $6,000/house is a reasonable indicative figure for the overall average cost per house of repairs to structures, and has been adopted for this study. In addition to this, an allowance of $2,000/house has been included to cover structural repairs needed before a localised drains solution is adopted.

House gardens

The effect of shallow groundwater on garden vegetation will depend on several factors, including the salinity of the watertable, and the severity of waterlogged conditions.

Hydro-geological modelling suggested that the cause of rising groundwater tables was predominantly the result of changed local water balances, as a result of run-off from an increased area of impervious surfaces (predominantly roads and roofs), and the importing of large volumes of water from the piped scheme supplies. The shallow groundwater associated with this increased recharge will tend to be fresh, and because of its lower density than saline water it sits at the watertable. Therefore, there may actually be a benefit to vegetation from the shallow groundwater table, as long as waterlogging does not become prolonged. Corrigin provides the most clear-cut example.

If vegetation is lost as a result of salinity or waterlogging due to shallow groundwater there will be some loss of domestic amenity and this would be reflected to some extent in property value. It was not possible to quantify this directly within the study. However, in the early 1980s the Perth Domestic Water Use Study did ask people how much their garden contributed to the value of their property. The survey found that on average a high quality garden could add up to 3 per cent to the value of the property. This percentage has been used as an indicative figure, and a general average residential property value of $60,000 was used, giving an average property loss of $1,800 per property. This is a generous figure given the number of gardens in these towns that are very poorly kept. It was assumed that the 3 per cent loss of residential property value would be imposed in the tenth year after the groundwater reached 0.5 m.

Residential utility services

Utility service providers were approached to determine the likely extent of damage from shallow groundwater to water pipes, sewers, sub-surface electricity lines and telecommunications cables. Gas is supplied in bottles and is not an issue.

The Water Corporation felt that there is very little additional repair or maintenance expenditure in respect of shallow groundwater. Water supply pipes and sewers are usually sufficiently well anchored by the overburden to be stable even within a watertable. As for water quality, these structures tend to degrade from the inside rather that externally. One item, which could require additional expenditure, is the replacement of saddle tappings. These are sub-surface valves placed throughout the water supply distribution system for shutting off sections, and are usually of galvanised steel.

Most electricity services are above-ground. The main item of potential additional cost is more rapid rotting of electricity posts, but this was not considered significant in the context of this study. Given the corrosive nature of saline water and its effect on electrical and telecommunications systems, a provisional estimate of costs was made by the team engineers.

Table A6.1: Costs of damage to underground utility services in residential areas ($/household/year)

Item	Depth to groundwater		
	1.5 to 1.0 m	1.0 to 0.5 m	<0.5 m
Communications	0	0.6	6.0
Power	0.6	2.4	6.0
Total	0.6	3.0	12.0

Public parks and gardens

In the towns studies there are generally two classes of public parks/gardens. Firstly the centre of towns may have a cultivated 'focal' park/garden, often with lawn and exotic plants. Nearer the periphery of the town there are usually a number of areas of remnant native vegetation designated as public areas, and perhaps with tracks.

The Prosser Park experience in Katanning suggests a relatively high willingness to pay for rehabilitation of a centrally-located focal park. This park was badly affected by a shallow saline watertable, and was treated with a substantial amount of clean sand fill, relawned, re-stocked with shrubs and re-landscaped. The cost suggested by this example is $12,000/ha, which was used as a general estimate for all towns.

In addition a cost of $20,000 per oval was imposed on developed football fields of in Year 1, followed by $500 per year thereafter. This cost would be incurred when the groundwater is at 0.5 m. Costs of $10,000 per year post 0.5 m were assumed for other sporting grounds. No costs have been included for remnant vegetation.

Offices

Most office buildings in the towns studied are of brick construction, and would require the same kinds of defensive expenditure as brick houses. Therefore the same approach was used, with an allowance of \$3,000/1000 m^2 for the cost of repairing existing structural damage, plus an allowance of \$8,400/1000 m^2 for localised drainage works.

Land uses where no costs were included

A number of costs that were thought likely to be significant at the outset of the study were downgraded or eliminated.

All towns studied have a significant number of light industrial sheds usually built with a steel frame and a concrete floor, and used for a wide variety of purposes. These include vehicles and machinery repairs, storage of chemicals, depots of utility operators and oil companies, and a wide variety of low-density retail and wholesale outlets. In many cases the buildings are elementary in construction and low in value. The main potential problem is rusting of uprights and access to the buildings if the ground becomes waterlogged. The uprights are usually treated by adding concrete at their bases. The cost of adding fill to an industrial driveway may be little more than the costs of routine repair and maintenance. Total costs involved are therefore very minor, and have been excluded.

Discussions with representatives of oil companies suggested that there is no known problem with underground petrol and diesel storage tanks. These have an effective bitumen coating, and are strongly anchored. Therefore, no additional cost was reported.

Cellar pump-outs, or alternatively the cost of replacing storage capacity following permanent inundation of a cellar, were disregarded. There are some cellars that are already affected, but the damage has already taken place and is not likely to be easily reversible (pump-outs are potentially dangerous to structures once the cellar has been inundated for some years). There are few cellars that are likely to be affected in future that are not already affected.

Below-ground rubbish tips would pose a serious cost if the watertable intersected the pit base. In the towns studied all rubbish tips were above-ground, and no costs were identified.

Large swimming pools can suffer damage, due to lifting, if they are sitting within a watertable and are emptied for cleaning. However, given knowledge of groundwater conditions this should be avoidable if suitable cleaning methods are used.

No defensive expenditures were assumed for vacant land.

Table A6.2: Defensive Expenditure Cost Factors: groundwater depth 0.5 m or less

Zone/Building Type	Cost ($)	Notes
House: brick on ground	$6,000/house in 3rd year after groundwater reaches 0.5 m	Construction of perimeter drains around each house block, with slotted pipe and granular fill, to promote discharge of groundwater to surface run-off, such as natural channel, or exiting kerb-side drain; with a sump serving the whole street and a pump to surface channel/disposal route if required
House: brick on ground	$2,000/house in 1st year after groundwater reaches 0.5 m	Repair of fretting brickwork, crumbling mortar; assumed to be a once-off expenditure, due to assumed installation of perimeter drains (see above), which would prevent re-occurrence
House on stumps	$1,000/house every five years, starting in the 1st year the groundwater reaches 0.5 m	Jacking and re-stumping where necessary
House: garden	3 % of property value in 10th year after groundwater reaches 0.5 m	Loss of property value due to dying garden vegetation: only if groundwater is saline at the watertable
House: underground services	$0.60 and $3.00	More frequent replacement of saddle tappings.
Public park: cultivated	$12,000/ha in 2nd year after groundwater reaches 0.5 m.	Sand fill followed by revegetation and landscaping.
Football ovals	$10,000 (per field or hectare/year	
Offices on ground of brick construction	$70/linear metre of building perimeter, or $8,400/1000 sqm. block in 3rd year. $3,000/1000 sqm in 1st year after 0.5 m	Construction of perimeter drains around each office block, with slotted pipe and granular fill, to promote discharge of groundwater to surface run-off, with a sump serving the whole street and a pump to surface channel/disposal route if required. Repair of fretting brickwork, crumbling mortar, paintwork etc.
Concrete grain silos (a) with steel-reinforced foundations and underground conveyancing corridors	$10,000/year/ unit of measure?	Not included in costs assessments – treated separately in the Town Reports
Concrete grain silos (b) pavements and drainage structures	$5.0/sqm/year	

Table A6.2 (continued)

Zone/Building Type	Cost ($)	Notes
Light industry	Zero	See above
Caravan parks		Did not include all of caravan parks as this may be misleading – the building and toilets were costed, only the vans were excluded
Rubbish tips: above-ground Vacant land Swimming pools Sporting grounds Livestock saleyards	Zero	

Table A6.3: Defensive Expenditure Cost Factors: groundwater depth 1.5 to 0.5 m

Zone/Building Type	Cost ($)	Notes
Concrete grain silos (a) with steel-reinforced foundations and underground conveyancing corridors	$6,000/year	See comments above
Concrete grain silos (b) pavements and drainage structures House: underground services (same costs as those in table above) Football field (same costs as those in table above)	$1.0/sqm/year	See comments above