Economic and Social Values of Land and Water Uses on the Gnangara Groundwater System

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This document has been produced as part of the Gnangara Sustainability Strategy (GSS). The GSS is a State Government initiative which aims to provide a framework for a whole of government approach to address land use and water planning issues associated with the Gnangara groundwater system. For more information go to www.gnangara.water.wa.gov.au
EXECUTIVE SUMMARY

As part of the Gnangara sustainability strategy (GSS), CSIRO was asked to carry out a study with six objectives:

1. Economic values of land and water use on the Gnangara groundwater system (GGS);
2. Economic costs of direct management interventions for improving ecological outcomes;
3. Social values of land and water use on the system, and social impact of alternative options;
4. Criteria for reporting on non-market ecological values;
5. Decision support system (DSS) model or a suite of decision support tools (DST); and
6. Quantitative input to local area planning processes.

This report meets objectives 1, 2, 3 and 4.

This report focuses mainly on economic values, as only a few good studies of social values have been carried out. It summarises the findings from a number of independent and often unrelated studies that used different techniques. It also highlights the costs associated with maintaining some of the ecological services provided by the GGS.

The economic, social and ecological values obtained and compiled for this report are of interest by themselves but will also be inputs into the DST (Objective 5 above). Collating them in this report therefore fulfils several needs.

Key findings from the review of the literature, comprising theoretical and empirical studies, suggest the following:

1. There is an existing, significant body of theoretical literature that measures the economic and ecological values of the assets associated with the GGS in monetary terms. However, not all values can be monetised to the satisfaction of those people who hold strong social values around environmental assets. Hence, alternative evaluation frameworks, such as benefit-cost analysis (BCA), multi-criteria analysis (MCA) or ecological value ranking may be used to prioritise the importance of environmental assets using an ordinal rather than a cardinal scale.

2. Land and water resources on the GGS have high economic, social and ecological values. The extractive value of groundwater to six major users, namely, the Water Corporation, garden bores, parks and recreation, industry and services, and agriculture and rural lifestyle users has been estimated to total about $300M/yr (Marsden Jacobs Associates 2006). Restricting the use of water also results in welfare loss (in other words, people feel or become worse off compared to unrestricted water use) from households not being able to maintain their private gardens and lawns, public open space not being aesthetically pleasing and useable, and job losses from industries that rely on irrigated gardens and lawns.

3. The total value of the pine plantations on the GGS is estimated to be $12.3M, with around $1.75M contributing to road maintenance and control bush-burning a year.

4. Urban wetlands provide direct economic value to people living nearby, as reflected in elevated land prices in their vicinity. For an average price property that is within 1.5km of a
wetland, moving 1m closer to the wetland increases the land value, on average, by around $829 (Tapsuwan et al. 2007).

5. Maintaining cave water and protecting those species living in the Yanchep cave ponds has value for tourism. A visitor survey by Perriam et al. (2008) showed that visitors were willing to pay over $3 more on their entry fees to support the Yanchep Caves Recovery Project. This would result in increased park revenue of $185,000/yr.

6. The growing value of urban land on the GGS will have significant implications for the environment, as demonstrated through the higher property price premium of urban wetlands as compared to peri-urban wetlands. Assuming that the preference for the environment rises with income, the value of the environment in the vicinity of urban areas will increase in the future.

7. Having horticultural land near the city provides a horticulture 'feel' to the peri-urban communities, enables horticulturalists and their families to have access to a large workforce and urban amenities (e.g. education for their children), creates over 1,000 jobs, and enables fresh and locally grown fruit and vegetables to be supplied over a short distance to Perth consumers. However, there is a tradition for horticultural land to be converted to housing as a form of ‘superannuation’ for aging horticulturalists, enabling them to realise a capital return on their investment and to receive the funds to expand further if the family decides to do so.

8. Despite the benefit derived from urban expansion – namely, reducing the pressure on land sale prices – the 2007 State of the Environment Report identified the pressure of urbanisation on the environment as a key concern for the state.

9. State funding invested in direct management interventions for improving ecological outcomes is a strong indicator of community support and government commitment to retain environmental assets, and their ecological and social services.

10. Benefits gained from direct investment in preventing the outbreak of European house borers (EHB) are greater at the national level than at the local level. Therefore, cost-benefit considerations need to incorporate the full cost of pest spread on a much wider area in the long term.

11. There is community support for bush-burning if the objective is to maximise terrestrial biodiversity values and prevent wildfires, as opposed to increasing groundwater recharge (Sands 2008). The option of using water more efficiently to increase water availability is preferable to controlled bush-burning.

12. The acceptance of the need to stop augmentation efforts in some projects (e.g. ceasing to pump water into drying wetlands) may reflect a gradual change in community values towards the environment. As the memory of past environments is diminished with each succeeding generation, there is an increasing acceptance of climate change as a real and significant fact.

13. There are significant links between climate change and land and water use, yet there are few examples from other areas that demonstrate how to successfully incorporate climate
change mitigation and adaptation options into land- and water-use policies. The impact of urban sprawl on energy requirements must be weighed against the gain in groundwater recharge from urbanisation. Similarly, the choice of re-vegetation needs to take into account the threats placed by higher temperatures and lower rainfalls. Migration of invasive pests that are advanced by climate change could threaten habitats like banksia woodlands.

14. Renewable resources such as wind energy, in contrast to more conventional systems, present ways of simultaneously meeting water needs while decreasing carbon emissions. Future possibilities for such options need to be explored.

15. Urbanisation options should not be overly water-centric and need to incorporate aspects such as the impact on transport costs, urban sprawl, the ability to sustain employment, ways of avoiding duplication of infrastructure, and the creation of social issues.

A finding of this literature review is that while the GGS is the most extensively studied urban groundwater resource in Western Australia, there remain significant shortcomings in our understanding of the key economic, ecological and social values of assets associated with the system. Failure to fill this gap in understanding could be detrimental to the objective of providing a sustainable strategy for the GGS, and also for Perth, which benefits from the water-related benefits and values that the system provides.

In order to better comprehend the economic and social value of land and water use on the GGS, further work is needed in the areas of

- the overall ‘sense of place’ associated with landscapes on the GGS
- the impact of ecosystem loss (especially wetlands) and its value to society and the wider environment (e.g. migratory birds);
- the value of keeping horticulture within close proximity to Perth; in particular, the importance of food security, food mileage and local employment concerns versus increased commuting distances and neighbour issues if horticulture is distributed through urban areas;
- the impact on other industries of declining horticulture production; and
- the removal of peri-urban bush by urban sprawl;
- the relative values of commercial timber production (with their shade and wood production but reduced recharge), native bushland (with high conservation values but the need to meet management costs of providing fire management, weed and pest control, and managing access), open grasslands (with their water production values but lower biodiversity and commercial values); and water-trading within and among industries.

It is therefore recommended that such additional targeted studies be undertaken to further improve the management of the GGS. The CSIRO has commenced a sense of place study to help overcome one of the deficiencies in understanding intrinsic values associated with land uses on the GGS.
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<td>IRP</td>
<td>Interim Recovery Plan</td>
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<td>Integrated water supply scheme</td>
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<td>Leaf area index</td>
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<td>Long-run marginal cost</td>
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1. INTRODUCTION

It is generally accepted that the south-west of Western Australia (WA) underwent a climate shift in the mid-1970s, which resulted in reduced runoff into the dams – to less than 25% of their long-term average – that, at that time, supplied most of the water to Perth and the surrounding areas. At about the same time Perth also started to develop urban and peri-urban well fields that augmented the dam supplies with water from a sandy, unconfined aquifer. Most well fields were located to intercept groundwater before it flowed under urban areas and to channel it away from the most important wetlands that were also supported by the groundwater system. By 2005, groundwater from both the superficial (unconfined) and confined groundwater systems that comprise the GGS were supplying over 60% of Perth’s drinking water (population 1.5M and growing by 2–3% each year), as well as supporting peri-urban horticulture, council and school ovals and parklands, backyard bores, and industrial demands for non-potable water. The amount of water withdrawn from the various aquifers by user groups in 2004 is shown in Figure 1.

The continuing drier conditions, abstraction for public and private purposes, and reduced recharge (or net discharge) under the 22,000ha of plantation pines on the GGS resulted in groundwater storages in the upper- and mid-parts of the GGS, declining by about 20GL/yr between the late 1980s and late 1990s, and by about 45GL/yr since the late 1990s (see Figure 2). Groundwater levels have declined by up to 5m in some areas, resulting in wetlands drying and being replaced by terrestrial vegetation.

Because land use (e.g. urban, horticulture, pines, bushland) and land management (e.g. burning frequency, pine-thinning) above the shallow sandy aquifer affects both groundwater recharge and demand for groundwater (e.g. irrigation of horticultural crops), there have been moves to plan both land and water resource together. The Gnangara Taskforce was established by the WA government in 2007 to develop the GSS to explore feasible options that balance social, economic and environmental values in a more transparent and effective way than is currently the case. More detailed information regarding the GSS, and the GGS and its properties, can be found on the website located at: http://portal.water.wa.gov.au/portal/page/portal/gss.

Some values are relatively easy to establish because they are reflected in the marketplace (e.g. drinking water sales), but environmental services and social preferences are not. This report is a review of the current understanding of the values that are apparent on GGS, as reflected in the literature and reports. These reports were often commissioned by government agencies to meet ministerial conditions set on the abstraction of water from public well fields that were established in the early 1990s. The report also draws upon the international literature where it is considered relevant.
Figure 1 Groundwater use by user groups in 2004
(Source: Dept of Water)

Figure 2 Changes in groundwater storage on the GGS
(Source: Dept of Water)
Non-urban use of groundwater, such as agriculture and the environment, presents difficult trade-offs as it cannot be discounted given Perth’s relative isolation from the rest of the country and subsequently need to maintain adequate food security, and a critical level of environmental and ecological services.

The challenge for society is to find a sustainable growth pattern that meets biophysical constraints without inducing considerable shock to the existing socio-economic and ecological systems, which also allows enough time and resources for adaptation to the changing climate. Economic principles fall short of guiding us towards the achievement of such objectives, as they can only inform policy-making that are related to the trade-offs that can be brought within the reach of the market. Environmental services, social valuation of lifestyle choices and future food security issues are some examples that do not necessarily meet these criteria. Nor do the current social and political institutions that must evolve to incorporate within their policy-making the behavioral resilience of the community and collective co-management of threatened natural resources.

Public policies must consider carefully the two types of irreversibilities that are typical of climate change problems, which have high uncertain impacts. First, over-investment in adaptation options, such as building more seawater desalination plants, may lead to future redundancies if the impact of climate change turns out to be less extreme than anticipated. Second, under-investment may lead to irreversibilities associated with loss of the environment and agriculture, which may adversely affect Perth’s future growth potential. While these are the broader trade-offs, there are several related second-tier trade-offs that arise between sectors and within sectors that need to be incorporated to ensure sustainability. Very often these trade-offs do not share a common denominator. For instance, economic values must be weighed against social and environmental values, and the latter values are mostly unknown.

Evaluation of these trade-offs is limited in the current literature, yet these issues must be tackled to ensure formulation of good public policies. In order to evaluate these trade-offs, it is pertinent that the value of the services water provides to urban, agricultural, environmental and social systems are brought under a common denominator. This report is an attempt to present the existing literature on economic values of the GGS in light of the above trade-offs, and to lay out a course for future works required to plan a sustainable future for Perth and the GGS.

As part of the GSS, CSIRO has been asked to provide
1. economic value of land and water use on the GGS;
2. economic costs of direct management interventions for improving ecological outcomes;
3. social value of land and water use on the GGS and social impact of alternative options;
4. criteria for reporting on non-market ecological value;
5. DSS model or a suite of DSTs; and
6. quantitative input to local area planning processes.

This report meets objectives 1, 2, 3 and 4.

Section 2 reviews methods of estimating economic and social values, and touches upon the criteria for assessing non-market ecological values (Objective 4). Section 3 provides a summary of literature review of the environmental and urban amenity values on the GGS (Objective 1).
The literature in this section comprises the economic values of groundwater users, pines, urban wetlands, peri-urban wetlands; the willingness to pay for Yanchep caves recovery projects, the value of rare and endangered species, and threatened ecological communities; the economic impact of sprinkler restrictions; and the social value of water use such as public and private lawns.

In order to maintain the future value of the above groundwater uses, certain actions are required that may come at significant economic, social and ecological costs to society. Of these, the ecological sector needs particular attention because it is not easy to bring it within the purview of the market. Section 4 presents the economic cost of direct management interventions for improving ecological outcomes (Objective 2). Specifically, we discuss the costs of prescribed burning of the banksia woodland, the EHB eradication program, phytophthora management costs, the Yanchep Caves Recovery Project, wetland augmentation, the Perry Lakes aquifer replenishment, and the post-pine re-vegetation of native bushland.

Section 5 presents the social value of groundwater (Objective 3) and section 6 considers the change in the future value of these services. Section 7 draws some overall conclusions and makes recommendations for further work.

While the report provides a comprehensive review of the existing literature and a collation of the existing socio-economic and ecological data, a secondary objective is to incorporate this information into the DST being developed by the CSIRO for the GSS.
2. ELICITING ECONOMIC, SOCIAL AND ECOLOGICAL VALUES

Before presenting the summary findings of previous literature on the economic and social values of amenities on the GGS, this section provides an overall summary of the theory and techniques behind the valuation of environmental goods.

2.1 General Theory to Non-market Valuation

The value of environmental goods and services can be broadly grouped into two categories: use and non-use values. Use values are values arising from the actual use or consumption of the environmental good (Pearce and Moran 1994). Non-use values are values that are not directly related to use or consumption of the environmental good, but still have an impact on the wellbeing of an individual (Nunes 2002). The total economic value (TEV) of an environmental good comprises its use and non-use value combined.

Use values are further divided into direct values, such as harvesting timber, and indirect use values, such as clean air from trees. Direct values can be further divided into consumptive, such as timber harvesting or non-consumptive, such as a forest’s visual amenity (Asafu-Adjaye 2000).

Non-use values may be existence, bequest or option. Existence value is the value one places on knowing something is there (Asafu-Adjaye 2000), such as knowing that the wetlands still have water. Bequest value is the value one gains from being able to conserve something for future generations. Option value is defined by Asafu-Adjaye (2000) as the amount of money someone is willing to pay to ensure that a resource is available in the future, should they decide to use it. Figure 3 depicts use and non-use values in taxonomy of TEV.

Generally, use values are simpler to estimate as the values are reflected in the marketplace. For example, the value of forest timber is measured in terms of the dollar amount the timber can be sold for. Likewise, the value of forest parks can be measured by the amount people pay to visit the parks. Non-use values are difficult to measure as there is no market for such services. For example, it is difficult to calculate the benefit in dollar terms of preserving a wildlife species.

Some resource managers and economists believe it is important to monetarise non-market values as much as possible so that they can be considered in economic analyses, and not to attempt this runs the risk of them being ignored altogether (P. Hardistry pers. comm. 2007). Others, however, find the monetarisation of non-marketed or intangible values offensive, immoral and/or unrealistic, and oppose the idea of money being the measure of all things that people value.

Where values are high but not monetarised, they can be incorporated in the form of absolute constraints or conditions that cannot be breached as part of management practice (e.g. the preservation of species). This effectively places an infinite value on the asset in question. This approach has been used to some extent on the GGS where ministerial conditions were placed on the state water manager (initially the Water Authority of Western Australia but now the Department of Water) to maintain groundwater levels around wetlands adjacent to well fields.
that may impact on their ecological value. Failure to meet these conditions could result in the manager being fined or gaol ed if the ministerial conditions continued to be breached and there was no agreement on amending the condition (under Section 46 of The Environment Protection Act 1986). Problems arose when the breach was not able to be influenced by the water manager because it was caused by climate change and/or land use outside their power (e.g. the thinning of pines to increase recharge).

The methodology adopted in resource economics to handle non-use values is inherently anthropocentric. Anthropocentrism is the belief that humans are the most significant entity of the universe, thus interpreting environmental value in terms of human values and experiences (Mazzotta and Kline 1995). Non-use values of environmental goods are thus measured in terms of human benefits or human preferences. Non-use values can be estimated by people's willingness to pay (WTP) to preserve the environmental goods. WTP is a useful proxy for measuring non-use values in the absence of other methods. While it is not a direct measure of value, it does provide a quantifiable measure the general public can understand.
Figure 3 The components of total economic value (TEV)
Source: Barton (1994) as cited in Hoagland et al. (1995)
There are overlaps in social values and TEV. Social values can be both consumptive (i.e. use) and non-consumptive (i.e. non-use) (Beckwith 2006). Previous studies have shown that the public attaches a variety of values to the environment, such as historical/cultural, aesthetic, ecological, recreational, educational, moral/ethical, therapeutic, scientific, intellectual, spiritual and economic (Manning et al. 1998; Ananda and Herath 2003, as cited in Beckwith 2006).

Economists have developed a number of techniques to capture or estimate the value of both use and non-use values of environmental goods. The two main methods of non-market valuation can be placed into two categories: revealed preference (RP) methods and stated preference (SP) methods. RP aims to find the value people place on a good from observed behaviour in markets for related goods (Hanley et al. 2001), while SP works on creating a hypothetical market for the environmental good in question to be traded.

The two main RP methods are the travel cost method (TCM) and the hedonic pricing method (HPM). TCM values the recreational use of an environmental good, such as parks and wetlands, by estimating the costs people incur in order to travel there. HPM uses the market price of substitute goods to value an environmental resource. Avoidance cost infers the benefit of a good quality environmental resource by measuring the consumption of goods and services that substitute for the environmental quality change (Hardistry and Ozdemiroglu 2005). Market price is the actual market price of the good, such as the price of timber.

The two main types of SP methods are contingent valuation (CV) and choice modelling (CM). CV asks people how much they are willing to pay to prevent the loss of an environmental asset, or how much they are willing to accept (a compensation) to let the environmental asset go. CM method is similar to CV in that it tries to measure willingness to pay/accept, but the environmental good in question is described in terms of its attributes and the levels that the attributes take. Therefore, the willingness to pay/accept can be broken down into the willingness to pay/accept for each attribute of the environmental asset. For more details on non-market valuations see, e.g. Bateman et al. (2002) and Freeman (2003).

Figure 4 shows a simplified version of the valuation techniques for measuring use and non-use values.
A review of a number of studies in section 3 presents the empirical analysis results of values for urban and environmental assets on the GGS applying the non-market valuation techniques discussed above.

### 2.2 Alternative Evaluation Frameworks

#### 2.2.1 Benefit-cost Analysis to Multiple Criteria Analysis

Quite often the benefits and costs of a policy option or of conserving an environmental asset cannot be measured in monetary units or valued using non-market valuation techniques because of reliability and affordability.

Hence, there are a number of alternative evaluation frameworks available, namely, benefit-cost analysis (BCA), cost-effectiveness analysis (CEA), cost-utility analysis (CUA), and multiple criteria analysis (MCA).

BCA is a framework that is used for evaluating and ranking one or more investment alternatives (Asafu-Adjaye 2000). It is basically the ratio of the total investment benefits (such as profit) over the total cost of the investment. If the ratio is greater than one, then the project is not going to result in a loss.
When it is not possible to monetise all project benefits, CEA is a more appropriate framework than the BCA. Similar to the BCA, CEA handles costs in monetary terms, but the benefits are measured in output units, such as tonnes of carbon sequestered. Therefore, deciding between BCA and CEA depends on the extent to which there are quantifiable benefits and the extent to which the benefits can be valued in monetary terms (Asafu-Adjaye 2000).

A CUA framework can be used as a tool to help decision-makers decide which multi-objective environment policy meets a desired level of utility at the least cost (Hajkowicz 2008). CUA is often used when the benefits of a project cannot be measured in dollar outcomes and when projects have low social value but high ecological value. The costs are measured in monetary terms, like BCA and CEA, but benefits are measured with some type of utility metric, which comprises outcomes that can be in different units.

MCA is an evaluation framework that ranks or scores the performance of decision options (e.g. policies, projects, locations) against multiple objectives measured in different units (Hajkowicz 2008). The costs and benefits do not have to be in monetary terms, unlike BCA, CEA or CUA. Typically, an MCA model has at least two criteria and two options, and the criteria are weighted by decision-makers to reflect their relative importance.

Figure 5 shows the five stages of the MCA framework summarised by Hajkowicz (2008).
The stages of MCA include:

1. **Problem structuring:** This crucial stage of MCA, typically requiring the bulk of the effort, involves the identification of criteria and decision options and obtaining performance measures (Janssen, 2001).

2. **Criteria weighting:** This involves obtaining information from decision makers about the relative importance of criteria. Weights may be expressed at either an ordinal or cardinal measurement level.

3. **Criteria transforming:** As the criteria are in different units they need to be transformed into commensurate units prior to aggregation in the ranking or scoring function.

4. **Option ranking and/or scoring:** The weights and transformed performance measures are combined to determine the overall performance of each option, relative to other options.

5. **Sensitivity analysis and decision making:** Variation of MCA methods, performance measures, and weights test the sensitivity of the result. The decision maker(s) can then make a final choice.

Figure 5 The multiple criteria analysis decision-making process

**2.2.2 Comparing MCA and BCA**

The first formal application of BCA was in 1768, when it was used to evaluate the net benefits of the Forth-Clyde canal in Scotland (Asafu-Adjaye 2000). MCA started off as fuzzy-set theory, which was first used in the development of decision support models in 1965, and was later applied in MCA applications (Hajkowicz and Collins 2007). BCA has been around for much longer than MCA; however, both have advantages and can be applied in different circumstances. The difference between BCA and MCA is summarised by Hajkowicz (2008) and is presented in Table 1.
Table 1 The difference between MCA and BCA

<table>
<thead>
<tr>
<th>MCA Task</th>
<th>BCA Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Problem structuring</td>
<td>In BCA the criteria are already identified, they are the benefit and cost items, but identification of decision options and obtaining performance measures are part of the process.</td>
</tr>
<tr>
<td>2. Criteria weighting</td>
<td>For BCA, weighting is by market prices, or surrogates. Hence, the weights are determined by aggregate consumer preferences, and not by decision-maker preferences, which may not be representative of societal preferences.</td>
</tr>
<tr>
<td>3. Transforming criteria</td>
<td>In BCA all outcomes are measured in dollar units, so the transformation is already completed via the valuation process.</td>
</tr>
<tr>
<td>4. Ranking and/or scoring options</td>
<td>The scoring in BCA is on the basis of net present value (NPV), benefit-cost ratio (BCR) or internal rate of return (IRR).</td>
</tr>
<tr>
<td>5. Conducting sensitivity analysis and making a decision.</td>
<td>The same is done in BCA. Input parameters such as the discount rate are systematically varied, and the impact on the result is assessed.</td>
</tr>
</tbody>
</table>

2.2.3 Process for Selecting an Economic Evaluation Framework

As different decision-making processes have varying degrees of information availability, particularly in terms of cost and benefits, careful consideration needs to be given when deciding which evaluation framework to choose.

Hajkowicz (2008) summarises the process for choosing between BCA, CEA, CUA and MCA and is explained in Figure 6.
Figure 6 Process for selecting an economic evaluation framework

The process for choosing which of BCA, CEA, CUA, and MCA to apply depend largely on the valuation of benefits. If benefits are adequately measured in monetary units, then BCA provides an appropriate framework. If this is not the case, the analyst will need to contemplate non-market valuation, such as choice modelling or contingent valuation, which will require attention to both reliability and cost effectiveness. If it is decided that non-market valuation is not feasible or worthwhile, then CUA may be appropriate. If there is no monetary cost data, e.g., the options are strategic policy directions, then MCA can be used. It is also noted that MCA can be used with ‘cost’ as one of the criteria.

There has been ongoing debate as to the reliability of results generated from non-market valuation techniques, as the scope of the analysis can sometimes be at a hypothetical level. BCA, CEA, CUA and MCA offer an alternative technique to valuing environmental assets that may be beyond the realm of monetary quantification and can provide a more robust and methodologically sound analysis (Hajkowicz 2008).
2.3 Criteria for Non-Market Ecological Values

Ecological values of species are based upon their biodiversity and rarity value, and the complex interaction they generate between the biotic and the abiotic environments (Miller and Patassini 2005). Their values could be measured through their species richness, genetic richness or ecosystem richness (Nunes et al. 2003). Genetic diversity valuation techniques involve genetic difference, genetic distance and phenotypic trait analysis (Miller and Patassini 2005). Species diversity is measured through biodiversity index analysis, whereas ecosystem diversity is measured through keystone processes, health index, ecosystem resilience and stability analysis (Miller and Patassini 2005).

2.3.1 Assessing Ecological Values – A Gnangara Example

While there are various state-of-the-art methodologies available for bringing ecological valuation under the same denominator as the social and economic values, data limitations become a binding constraint for the case of species on the GGS. Risks posed to most of the species that are valuable and threatened may not necessarily be water-based. In fact, most species are more susceptible to fire hazards and threats from invasive species than from declining groundwater levels. Moreover, the risks posed to these species and ecosystems are only qualitatively identifiable at best at present.

In light of these limitations, the DST, being developed by CSIRO, aims to create a spatial mapping of the existing species based upon the qualitative risks that are influenced by land-use changes, and the consequential fire and invasive pest hazards and water levels. Further, it will derive an indirect, albeit imperfect, measure of value of species based upon the current and future restoration costs required to sustain a critical threshold level of species. These restoration costs include those of direct management intervention through variable and fixed inputs, such as manpower and other physical, biological and chemical inputs. Where critical threshold levels of species require groundwater levels on a part of the GGS to be maintained, the opportunity costs of water could become significant. The DST would have a built-in capability to derive these opportunity costs of direct management intervention through their impact on land and water management over the GGS.

The proposed preliminary criteria for incorporating the non-market ecological values into the DST are briefly explained as follow.

Two types of inputs will be gathered by the Department of Environment and Conservation (DEC) for incorporation into the DST. The first input involves identification and ranking of terrestrial vegetation biodiversity values across the GGS study area. This will be used to identify the extent of possible biodiversity values that could be retained into the future. Ranking will be done on a 100m X 100m grid based on criteria developed by the DEC and using spatial data obtained by the DEC. Table 2 below presents the format used for collecting data.

The draft flow chart compiled by DEC presented in Figure 7 shows possible criteria for the ranking of terrestrial biodiversity assets. This ranking, however, is not always definitive and could change as the threat perceptions on which these are based are dynamic and are land-use and water-use dependent. DEC will be seeking further expert ecological input in order to
finalise the criteria for the ranking. The spatial distribution of biodiversity assets based on the
draft criteria previously discussed is also presented as a map in Figure 8. Note, however, that
the spatial map presented in Figure 8 is based on very basic criteria and limited data set.

The second input will be designing a relationship between key biodiversity assets on the GGS
and the processes that threaten them. The approach for identifying the most cost-effective way
of preserving biodiversity assets involves classifying them based upon the nature of the asset,
how the asset ranks against other assets, the level of threats to the asset, the nature of the
relationship between the asset and threat, possible mitigation options, and the costs and
likelihood of success of these interventions. The key components of this analysis are:

- Asset/criteria: Refers to the actual asset being assessed, and includes association with
  other biodiversity assets (e.g. aquifer);
- Rank: Criteria used to undertake a basic assessment of biodiversity assets across the
  GGS study area, devised by DEC;
- Threat: Identifies the main threat(s) to the asset (e.g. decreasing groundwater,
  phytophthora control, land clearing, fire, etc);
- Functional relationship: Identifies the way the specified threat affects the asset (e.g.
  increase in clearing leads to decrease in species richness). Non-linear effects such as
  resilience and hysteresis would also be incorporated where applicable;
- Mitigation: Identifies preventative/management actions that will reduce/alleviate threats
  (e.g. retaining at least 30% vegetation cover, reducing the risk of invasive pests, etc.);
- Cost: Refers to the monetary value associated with each mitigation measure (subject to
  information being available); and
- Likelihood of success: Indicates whether or not the mitigation methods are likely to work.

Currently, DEC and CSIRO are working together to determine the most appropriate specific
format in which the ecological ranking criteria will be incorporated into the DST.
Table 2 Data collection format of priority ranking in each sub area

<table>
<thead>
<tr>
<th>Protection class *</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<td>P</td>
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<td>P</td>
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<td>P</td>
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Proportion of sub area in rank/protection class
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Proportion of sub area in rank/protection class
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</table>

# Rank: 1 (highest) – 7 (lowest) [note: ranking may change]

* Protection class: P = protected for biodiversity conservation, PP= proposed to be protected for biodiversity conservation, U = unprotected
Figure 7 Draft criteria for undertaking basic assessment of biodiversity assets in the GGS
Figure 8 Spatial distribution of biodiversity assets
2.4 Section Conclusions

In land-use and land-management planning, one way of incorporating the social and environmental value of assets into decision-making could be to assess them under a common denominator; in other words, estimate the value of such assets in monetary terms.

As presented in this section, there is a significant body of existing theoretical literature to guide us through the process of selecting the appropriate tool to measure the economic and ecological values of the assets associated with the GGS in monetary terms. However, not all values can be monetised to the satisfaction of the people who hold strong social values towards an environmental asset or lifestyle that may be lost due to the loss of the asset or value.

In these circumstances, alternative evaluation frameworks such as BCA, CUA, CEA, MCA or ecological value-ranking may be used to prioritise the importance of environmental assets using an ordinal scale system.

Nonetheless, these methods have their own limitations. It is therefore advisable to choose the technique that best suits the policy question at hand, as well as the availability of data and resources.

In DSS, which is part of this project, social, environmental and economic indicators are used as a means of aggregating values with different measures. This enables an assessment to be made of how different land-use and management changes may affect these indicators. Weighting may also be used to assess the sensitivity of assumptions to changes in land-use and management decisions.
3. ECONOMIC VALUE OF LAND WATER USE ON THE GNANGARA GROUNDWATER SYSTEM

This section summarises a collection of previous studies which have estimated the value of environmental and urban assets on the GGS and highlights their significant findings. The scope of economic value spans a number of assets including pines, wetlands, caves, private and public irrigated open space, horticulture, and threatened ecological communities. The section begins with the value of groundwater on the GGS itself.

3.1 The Economic Value of Groundwater to Major Groundwater Users

A report produced by Marsden Jacob (Marsden Jacobs Associates 2006) derived the economic value of the GGS water for six major users. These comprised the Water Corporation ($178.6M/yr), garden bores ($61.5M/yr), parks and recreation ($33.2M/yr), industry and services ($11.7M/yr), agriculture ($11M/yr), and rural lifestyle users ($4M/yr). The value of groundwater totalled $300M/yr.

In identifying the value of water for the six main users, the report made key assumptions about the different methods used to estimate the opportunity costs. For the Water Corporation, the opportunity cost of water was the long-run marginal cost (LRMC); for the agricultural sector it was the minimum of the costs of increased water efficiency and the loss made if production were constrained; for the backyard bores, the lower bound was the unit pumping cost and the upper bound was LRMC; for parks and recreation it was water use efficiency and LRMC; and for the industry and the rural sectors it was LRMC.

These estimates were based upon the marginal costs to the six users from 100% reduction in water use. The Water Corporation bears the largest cost of $178.6M/yr. In order to arrive at this estimate, the report assumed that the LRMC of water was $1.01/KL for the first 50% reduction and $1.5/KL for the next half of its current total water use of 152GL/yr. The second 50% water consumption was assumed to come from desalination plants.

Agriculture would suffer a loss of $11M/yr. In order to arrive at this value, the report assumed that the first 50% reduction in water availability led to a cost of $5.4M/yr and the second 50% reduction led to a loss of $5.6M/yr. This represented a loss in agricultural productivity at the rate of 25 cents/KL. While the total agricultural and horticultural revenue had been estimated to be much higher at $170M/yr, the lower losses in output water reduction were based upon assumptions of water-saving technology adoption. Inter-industry purchase of water from the integrated water supply scheme (IWSS) or through recycling were ruled out for agriculture, as the profit margins for agriculture were far exceeded by the LRMC of water for the Water Corporation at $1.01/KL and the costs of recycled water at $0.70/KL.

As is evident from above, there is a significant gap between the value of water in agriculture at $.25M/GL and the value of water to the urban consumer at roughly $1M/GL. However, losses from water restriction to these sectors could be much higher, depending
upon their ability to substitute or source water from elsewhere. Assuming that industries have no substitution capability, multipliers could be used to assess the impact of water restrictions. When both the direct and indirect impact of water reduction is taken into account, the losses to WA’s economy could be much higher. Tables 3 and 4 present multipliers for both primary and secondary agricultural industries in WA. These multipliers represent the impact of one unit reduction (or an increase) in output, income, employment and value-added in the agricultural sector on the overall economy of WA. Note that the income multipliers for the primary agricultural sector are much higher than the WA average multiplier representing 105 industries. Further, for the secondary agricultural industry, all the multipliers are significantly higher than the average multipliers.
### Table 3 Primary agricultural industry multipliers

<table>
<thead>
<tr>
<th>Primary agricultural industries</th>
<th>Output</th>
<th>Income</th>
<th>Employment</th>
<th>Value-added</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheep</td>
<td>2.23</td>
<td>3.46</td>
<td>1.46</td>
<td>2.41</td>
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<tr>
<td>Grains</td>
<td>1.65</td>
<td>3.71</td>
<td>1.49</td>
<td>1.51</td>
</tr>
<tr>
<td>Beef cattle</td>
<td>2.33</td>
<td>5.17</td>
<td>1.8</td>
<td>2.5</td>
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<tr>
<td>Dairy cattle</td>
<td>2.07</td>
<td>2.87</td>
<td>1.39</td>
<td>1.97</td>
</tr>
<tr>
<td>Pigs</td>
<td>2.3</td>
<td>4.06</td>
<td>2.49</td>
<td>2.35</td>
</tr>
<tr>
<td>Poultry</td>
<td>2.75</td>
<td>2.67</td>
<td>2.09</td>
<td>2.95</td>
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<tr>
<td>Horticulture</td>
<td>2.22</td>
<td>2.8</td>
<td>1.79</td>
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<tr>
<td>Average</td>
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<td>3.54</td>
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<td>2.26</td>
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<tr>
<td>WA average (105) industries</td>
<td>2.39</td>
<td>2.86</td>
<td>3.24</td>
<td>2.91</td>
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</table>

Source: Peter Johnson 2006, *Prime Research WA*

### Table 4 Secondary agricultural industry multipliers source

<table>
<thead>
<tr>
<th>Secondary agricultural industries</th>
<th>Output</th>
<th>Income</th>
<th>Employment</th>
<th>Value-added</th>
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<td>4.12</td>
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<td>Dairy products</td>
<td>2.97</td>
<td>4.75</td>
<td>11.26</td>
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<td>Fruit and vegetable products</td>
<td>2.69</td>
<td>3.74</td>
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<td>3.46</td>
</tr>
<tr>
<td>Oils and fats</td>
<td>2.53</td>
<td>4.18</td>
<td>11.85</td>
<td>3.88</td>
</tr>
<tr>
<td>Flour mill products and cereal foods</td>
<td>2.78</td>
<td>4.71</td>
<td>5.45</td>
<td>4.27</td>
</tr>
<tr>
<td>Beer and malt</td>
<td>2.48</td>
<td>4.59</td>
<td>12.04</td>
<td>3.05</td>
</tr>
<tr>
<td>Wine and spirits</td>
<td>2.75</td>
<td>4.33</td>
<td>5.68</td>
<td>3.92</td>
</tr>
<tr>
<td>Average (secondary agriculture)</td>
<td>2.76</td>
<td>4.35</td>
<td>8.09</td>
<td>4.26</td>
</tr>
<tr>
<td>WA average (105) industries</td>
<td>2.39</td>
<td>2.86</td>
<td>3.24</td>
<td>2.91</td>
</tr>
</tbody>
</table>

Source: Peter Johnson 2006, *Prime Research WA*

The value of water for garden bores was estimated to be 8 cents/KL for an individual bore water use of 800KL/yr. The economic value of bore water was estimated to be the lesser of the amenity value and the costs of water savings. Garden bores used about 67GL/yr, which, if supplied by the IWSS at $1.5/KL, would lead to a cost of $61.5M/yr.

Similar assumptions were applied in estimating the value of water for parks and recreation services that used 38GL/yr. The value of water to the industry and domestic and rural
lifestyle users, which used 4GL/yr and 2GL/yr respectively, was also based upon their water purchase from the IWSS at $1.5/KL and $6.5/KL respectively. Because rural lifestyle users do not have direct access to the IWSS, they would need to have water delivered to them.

The Marsden Jacobs report also estimated the present value of a 100% water reduction-related losses for 15 years for all of the above sectors at about $2.28B. The permanent costs to the Water Corporation from a 50% reduction in water availability were estimated to be $911M for a 15-year period, assuming a discount rate of 10% and cost of an alternate source of $1.5/KL. When the cost of an alternate source was reduced to $0.82/KL, the total costs were reduced to $456M. The long-term (15-year) cost of a 50% reduction in water availability was estimated to be $54M for agriculture, $57.9M (lower bound) for garden bores, $22.4M for parks and recreation, and $2.3M for domestic and rural lifestyle services.

If only the cost of using the water is considered and not the amount being used, findings from this report suggest that rural lifestyle users are currently the highest-value user, paying $6.5/KL, followed by urban and industrial users, paying $1.01–1.5/KL. Although it cost private bore owners 8cents/KL to pump water, if groundwater is no longer available these users would also have to pay around $1.5/KL in order to have access to the IWSS. This leaves the agriculture sector as the lowest-value user, with only 25cent/KL.

3.2 The Economic Value of Pines

In 2000, the Forest Products Commission (FPC) signed the Wood Processing (WESFI) Agreement Act with WESFI (since taken over by the Laminex Group) to supply softwood resources to plants in Welshpool and Dardanup (AustLII 2008). The Laminex Group (TLG) produces 133,000 cubic metres of medium-density fibreboard (MDF) panel products annually from its Welshpool factory, WA (Wells 2008). This product is made by utilising thinnings from local forests close to Perth, including from the Gnangara, as well as waste wood material in the form of chips and fines from local timber manufacturers, some as far away as Bunbury (Wells 2008). The factory supports direct employment for approximately 150 full-time personnel and over 200 sales personnel within the Perth region (Wells 2008). The factory runs an annual budget of approximately $50M, with most of this spent within the local economy. The combined payroll for the factory and sales personnel is greater than $25M annually (Wells 2008).

Later, in September 2002, the WA state government entered into a contract with Wesbeam which allows Wesbeam to have access to pine logs, mainly from the GGS, for a period of 25 years (Wesbeam 2004). Wesbeam is a forest industries company located at Neerabup, approximately 45km north of Perth and adjacent to the GGS pine plantation (Wesbeam 2008). Wesbeam markets a range of laminated veneer lumber (LVL) and LVL I-joist products for use in housing construction and other structural applications. The plant is worth around $85M and employs up to 140 people during full production (Wesbeam 2004).

The target stumpage supplied to Wesbeam and Laminex are around 120,000 and 100,000 tonnes/yr, respectively. The FPC has a target gross revenue of $5.8M/yr received from the two plants. With revenue from stumpage sales, FPC pays DEC around $1M/yr for
machinery, equipment and wages for fire control in the commercial pine plantation. This includes fire surveillance; control-burning; wilding control; establishing firebreaks, additional roads, gates and fences; and tending of the plantation area (J. Parker pers. comm. 2008). FPC also invests around $750,000/yr for the road maintenance associated with the harvesting operation (J. Parker pers. comm. 2008). A more detailed revenue and cost breakdown is presented in Table 5.
Table 5 FPC Annual revenue and costs of supplying to Wesbeam and Laminex

<table>
<thead>
<tr>
<th></th>
<th>Wesbeam</th>
<th>Laminex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target weight annual (tonnes)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>120,000</td>
<td>100,000</td>
</tr>
<tr>
<td>Target average stumpage revenue ($/tonne)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>34.49</td>
<td>16.50</td>
</tr>
<tr>
<td>Target stumpage annual revenue ($)</td>
<td>4,138,800</td>
<td>1,650,000</td>
</tr>
<tr>
<td>Costs ($/tonne)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Roading</td>
<td>1.09</td>
<td>0.57</td>
</tr>
<tr>
<td>• In-forest</td>
<td>0.52</td>
<td>0</td>
</tr>
<tr>
<td>• Admin</td>
<td>0.52</td>
<td>0.83</td>
</tr>
<tr>
<td>Target net revenue ($/tonne)</td>
<td>32.36</td>
<td>15.10</td>
</tr>
<tr>
<td>Production cost</td>
<td>12.74</td>
<td>32.14</td>
</tr>
<tr>
<td>Cartage cost</td>
<td>6.29</td>
<td>11.30</td>
</tr>
</tbody>
</table>

<sup>a</sup> 1 cubic metre = 1 tonne
<sup>b</sup> Value of stumpage ($/tonne) varies with size of stumpage.

Source: FPC Operation Report FY 2007/08

Other costs incurred by the FPC that are fully subsidised by Wesbeam and Laminex are customer production costs and customer cartage costs, which are around $4.7M and $1.8M respectively. Thus the total value of logs delivered to Wesbeam and Laminex from the pine plantations on the GGS is $12.3M. The estimates of revenue and costs associated with Wesbeam and Laminex are based on estimates from the FY2007/08.

### 3.3 Valuing Urban Wetlands: A Hedonic Property Price Approach

At least 80% of wetlands that were once present on the Swan Coastal Plain prior to European settlement have been cleared, filled or developed (Dec 2006). Since many coastal plain wetlands are surface expressions of the superficial aquifer (throughflow lakes), any lowering of groundwater levels will potentially impact wetland water levels (Lund 1995). Excessive abstraction of groundwater will result in a further decline of water levels in wetlands on the GGS. In order to make informed decisions about conserving urban wetlands in existing urban areas, it is useful to try and monetise their social and ecological values.

In 2007, CSIRO conducted a hedonic property price study of urban wetlands where data on individual properties (e.g. number of bedrooms, bathrooms, block size, etc) along with neighbourhood attributes (e.g. distance in metres to the nearest wetland, beach, city, local parks, etc) were regressed against property sales price (Tapsuwan et al. 2007). The objective was to determine which attributes had a significant effect on the sales price and to infer the marginal value of that attribute. Property prices can be affected by all of these...
location-specific environmental, structural and neighbourhood characteristics. The method relies on observable market transactions (property sales data) to place values upon the various characteristics that make up a heterogeneous product (Boxall et al. 2005). The HPM approach can estimate how much the value of a property will change if the property were, for example, closer to a wetland by a specified distance.

Figure 9 Example of how wetlands affect surrounding land values
Source: Tapsuwan 2007

In 2006 it was estimated that the marginal implicit price of being closer to a wetland by 1m, evaluated at the mean sales value in the western suburbs of Perth (City of Stirling, City of Vincent, Town of Cambridge) was $829. If there was more than one wetland within 1.5km of a property, the second wetland increased the property price by $6,081. For a 20ha wetland, the total premium on sales due to wetland proximity for all surrounding residences was estimated to be $140M, based on average property characteristics and median housing densities.

As part of the Perry Lakes Aquifer Replenishment Study, estimates from the HPM were used to estimate the capitalised amenity value of Perry Lakes to nearby properties. The value of Perry Lakes was estimated at $54M for the existing nearby houses, and approximately an additional $25M for properties proposed in a new residential development adjacent to the Lakes (McFarlane et al. 2007, 2008).

### 3.4 The Economic Value of Peri-Urban Wetlands

Peri-urban wetlands in the north-eastern corridor part of the GGS are currently being examined to determine their capitalised benefits to properties nearby. However, preliminary results have suggested a weak correlation between proximity of properties to peri-urban wetlands and property prices. This may suggest that urban wetlands have
higher value than peri-urban wetlands, and that to improve the economic value of peri-
urban wetlands, urban area may have to be developed around them. However, results
from the preliminary analysis may be biased, as in the GGS there are also fewer properties
that have been bought and sold around peri-urban urban wetlands. This is because large
parts of rural land in the GGS are nature conservation areas or commercial pine
plantations, which are crown land and are not bought and sold on the real estate market.
Further analysis in the study of peri-urban wetland values is required.

3.5 The Value of Urban Land

According to ABS statistics, the price of established homes in Perth increased by 10.5%
from 1999 to 2000, and from 2003 to 2004. This is an average increase of 3.1% per year,
slightly higher than the average annual increase rate in the 1990s of 2.1% (ABS 2004).
This price increase was attributed to migrants from interstate and overseas, coupled with a
rise in real income and not due to limited housing supply (ABS 2004). Figure 10 shows the
median price of established homes in Perth from 1977 to 2007. The figure shows that price
increase from 2003 to 2004 was much greater than that experienced from 1999 to 2000,
and from 2003 to 2004.

Figure 10 Median price of established house sales (June quarter) at five-yearly intervals in Perth
Source: REIWA (2008)

On the GGS, there are areas that are zoned urban, rural, urban deferred, industrial, parks
and recreation, and state forest, to name the major ones. Urban has the highest land value
as shown in Figure 11. Records of property sales data during 2006–07 showed that the
highest-priced suburbs on the GGS were situated close to the city or the beach.

The increase in demand for housing has resulted in construction of new homes and
infrastructure to support them. These infrastructures include electricity, roads, railways,
recreation areas and others. The Australian Bureau of Statistics (2004) stated that the
value of work done on roads, highways and subdivisions in the state had increased by 33.5% over the five years to 2003–04, from $752M to $1,005M. In real terms the increase was 19.9%.

3.6 Willingness to Pay (WTP) for Yanchep Caves Recovery Project

Caves in Yanchep National Park contain unique stygofauna, whose existence is seriously threatened by falling groundwater levels. Groundwater levels have fallen below the cave floors in many instances and the only way to ensure the survival of these species is to artificially pump water into the caves in order to raise groundwater levels. The capital cost of the infrastructure to extract, filter and inject water into the aquifer near the caves was around $1.7M and there is an additional $110,000 in operating costs each year. This expenditure needs to be justified in terms of ensuring that funding is being spent on an investment of sufficient value. A project was undertaken to measure the value that cave visitors derived from recreational use; and also the non-use values that non-cave visitors derived from knowing that water was being retained in the caves.

A survey by CSIRO found that Yanchep park and cave visitors were willing to pay a median park entry of $13.85, which represents an increase of $3.67 on the current adult entry fee. The median WTP for cave entry was $9.95, an increase of $3.45 on the current fee for adults. These increases would raise annual revenue by $184,800/yr for park entry, and $61,056/yr for cave entry. Although consistent with the user-pays principle, raising the cave entry fee only will not, unfortunately, be sufficient to cover the ongoing costs of the restoration project of $110,000 (which includes electricity, general maintenance and replacement of parts). Yanchep National Park may have to consider raising the park entry fee to help supplement the cost.

A study has been conducted by CSIRO and the University of Western Australia to estimate visitors’ WTP to support the Yanchep Caves Recovery Project (Perriam et al. 2008). A non-market valuation technique – contingent valuation – was used in the study to estimate what visitors to the park were willing to pay towards preservation of the water level in the caves using two payment methods. The survey used double-bounded dichotomous choice questions to measure respondents’ willingness to pay higher fees for entry to the park and for entry to the caves in order to meet the costs of a cave restoration project.

Estimates from the survey result showed that the median WTP for park entry was $13.85 per person, which represents an increase of $3.67 on the current fee (Perriam et al. 2008). Median WTP for cave entry fee was $9.95 per person, which is an increase of $3.45. These increases would raise annual revenues by $184,800/yr for park entry and $61,056/yr for cave entry. In order to raise revenue to cover the operating costs of the project, Yanchep National Park could either increase the fees at park entry level, or at both park and cave level, as increasing the fee at cave entry level by itself would not be sufficient to support the ongoing costs of the project.
In addition to the estimates of the WTP for entry fee, the model indicated that responses were influenced by peoples’ perceptions of the restoration project, their confidence in its success and whether or not they intended to visit the caves in the future. Those that were more positive towards the success of the project were willing to pay more.
3.7 The Value of Rare and Endangered Species and Threatened Ecological Communities

It is extremely difficult to credibly assign monetary values to a species’ worth. However, there are indirect ways of estimating these values. One indirect approach is simply to estimate how much it would cost society to restore the species to their original status in the event of a water-scarcity-related local extinction or depletion. DEC is currently undertaking restoration efforts to extend the Ellen Brook Nature Reserve to the west to include additional western swamp tortoise habitat to help increase its population to over 110. This exercise includes captive breeding, translocations and monitoring, and public education exercise. The total costs of this project are estimated to be over $3.5M in the next 5 years.

3.8 The Economic Impact of Sprinkler Restrictions

The value of groundwater resources can sometimes be reflected in the impact resulting from prohibition of their use. In Perth, a 2-day-per-week sprinkler regime has been in place since 2001. A number of householders have had to change their watering behaviour, or their gardens and lawns, to accommodate the reduced ability to water over the hot dry summer. Households with differential preferences over private green spaces are impacted differently. For example, some may prefer their gardens and lawns lush and green all year, while others may not worry about their gardens and lawns being brown during the peak of summer.

3.8.1 The Welfare Cost of Outdoor Water Restrictions

One way to estimate the impact of water restrictions is to measure the welfare cost. The welfare cost in this context is the opportunity cost of time that households spent on watering their gardens and lawns which cuts into their leisure time. Brennan et al. (2007) showed that the preferences towards lawn greenness, and the time cost or disutility associated with hand-held watering, would influence the extent to which a sprinkler restriction policy is effective. Although water restrictions are in place, the restriction only applies to sprinklers, and households could still supplement with hand-held watering. For households that prefer to keep the private gardens and lawns green, they will invest in the time to hand-hose. Water restrictions provide a disincentive to water with sprinklers but not to water with a hand-held hose. Hence, people with low value or low appreciation for their lawns will respond to this disincentive, while some others who value their green lawns over and above the time and effort ‘costs’ of water restrictions will not.

Brennan et al. (2007) argued that the effectiveness of such sprinkler regimes can be reflected in the household welfare impacts and the amount of water saved from each level of restriction. They estimated that the household welfare costs of a sprinkler restriction appeared to be less than $100 per season when the restriction level was set at 2 days per week, and the associated water savings were about 36% of current consumption. However, the welfare cost could range between $347 and $870 per season when a complete sprinkler ban was in place, and the associated water savings were about 42%. Basically, Brennan et al. (2007) showed that for every unit of welfare loss compared to
water-saving gains, the 2-day-per-week restriction regime was more desirable than a total sprinkler ban.

3.8.2 Household Willingness to Pay to Avoid Drought Water Restrictions

Another study that attempted to measure the welfare impact of water restrictions was conducted by Tapsuwan et al. (2007). This study applied CM to ascertain household WTP to avoid drought water restrictions. They found that households were willing to pay, on average, 22% more on their water usage bill to be on a 3-day-per-week restriction; in other words, they were willing to pay to be able to water their lawns and gardens one extra day per week. This indicates a reduction in utility associated with the current 2-day-per-week restrictions. The study also showed that households were willing to pay on average 50% more on their water bills to support sourcing new supplies instead of having to endure severe water restrictions. According to the ABS (2006), the average household occupancy in Perth is 2.5. If it is assumed that each person in the household consumes 105KL/yr (the average estimated by the Water Corporation), then the average household consumption would be 387.5KL/yr. This would imply that the average household water usage bill is $189/yr. Using WTP estimates from Tapsuwan et al. (2007), an average household would have to pay $41.58/yr more on their water usage bill to be able to water one extra day per week, and would have to pay $94.5/yr more to avoid severe water restrictions by supporting the sourcing of new supply. Considering that the usage charge is a small component of the total water bill (fixed component plus volumetric component), the total water bill increase per year would be relatively marginal.

3.8.3 Water Restrictions’ Impact on the Western Australia Economy

A study conducted for the Water and Rivers Commission in November 2002 by Economic Consulting Services (ECS) examined the impact of level 6 (a sprinkler ban) and level 7 (outdoor water use ban) restrictions on employment and the economy.

In the first year of introduction of level 6 restrictions, there would be an estimated reduction in business turnover associated with the garden and lawn industries of about $406M, with this rising to about $450m after 3 years. There would be associated gains in other industries (e.g. paving, bore installation) of about $22m, rising to about $64m after 3 years. The net annual loss was therefore estimated to be about $385M each year, to which the loss of Water Corporation sales of about $54m would need to be added.

Employment losses in the garden and lawn industries as a result of level 6 restrictions were estimated to be about 4,000 people in year 1, rising to about 4,500 in year 3, which would be offset by gains of between 137 and 470 in businesses that would benefit from the restrictions. Net employment losses were therefore estimated to be 3,830 in year 1 and 4,045 in year 3.

Anecdotal evidence was that the introduction of sprinkler bans in Sydney resulted in the immediate loss of about 5,000 jobs, so these estimates may be close to the actual value. Level 4 restrictions (2 days per week) have resulted in an estimated saving of 45GL/yr, and introducing level 6 restrictions was only thought to increase these savings to about 70GL/yr.
The ECS (2002) also estimated the impact of a complete outdoor watering ban except by watering can and an inability to fill swimming pools (level 7), which is much less likely to be needed but has wider implications than level 6.

In the first year of introduction of level 7 restrictions there would be an estimated reduction in business turnover associated with the garden, pool and lawn industries of about $750M, with this rising to about $480m after 3 years. There would be associated gains in other industries (e.g. paving, bore installation) of about $51m, rising to about $278m after 3 years. The net annual loss was therefore estimated to be about $700M in the first year, to which the loss of Water Corporation sales of about $77m would need to be added.

Employment losses in the garden, pool and lawn industries as a result of level 7 restrictions were estimated to be about 7,300 people in year 1, rising to about 7,600 in year 3, which would be offset by gains of between 350 and 1,800 in businesses that would benefit from the restrictions. Net employment losses were therefore estimated to be about 7,000 in year 1 and 5,800 in year 3.

While these estimates are relatively small in the total WA economy and workforce, the industries that would have been affected were very vocal in pushing for other methods than restrictions to close the supply-demand gap in the period 2001 to 2005, when the first desalination plant was built.

3.9 Economic Value of Groundwater Used to Irrigate Lawns and Gardens in Perth

Gardens and lawns are an integral part of households’ recreational uses and provide outdoor areas for recreation and relaxation. With water becoming a limited resource, irrigating gardens and lawns becomes a discretionary use for potable water compared with indoor uses, especially cooking and drinking. This is reflected in the price elasticity of demand (PED) for indoor and outdoor use of water in Perth, which has been estimated by Xayavong et al. (2008) to be about –0.32 and –1.052 for indoor and outdoor use respectively. However, the elasticity estimates are based on single-family residential unit data only. Householders that have given up maintenance of their private green spaces due to water restrictions can still choose to seek alternative green spaces in public parks and gardens. Most public green spaces in Perth are irrigated with bore water to reduce demand on the scheme water. Now with growing pressure of groundwater abstraction on the GGS, councils are being asked to improve their water-use efficiencies and to retire some areas from irrigation altogether. Two studies by Lieb (2007) and Lieb et al. (2007) provide estimates of the economic value of private and public bores, and the welfare impact of water restrictions on public green space (outlined below).

3.9.1 The Value of Private and Public Bores for Watering Green Space

In 2004–2005, CSIRO conducted a study of the potential for increasing the use of urban groundwater using backyard bores to relieve pressure on the reticulated scheme (Smith et al. 2005). The CSIRO found that in the previous 10 years a trend could be established showing that groundwater levels across Perth had fallen. If the dry climatic conditions continued or became worse, the increased use of backyard bores could further reduce
overall aquifer storage, which could lead to salt-water intrusion along the coastline and the loss of urban wetlands. If the management response to these adverse impacts is a withdrawal of bore access rights, then the consequences would include stranded bore assets and an increased demand for scheme water (Lieb et al. 2007). Since this study, the subsidy available for householders to install a bore that reduces scheme demand has been restricted to certain parts of Perth, and bore use has been restricted to only 3 days per week.

In 2006–2007, a study was conducted by CSIRO to quantify the value of groundwater extracted from the superficial aquifer for the purpose of irrigating lawns and gardens in the Perth metropolitan area. Lieb et al. (2007) estimated that the annual financial saving associated with using groundwater for the purpose of irrigating private and public lawns and gardens, instead of using scheme water, was $118M. The value to households, councils and other suppliers of public green space associated with adopting bores is considerably lower than this ($63M) because prices paid for scheme water use do not reflect the cost of supply augmentation. The total capital invested in bores for the purpose of irrigating private and public lawns and gardens was estimated to be about $520M. In addition, the capital value associated with investment in irrigation infrastructure for watering public green space is estimated to be $228M.

Lieb et al. (2007) suggested that whilst continued abstraction from the superficial aquifer for irrigating gardens and lawns could reduce the demand for scheme water and defer the need for the next drinking water source, thus delaying the increase in scheme water price, this gain needs to weighed against environmental impacts. The mechanism for transferring allocations between users – public and private use against the environment – will become imperative once the groundwater resource becomes more limited.

### 3.9.2 The Value of Public Green Space

A study by Lieb (2007), which measured the welfare impact of sprinkler restrictions on the irrigation of public green space by estimating household WTP to avoid such restrictions, was conducted in 2006. Lieb selected Knight Avenue Reserve in the north Perth suburb of Yokine for the study because the catchment area had a high population, with a number of people using public parks, and also a well-maintained public green lawn. If sprinkler bans were imposed, people would be able to detect a change in lawn condition.

Lieb (2007) found that the average respondent was willing to pay $460 per annual water bill to maintain a local green park in summer, which was an 87% increase in the average water bill. However, Lieb cautioned that some residents were concerned about the park being redeveloped and may have strategically overstated their WTP to send a message to the council regarding their disagreement with the redevelopment. For reference, other studies that have valued public green space in other cities have estimated much lower amounts. Lockwood and Tracy (1995) estimated that the average household WTP was only $26 for maintenance of an urban recreation park. Blamey et al. (1999) found that Canberra households had a WTP of $18 to avoid the city having brown lawns, but were willing to accept some brown lawns.
Despite the disparity in the amount households were willing to pay, the strong indication is that households would experience a certain amount of welfare loss (reflected in their WTP to avoid the loss) if public green space were to have resulting poor turf because it was watered less, assuming that there were no water-use efficiency gains that could be made. Hence, we can deduce from the above studies that there is significant economic and social value to irrigating public green space. However, these findings were based upon a partial survey where people were not made aware of the impacts on drying wetlands from the declining groundwater table.

3.10 Section Conclusions

This section has summarised a number of empirical studies that have tried to value urban and environmental assets on the GGS. In the context of groundwater, there are those that stand to gain and lose from restricting abstraction. Some may have higher costs than others if water use restrictions are applied. This is demonstrated through a number of studies that estimated the societal welfare loss from sprinkler restrictions to the community from not being able to maintain private and public gardens and lawns green. The impact of sprinkler restrictions also affects industries that rely on gardens and lawns, such as the nursery industry and lawn mowing contractors, by causing lower profit margins and job losses, as well as local councils that may have stranded assets by no longer being able to use their bores and reticulation systems.

Nonetheless, high-value urban wetlands and surrounding property owners stand to gain from restricting groundwater abstraction if this results in more water going into the wetlands. The benefits would also be felt by Yanchep cave visitors, as they would have a chance to see water in the caves. The aquatic ecological system, groundwater dependent ecosystems (GDE) and species that depend on wetlands would benefit from more water. However, as will be seen in the next section, such a gain in aquatic ecology may be at the expense of terrestrial ecology if the additional water were to come from increased burning of native vegetation.

The growing value of urban land on the GGS will have significant implications for the environment, as demonstrated through the higher property price premium of urban wetlands as compared to peri-urban wetlands. Assuming that the preference for the environment rises with income, the value of the environment in the vicinity of these settlements is likely to increase in future.

Although high density commercial forestry is known to significantly reduce recharge (and in cases of a shallow water table, net groundwater uptake) and there is an arrangement to remove the existing pines on the GGS by 2023, the forestry sector provides other social services, such as maintenance of roads and bushfire prevention that is worth around $1.75 M/yr. This contribution from the forestry sector should be considered when making decisions regarding future land-use decisions.

The summarised literature gives us some idea of the value of urban and environmental assets on the GGS, as well as the value of water to different users. Whether water should be provided to the highest economic value user is a key question, as removing water from
other users may result in a significant social and environmental impact that may not be reflected in economic terms. Some of the findings presented here will be incorporated into the DST in order to help policy-makers answer such questions and make better-informed decisions.

4. ECONOMIC COSTS OF DIRECT MANAGEMENT INTERVENTIONS FOR IMPROVING ECOLOGICAL OUTCOMES

Unlike some environmental assets, such as wetlands or pines, there is currently no direct market for ecological services on the GGS where their monetary value can be derived. In order to maintain the current levels of ecological services by the system in the face of declining groundwater levels, local or state government intervention will be required. The following section provides an account of the existing estimates of the economic costs direct management interventions.

4.1 Prescribed Burning of Banksia Woodland

On the GGS, the DEC conducts prescribed burning across 69,000ha of native woodlands and 22,000ha of pine plantation, the latter being completed with funding from the FPC (see section 3.2 for details). The controlled burns are primarily for the protection of assets (e.g. plantation timber, flora, fauna, biodiversity, recreational assets) and for the protection of life and property of neighbours to the publicly owned land. Currently, the primary objectives of prescribed burning do not include the production of water resources, although this should be investigated. Benefits that may result from more frequent burning include additional recharge that would benefit wetlands and GDEs.

Currently the native woodlands across the GGS are burnt during either autumn or spring on an 8–12-year rotation, with some areas left unburnt for longer. There is usually no burning from December through to March, as there is a high risk of a fire going out of control. Winter burning is becoming a possible option due to reduced rainfall in the drying climate. The needle bed under pine canopy is burnt on a 3–4-year rotation during winter or early spring to ensure there is minimal damage to the pine trees.

There are approximately 20,600ha of the Commonwealth Department of Defence (CDD) and unallocated crown land (UCL) on the eastern and northern sections of the GGS. Small areas of prescribed burning strategically placed around their infrastructure and military sites are funded by the CDD. The responsibility of fire management of UCL has been recently transferred from Fire and Emergency Services (FESA) to DEC across the whole state, but there has been no additional funding to the Swan Region for this activity on the Gnangara. There is the potential to burn UCL and defence lands more frequently if resources were made available.

Currently, the cost of fuel reduction burns (to prevent wildfires) for native bush on the GGS is around $15,000–$16,000 per average-sized burn and there are at least five bushland burns completed each year (cost $75,000/yr) when this cost is distributed over the
69,000ha area of native bush (P. Brown pers. comm. 2007). There is some capacity for the current prescribed-burning proposals to either be brought forward by one year and/or done as prescribed. Due to resource restrictions, not all of the proposed spring and autumn burns under native woodlands are completed. The DEC could complete 1 to 3 additional burns per season at an estimated cost of $25,000 per burn.

There is also a proposal to burn in autumn under the large, well-spaced and older pines in the Gnangara pine plantation to remove the stumps and dead wood on the ground to reduce the EHB food source. Such burning would supplement needle-bed burning in this southern plantation.

There are still some unknowns about the use of prescribed burning of native woodlands to increase recharge to groundwater and any impacts (positive or negative) on biodiversity. As part of the GSS, CSIRO (led by Richard Silberstein) is collaborating with DEC to study the effects of bush-burning regimes on rates of groundwater recharge. The DEC study will also examine the impacts of bush-burning frequency on biodiversity.

The most common health concern with bushfire smoke is from the resultant particles and other air pollutants such as volatile organic compounds (Hinwood et al. 2002). Some studies have shown that an increase in particle concentration has an associated increase in hospitalisations for respiratory diseases, including asthma and cardiovascular diseases (Voiget et al. 1998; Pope et al. 1991 cited in Hinwood et al. 2002). Damage to human health from fire and bush-burning can be evaluated by determining the total expenditure on respiratory illness treatment that had been spent by the health system as a cost directly attributable to poor air quality as a result of bushfires where the smoke blows over urban areas. This could be estimated from the number of patients suffering respiratory diseases that relate to resultant particles and other air pollutants generated by bush-burns, and the average hospital treatment cost for each case.

However, Hinwood et al. (2002) found no significant relationship between hospital attendance and admittance records for asthma at a time when a bushfire in WA had been burning for eight consecutive days, during which time particulate levels remained elevated. As there is no quantitative evidence that burning causes additional health costs, and it is uncertain whether more frequent prescribed burning would increase or reduce the likelihood of smoke haze over Perth (given that controlled burns will be carried out when the wind is blowing away from the city), it is proposed that no further effort be undertaken to calculate these costs.

People living on properties bordering the banksia woodlands are not only subject to health risks arising from burning but also to risks to their lives and assets. The main reason for fuel reduction burns is to reduce the likelihood of wildfires that may endanger lives and properties. It is likely that people are more accepting of smoke haze that may affect them for a few days if it reduces the likelihood of them losing their assets and lives.

An estimate of the impact of burning banksia woodland more frequently on groundwater levels has been made by Vogwill et al. (2008). An increased frequency of burning from 2.5% of the area per annum (2002–2004 practice) to 7.5% showed groundwater level rises of above 0.1m over most of the areas under native vegetation, and over 1m on the top of
ECONOMIC COSTS OF DIRECT MANAGEMENT INTERVENTIONS FOR IMPROVING ECOLOGICAL OUTCOMES

the GGS by 2014 relative to the base case under a moderately dry climate scenario (1976–2004 rainfall). Rises were modest compared with other land-use changes, such as removal of the pines, but because they could occur over large parts of the GGS the total storage volume increase was estimated to be significant – 135 GL compared with 256 GL for pine removal.

Until the DEC and CSIRO studies on the impacts of burning frequency on biodiversity and recharge are complete, the relative benefits and costs of increased burning frequency cannot be more accurately estimated than that detailed above.

4.2 European House Borer (EHB) Eradication Program

EHBs are exotic timber pests of seasoned pinewood that were first detected in Western Australia in 2004 (DAFWA 2007). They attack the dead parts of pine trees in the Gnangara pine plantation, but it is feared that they will migrate to pine furniture and untreated timber in nearby houses (such as timber-framed roofs) if not eradicated.

The spread of EHB can have negative economic impact on households, the pine plantation industry, the pine timber industry, the furniture industry, the transport industry and society as a whole. It is estimated that if there is no intervention to abate the spread of EHBs, damage costs nationwide could escalate up to $6B dollars over 100 years (DAFWA 2007).

Five proposed EHB management options are

- no control;
- mitigation through pine removal;
- pine treatment only;
- limited containment; and
- eradication.

Despite high biosecurity costs, eradication is the lowest-cost option among the five management scenarios, considering the cost savings from avoiding damaged houses constructed using structural pine that may require major restoration (DAFWA 2007). The public costs of the spread of invasive species are much higher than the private costs, as infestation on a private property paves way for future infestations on a much larger area through enhanced pest population. Therefore, an effective management program should involve an Australia-wide coordinated effort in surveillance, containment and disposal of infested material.

A BCA of the containment and eradication by the Australian Bureau of Agriculture and Resource Economics (ABARE) indicates a positive return of $64 for each $1 invested in containment and eradication throughout Australia. For WA alone, it is expected that over $7 of pine treatment and EHB damage costs could be avoided for every $1 invested in biosecurity measures (DAFWA 2007).

The EHB eradication program may have some implications for the management options for the Gnangara pine plantation. Pines are preferentially removed in infested areas affecting the 25-year delivery program of pines to the LVL plant at Neerabup. It also results in pines not being a future land-use option in harvested areas. However there may be some social resistance to pines being cleared entirely due to their implied social values. This is evident
from householders’ objections in the Ellenbrook estate, where they are campaigning for pines to be retained for amenity and shelter.

In conclusion, it may not be economically sensible to consider only the local costs and benefits of EHB eradication when the benefits are national in scope. As a result of this, EHB will be factored into the DST in the Gnangara sub-area and other areas where pines are a factor. While removal of pines is a direct option for mitigation of risks of EHB spread, adaptation options through biological control are also available. Ideally, the optimal management of pines should involve consideration of both options of mitigation of the risk and adaptation to EHB presence. However, due to the uncertainty associated with tracking their stock and treating them, the costs of biological control may far surpass the costs of mitigation, thereby rendering mitigation the only viable alternative.

4.3 Phytophthora Management

*Phytophthora cinnamomi* is a deadly soil-borne pest of the banksia species that is currently a threat to the banksia woodlands on the GGS. The loss from such an infestation is predicted to be as high as 95% for biomass and 60% for species diversity (P. Brown. pers. comm. 2008). Currently, about 256 plant and vertebrate species in the Swan Coastal Plain face the risk of extinction from this soil-borne pseudo-fungus, *Phytophthora cinnamomi* (Wilson et al. 2007).

Amongst the three given options of re-vegetation, phytophthora control and invasive predator control for the Swan Coastal Plain, Wilson et al. (2007) found that phytophthora control leads to the protection of the highest number of species – about 108 of them. Re-vegetation costs $301,118/km², phytophthora control costs $514,626/km² and predator control costs only $7,125/km². However, in terms of the cost-effectiveness of the three options, phytophthora control is the best option. Spending $2M on phytophthora control may lead to protection of about 49 species (Wilson et al. 2007).

When faced with the task of preserving biodiversity on the GGS, several options emerge. However, given resource constraints and the uncertainties associated with the effectiveness of such options, the choice of policy tools may not be straightforward. For invasive species, the available management options include prevention, control and eradication. However, it is rarely that only one of the options suffices to take care of the problem. Given the complex interactions of land-use changes on the GGS with the climate-induced shifting habitats of the species, it is important to further research these areas so that advanced preparedness could be maintained in wake of future invasions.

4.4 Yanchep Caves Recovery Project

Water pools in the Yanchep cave system have reduced because of the falling watertable of the superficial aquifer on the GGS. This is mainly attributable to reduced rainfalls (Yesertener 2007) but is also due to abstraction for irrigation of agriculture crops (southern caves) and pine plantations intercepting water upgradient (northern caves). Reduced burning of the areas around the caves was a possible cause, but the DEC has recently
carried out prescribed burns to reduce the effect of water use and interception by dense native vegetation.

The GDEs that are threatened by the fall in water levels include the banksia woodland and the cave pool fauna of Yanchep National Park (Davis et al. 2001). One type of GDE is stygofauna, the small invertebrates that live in the cave pools and associated aquifers using tuart root-mats as a food source. The GDEs that live in the cave systems require water levels to be high enough to reach the tuart root-mat in the cave pools.

In 2001, the WA government responded to the declining water levels by creating an interim recovery plan (IRP) for the caves (English et al. 2000). The IRP resulted in the caves recovery team constructing a pumping system that would re-fill five caves using water from the superficial aquifer down-gradient of the caves. Part of the aquifer is kastic limestone with a very high hydraulic conductivity (170M/day) requiring up to 3.6GL/yr of recharge to build a groundwater mound to support all the levels in caves, assuming that regional groundwater levels do not decline further (Yesertener 2006).

Costs for the pumping project’s infrastructure, including the costs of installing bores, a pumping station, pipes and a water treatment plant were met by grants from the DEC and the Department of Water (DOW). In total, these were estimated to be $1.75M – comprising $650,000 for the bore, pumping station and pipe work, and $1.1M for the water filtration system (P. Brown. pers. comm. 2008). The lifespan of capital investments is expected to be 10–15 years. The running costs, which include electricity, equipment replacement and general maintenance, are estimated to be $110,000/yr (P. Brown. pers. comm. 2008). The pump is capable of pumping more than 4.8ML/day into the caves, and it is hoped this will create a water pool so the water does not drain away. There should not be an overall impact on the superficial aquifer as it will be a closed system. Hence, there will be no net loss from the GGS (F. Felton. pers. comm. 2006).

4.5 Species Recovery Actions

The DEC is currently undertaking restoration efforts to extend the Ellen Brook Nature Reserve to the west to include more habitat suitable for the western swamp tortoise as a measure to increase its population to over 110. This exercise includes captive breeding, translocations and monitoring, and public education exercise. The total costs of this project are estimated to be over $3.5M in the next 5 years. However, there are significant risks associated with the failure of the project, thereby making indirect valuation of species based upon their restoration costs feasible for projects with limited risks only. Table 6 provides a breakdown of such costs.
<table>
<thead>
<tr>
<th>Cost of recovery actions ($000)</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administration of recovery team and program</td>
<td>$47,500</td>
<td>$49,000</td>
<td>$50,500</td>
<td>$52,000</td>
<td>$53,000</td>
<td>$252,000</td>
</tr>
<tr>
<td>Employment of chief investigator</td>
<td>83,600</td>
<td>87,300</td>
<td>90,700</td>
<td>94,200</td>
<td>93,800</td>
<td>449,600</td>
</tr>
<tr>
<td>Management of Ellen Brook, Twin Swamps &amp; Mogumber Nature Reserves</td>
<td>377,000</td>
<td>216,500</td>
<td>228,000</td>
<td>235,500</td>
<td>245,000</td>
<td>1,302,000</td>
</tr>
<tr>
<td>Tortoise population monitoring</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Captive breeding</td>
<td>331,600</td>
<td>339,100</td>
<td>346,100</td>
<td>151,500</td>
<td>152,600</td>
<td>1,320,900</td>
</tr>
<tr>
<td>Translocations</td>
<td>40,500</td>
<td>16,500</td>
<td>17,500</td>
<td>13,500</td>
<td>14,500</td>
<td>102,500</td>
</tr>
<tr>
<td>Education, publicity and sponsorship</td>
<td>35,900</td>
<td>25,500</td>
<td>26,000</td>
<td>26,500</td>
<td>27,000</td>
<td>140,900</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$916,100</td>
<td>$733,900</td>
<td>$758,800</td>
<td>$573,200</td>
<td>$585,900</td>
<td>$3,567,900</td>
</tr>
</tbody>
</table>

Source: DEC (Barb Wilson, 2008)
4.6 Wetland Augmentation

The GGS supports over 200 wetlands (WAWA 1995). Because most of these wetlands are surface expressions of the aquifer, their water levels are affected by abstraction, land use, land management (e.g. fire regimes) and rainfall variability (Davis et al. 2001). There have been growing concerns over the environmental impact of groundwater abstraction on the GGS, resulting in efforts to provide estimation of ecological water requirements (EWR) and environmental water provisions (EWP) for wetlands. The EWRs are the water levels required to maintain all environment values, while EWPs are the levels than best meet environmental, social and economic values, i.e. they may be less than the EWRs if the social and economic values associated with using the water are high in comparison with the environmental impact.

Lake Jandabup and Nowergup are two wetlands that have been subjected to artificial maintenance to maintain their EWRs. Lake Jandabup lies 22km north of Perth and is located within a nature reserve. The water level in Lake Jandabup has been affected by reduced rainfalls, changes in land use and groundwater abstraction for scheme water and private bores (Sommer and Horwitz 2001). One way of preventing Lake Jandabup and other wetlands from drying out is through artificial supplementation.

Lake Jandabup has been subjected to artificial water level maintenance through pumping groundwater into the lake. The Water Corporation is responsible for artificially maintaining Lake Jandabup (DoE 2004). Pumping of groundwater into the wetland ceased in autumn 1996, but recommenced in summer 2000 because minimum water-level criteria were not attained during the previous two summers (Sommer and Horwitz 2001). Water is pumped from the same Water Corporation bores (bores W210 and W220) as are used to supply scheme water. Therefore, the cost of pumping water into Lake Jandabup is the opportunity cost of using the same amount of water for the scheme (R. Harvey. pers. comm. 2008). If we assume that the opportunity cost is equivalent to the LRMC of sourcing water, then the cost of pumping water into Lake Jandabup can be up to $1.70/KL (in real dollar values for 2007/08, ERA 2008).

In the past 4 years, over 4GL have been pumped into Lake Jandabup. Details of water volume pumped into the lake each year are provided in Table 7, along with cost estimates based on LRMC. Water levels have continued to fall despite pumping (McHugh and Burke 2008).

<table>
<thead>
<tr>
<th>Financial year</th>
<th>Water pumped (GL)</th>
<th>Cost of pumping ($)</th>
<th>Value of water assuming LRMC ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003–2004</td>
<td>0.97</td>
<td>N/A</td>
<td>1,649,000</td>
</tr>
<tr>
<td>2004–2005</td>
<td>0.92</td>
<td>N/A</td>
<td>1,564,000</td>
</tr>
<tr>
<td>2005–2006</td>
<td>0.90</td>
<td>N/A</td>
<td>1,530,000</td>
</tr>
<tr>
<td>2006–2007</td>
<td>1.40</td>
<td>N/A</td>
<td>2,380,000</td>
</tr>
</tbody>
</table>

Table 7 Water volumes pumped into Lake Jandabup and estimated costs

The DOW has supplemented water levels in Lake Nowergup since 1989 (Beckwith 2006). The lake is part of a fauna reserve managed by the DEC and is believed to be the deepest wetland on the Swan Coastal Plain (Beckwith 2006). The lake situation continues to breach Ministerial Conditions and it is getting more difficult to maintain levels despite the ‘great cost’ incurred in augmentation using water from the Leederville aquifer (McHugh and Burke 2008).

Lake Nowergup requires water pumped into it at the rate of 1.4GL/yr at a monthly cost of $5000 and a fixed cost of $73,000 (Brock Ross, pers. comm. 2008). The main fixed costs comprise $23,000 in electrical equipment, $13,000 in motor pump, and about $10,000 each in pipelines and headworks.

Water is pumped into these wetlands due to the impact of falling groundwater levels on surrounding vegetation. Native vegetation may struggle to adjust to rapid changes in water levels during supplementation. This was observed in autumn 2002 when pumping ceased in Lake Nowergup and vegetation suffered a significant collapse as the water level dropped almost 3 metres in 6 months (DoE 2004).

With pumping efforts working against what is believed to be the natural change in the landscape due to the drying climate, the import policy consideration is whether artificial maintenance of wetlands will have benefits that will outweigh costs in the long run.

4.7 Perry Lakes Aquifer Replenishment

The Perry Lakes Aquifer Replenishment Study investigated the environmental and economic feasibility of artificially augmenting groundwater levels near two wetlands in Perry Lakes Reserve using treated wastewater. Some open water in the wetlands is currently being maintained using groundwater, but this is increasingly unviable and counter-productive as the pumping lowers groundwater levels around the lakes, which in turn increases outflow from the lakes.

A number of maintenance systems around Perth have either been, or are likely to be, switched off (e.g. Hyde Park, Mabel Talbot Reserve) due to falling groundwater levels and increased costs involved in maintaining some water in the wetlands. This raises the concern for species that depend on these drying wetlands for their survival.

Perry Lakes are located 7km west of Perth. Long-necked tortoises and waterfowl are the main fauna that would be impacted if the wetlands were to completely dry. There are also economic externalities associated with the destruction of wetlands, as houses in close proximity to wetlands have a 'proximity premium' within their prices (Tapsuwan et al. 2007).

The Town of Cambridge, in conjunction with the Water Corporation and CSIRO have been investigating the possibility of redirecting treated wastewater from the Subiaco Wastewater Treatment Plant through underground filtration galleries to create an underground water barrier that will slow natural groundwater flow to the sea. This is estimated to result in groundwater levels around Perry Lakes rising, which will then fill
the drying lakes with groundwater and help restore levels in areas that support public and private bores.

Estimations for a preliminary cost of the scheme:

1. A capital cost of supplying 5ML/day of treated wastewater to Perry Lakes Reserve of $907,000 (which includes a 20% contingency);
2. A capital cost of installing the galleries of $842,000 (including a 20% contingency);
3. On-going maintenance costs of 10 cents/KL or an annual fee of $182,000 to supply the area with treated wastewater; and
4. The annual operating cost of maintaining and monitoring the galleries (currently unknown).

The annual operating costs are causing some concerns for the council as it is unaccustomed to paying any outside body for its water, the costs having been included in park running costs. The cost of irrigating directly with treated wastewater is about 40 cents/KL as this includes chlorination. More details on the Perry Lakes scheme can be obtained in McFarlane et al. (2007; 2008).

The Perry Lakes Aquifer Replenishment Study is not the only project that is investigating the benefits of using treated wastewater. Other current water re-use projects:

1. Town of Cottesloe: Diversion of all stormwater into the aquifer, which has been funded by WaterSmart Australia and the Town;
2. Beenyup WWTP project: To inject highly treated wastewater of 25GL/yr into the Leederville aquifer for $256.1M, equivalent to a whole-of-life cost of $1.62/KL;
3. Brighton: Use of five communal bores using local groundwater to effectively eliminate the use of drinking water for private and public outdoor use; and
4. McGillivray Oval: Use of 1.8ML/d advanced secondary treated wastewater from the Subiaco WWTP to replace groundwater used for oval irrigation.

Re-using treated wastewater to supplement wetlands and reduce consumption from the IWSS is a possible option for helping WA reach its target for water reuse by 2020. However, there are still health and safety issues regarding the use of treated wastewater and the impact it could have on the natural environment.

4.8 Post-pine Harvesting Revegetation of Native Bush Land

With commercial pine not being the most desirable future land-use option on the GSS due to its negative groundwater recharge impact, re-vegetation of native bushland to replace what once was pine is being considered as a possible land-use option that could help maximise groundwater recharge and maintain ecological services.

Re-vegetation costs after pine harvesting has been calculated for soil types and areas where there remains some native understorey or viable (hard) seeds stored in the soil profile.
Complete restoration of land with little or no understorey or viable seeds has been estimated to cost about $10,000/ha. At the other extreme, some pine areas destroyed by wildfire have recovered to a moderately diverse ecosystem at no cost.

4.9 Section Conclusions

The amount of state funding invested in direct management interventions for improving ecological outcomes is a strong indicator of community support and government commitment to retain environmental assets and their ecological and social services. Nonetheless, some efforts are proving to be in vain as the effect from the drying climate is overriding the mitigation efforts, as demonstrated in the case of artificially maintaining wetlands.

Giving up efforts in some restoration projects may reflect a gradual change in community values towards certain environmental conditions as the memory of the earlier environment values is progressively lost with changing generations. It may also reflect a gradual acceptance of the profound impact of climate change and futility in trying to reverse the process. Trying intervention for a period of years may give people time to get used to the changes and also to feel better about having been active rather than passive acceptors of the change.

Some ecological systems, however, cannot be overlooked, particularly when invasive species are of concern. Public risks associated with invasive pests are usually much larger than the private risks and therefore cost-benefit considerations need to incorporate the full cost of pest spread on a much wider area in the long term.

The public may also accept local losses of habitat but not the total extinction of species as is at stake in the Yanchep caves.

5. REVIEW OF SOCIAL VALUES ON THE GNANGARA

While section 3 highlighted the main values of groundwater use and section 4 the main costs of ecological restoration, it is likely that the decisions over allocating scarce water and other economic resources would be influenced by the social perception of the trade-offs and the associated options. This is due to the nature of the decision-making process. It is often the subjective perceptions of the risks and values rather than the objective values that eventually matter in influencing public policies.

In this section, we explore social valuation aspects of the GGS. Values of a moral and ethical nature that are generally difficult or cannot be accurately measured in monetary terms can be considered as social values. One way of thinking of social value is that it is a feeling of attachment to places or objects (e.g. environmental goods like wetlands and GDEs) that embody meanings important to a community (Johnston 1992). Places of social value would be expected to be places that provide, for example, a spiritual or traditional connection between past and present, tie the past affectionately to the present, provide an essential reference point in a community's identity or sense of itself,
or have shaped some aspect of community behaviour or attitudes (Johnston 1992). Therefore, social values do not necessarily have to be use values. People can derive a feeling of satisfaction from the good without having to use it. These values are basically intrinsic.

Below is a review of literature and recommendations on what needs to be addressed.

5.1 Horticulture Production

In early 2008 the Department of Agriculture and Food Western Australia (DAFWA) commissioned a report called ‘Horticulture Precinct Feasibility Stage 1’, which focused on the strategic and economic advantages and disadvantages of an intensive horticulture precinct in close proximity to Perth. As part of the report, social values were also evaluated. The social advantages of preserving horticultural land reported include the preservation of a horticultural ‘feel’ near the City of Wanneroo; the preservation of 1,000 jobs in horticulture; enabling farmers to have easy access to a labour markets, and access for their families to urban amenities (e.g. education for their children); and enabling fresh, locally grown fruit and vegetables to be easily transported to Perth outlets.

The social disadvantages include precluding urbanisation in peri-urban horticultural areas, despite increasing pressure for the release of land for housing; crops grown in the precinct can be grown elsewhere (equity issues associated with subsidies); increased commuting times for people who have to build further from the city; and the need to create buffer zones to exclude odour, dust, noise and spray drift from adjacent housing areas. The precinct would require treated wastewater to be viable, as the groundwater in the peri-urban areas is already over-committed. This would require a government subsidy that would have an opportunity cost and would create inequality between horticulturalists supplying the Perth market.

In summary, the number of social, economic and environmental issues that would need to be considered is significant, and the social desire of some groups in peri-urban suburbs to retain their horticultural ‘feel’ is just one aspect of the decision.

5.2 Urban Expansion

According to statistics by the Western Australian Planning Commission (WAPC 2005), approximately 1.6M people (76% of the total WA population) are living in the Perth–Mandurah area and the Perth population is growing at a rate of about 22,500 people per year. The ABS projected that an additional 61,700 households will be formed in Perth over the period from 2006 to 2011, which equates to around 12,340 homes each year (WAPC 2006) to cope with the population growth. However, housing demand was found to grow faster than population growth due to decreasing household occupancy rates, which declined from 3.12 in 1971 to 2.5 in 2001 (WAPC 2006). Increases in population and housing demand resulted in an increase demand for essential services and community infrastructure such as water supply, wastewater and sewerage, electricity, gas, transport, education and health.
As the name suggests, essential services and community infrastructure are essential in any urban community. However, without sustainable design, this infrastructure may have negative environmental impacts. For example, about 430,000ha of land are occupied by roads and rail networks in WA (EPA 2007). Perth city has the highest road length per capita of any capital city in Australia, at around 10.7m per capita (Kenworthy et al., cited in EPA 2007). The construction of additional transport systems to accommodate urban expansion impacts the environment through loss or degradation of native vegetation, wetlands or other ecosystems from land clearing, atmospheric pollution from vehicle exhaust emissions, and generation of wastes (EPA 2007).

The 2007 State of the Environment Report identified a key concern that the current form of urban development is placing considerable pressure on the environment. Unsustainable planning can lead to environmental losses despite possible social and economic gains from reducing the pressure on land prices. The key here is to develop an urban plan that has minimal environmental impact, because social benefits from urbanisation rely not only on the provision of housing and essential services but also the state of the environment.

5.3 Community Perspectives about Bush Burning

Public perception seems to be a key factor in deciding whether there will be community support for controlled bush-burning, as stated by Rick Sneeuwjagt, DEC, Head of Fire Management (cited in Madden 2007).

On the GGS, the then Department of Conservation and Land Management (CALM) reported that as a result of prescribed burning to reduce wildfire fuel, the average size of fire had declined, as well as the number of property losses, fatalities and injuries (Braun 2002). Possibly as a result of the success of the prescribed burning, a community survey in Western Australia revealed that people perceived the risk of bushfires to be lower than that of home break-ins, road crashes, night and day time assaults and house fire (Odgers 2002).

From May to June 2008, the GSS organised a number of community forums attended by representatives from the state government, local government councils and interest groups, with experts discussing the issues on the GGS. The overall outcome of the forums suggested that there is community support for bush-burning if the objective is to maximise biodiversity values and prevent wildfires, as opposed to groundwater recharge (Sands 2008). Participants preferred water-use efficiency to control bush-burning as an option for increasing water availability.

5.4 Social Values Associated with Wetlands

Wetlands perform both ecological and social functions. In the case of the GGS, wetlands support GDEs. These GDEs include banksia woodlands, tuart trees, migratory waterfowl and microscopic vertebrates.

The social functions of wetlands can be related back to human use, both direct and indirect. A number of urban wetlands on the GGS have surrounding green space with
playgrounds, picnic and barbeque facilities, and walking tracks in which people can recreate. Other wetlands are open for water sports, such as Loch McNess in Yanchep National Park, which is open for canoeing. If these wetlands were to dry out, the impact of not being able to perform these activities is a social welfare or value loss, which can be monetised using various economic valuation techniques. However, there are other social values of wetlands that may not involve human use. These values are usually intrinsic, such as existence or bequest values. Wetlands also perform ecological functions by providing habit for GDEs and waterfowls.

Beckwith (2006) has summarised social values of wetlands on the GGS – namely Neerabup Lake, Lake Nowergup, Lake Jandabup, Lake Mariginiup, Lake Gnangara, Lake Pinjar, Lake Gwelup, Lake Claremont, Lake Monger, Herdsman Lake, Perry Lakes, Lake Jualbup and Jackadder Lake – as having the following in situ values:

1. Aesthetic values;
2. Aboriginal heritage values;
3. European heritage values;
4. Birding/nature observation values;
5. Recreational values, such as picnicking, walking, running and cycling;
6. Education and research values; and
7. Complementary land-use values, such as parks and pathways.

A number of wetlands on the GGS have Aboriginal heritage values and are registered as Aboriginal sites because the area was traditionally used for hunting, gathering, performing ceremonies and was used as campsites, burial sites, birthplaces and totemic places for indigenous people. Indigenous artefacts have been found in a number of wetland sites.

With regard to wetland augmentation through artificially pumping water into the wetlands, Beckwith (2006) reported the outcome of her workshop with stakeholders, experts and local community representatives. State agencies were generally supportive of artificially pumping water into wetlands while other stakeholders viewed it as a stop-gap measure until a permanent solution was found. There were also conflicting attitudes towards preventing acid sulphate soil occurrence from drying wetlands through supplementation. Some were supportive of it but others viewed it as an over-reliance on a technological fix.

Findings from the GSS community forums suggested that the communities were supportive in principle of allowing wetlands to dry and adapt with the naturally occurring seasonal cycles (Sands 2008), but expressed concerns of acidification. However, they were not supportive of wetlands drying from human activities, such as over-pumping, and nor were they supportive of wetlands with high biodiversity and social values being allowed to dry out (Sands 2008).

### 5.5 In situ Social Values of GDEs

Beckwith (2006) conducted a study on in situ social values that may be negatively impacted by declining water levels on the GGS through interviews with stakeholders, experts and local community representatives. She reported that participants to the
survey attached a variety of in situ values to the GDEs on the GGS. These included nature-based recreational activities, historic values, Aboriginal cultural values, aesthetic or amenity values, sense of place, educational and scientific values, and intrinsic values.

More specifically, Sands (2008) summarised findings from the GSS community forums that there was restriction of access to places of environmental significance in order to protect biodiversity for future generations. This suggests bequest values associated with the GDEs. There were also suggestions proposing nature corridors to connect Whiteman Park with Gnangara Park to provide important ecological linkages for flora and fauna.

A study by Savant (2008), which was commissioned by the DOW to survey the community's views towards a number of contentious issues on the GGS, reported that 57% of the people surveyed (total number of Perth people surveyed was 401) ranked serious and moderate threats to biodiversity as being

- feral animals and weeds (both 94%);
- dieback (93%);
- clearing and fragmentation (91%);
- climate change (88%); and
- burning (69%).

This ranking is for general biodiversity, not groundwater-dependent biodiversity.

Savant (2008) found that support for more frequent burning was mixed: with 34% indicating yes; 26% don't know, and 40% no. In some ways this reflects the lack of professional as well as lay understanding of the impact of more frequent burning on recharge rates and on biodiversity in both terrestrial and aquatic environments.

5.6 Section Conclusions

In this section we summarised a number of studies that have evaluated social values and social indicators related to a number of land-use or land-management practices. In terms of social indicators, we looked at the impact on employment, housing prices, and housing and food supply/security as social indicators of urbanisation or maintaining a horticulture precinct near Perth.

In terms of social values, we have identified the factors that may influence community support or hesitation towards controlled bush-burning, as well as the social use and non-use values associated with wetlands.

Despite a number of social value studies conducted in the past and summarised in this section, there are other social values – particularly those associated with the pine plantations, horticultural land, native bush conservation areas and general recreational areas on the GGS – that have not been fully identified and need further evaluation. These values are likely to be diverse amongst sections of the community and are also liable to change with time. Therefore, surveys need to be devised that are repeatable so
these changing attitudes can be monitored as climate change, land-use change and generational change takes place.

Current gaps in the knowledge of social values on the GGS include:

1. Sense of place: Emotional bonds to specific places and why are they important;
2. Intrinsic values or non-use values attached to the GGS;
3. Nature-based tourism values;
4. Recreational activities that promote community wellbeing;
5. Social values associated with the feeling of connection to nature;
6. Social values concerned with protecting fauna and flora in urban environments;
7. Non-indigenous historical and cultural heritage values;
8. Water security, including the diversity of water sources that Gnangara provides – the superficial, Mirrabooka, Leederville and Yarragadee aquifers;
9. Social preferences for individual houses and gardens rather than units, and more use of public open spaces (which affects both potable and self-supply water use through backyard bores);
10. Food security, given recent rises in food prices and protectionism
11. Social values associated with the pines; and
12. Other values such as education (pers. comm. Janine McDonald, 2008).

To address some of the gaps identified above, a survey of community attitudes towards land uses of the GGS needs to be carried out to fill in the current knowledge gaps.

6. FUTURE ECONOMIC AND SOCIAL VALUES OF LAND AND WATER USES ON THE GNANGARA

As previously mentioned, the Perth–Mandurah population is growing at around 22,500 people per year. In keeping with this forecast, the Water Corporation’s Water Forever program predicted the water demand for residential and other users in the Perth area to be 265GL/yr by 2020 and 294GL/yr by 2030 (Water Corporation 2008). In order to ensure future water security, the Water Corporation is looking into different water supply sources, such as surface water, groundwater, seawater desalination and treated wastewater, among many other possible options.

Since more than 50% of the IWSS is supplied by groundwater, a number of land-use and land-management scenarios are being considered by the GSS for sustainable use and replenishment of groundwater on the GGS. Potential positive and negative economic and social values will be created due to these policy changes. For example, many wetlands currently have no public access due to the rural nature of the surrounding area. Once the land is re-zoned for urban development, these wetlands will have recreational value to the community living in the new, surrounding housing area. It is therefore important when considering future land planning to incorporate social and economic considerations into the policies governing land releases.

6.1 From Changes in Land Use

The main land-use changes under consideration on the GGS include

- urbanisation (housing and commercial) of horticultural land;
• development of a new horticultural precinct on previous pine plantation and private land;
• re-vegetating with either native bush or grassland to increase recharge and/or biodiversity;
• re-vegetating previous pine plantation with commercial wood production such as eucalyptus;
• using bushland for active recreation; and
• limestone quarry, industrial zones and civic institutions such as cemeteries and prisons on bushland or previous pine plantation land.

Beckwith (2006) indicated that there would be future social values associated with changes in land use, particularly the social values gained from land re-zoning around wetlands. Urbanising around wetlands, and providing public access, such as walking trails, would increase the social values of wetlands to many people.. Living near wetlands impacts on the value of properties as previously discussed. Beckwith (2006) also indicated that there would be potential for on-farm tourism ventures around wetlands if the land were to be re-zoned to special use or rural living.

With urban areas encroaching upon the Wanneroo horticultural area, there may be potential economic and social gains if agri-tourism is considered. In times of drought and uncertainties about the availability of water for irrigation, farmers can diversify their business and possibly increase their cashflow through agri-tourism. The community can benefit from having a place to go for recreational and education activities, as well as a source of fresh and potentially cheaper food.

Unfortunately, groundwater levels under agricultural areas have also fallen, leading to increased costs in re-drilling bores, lowering pumps and pumping, and also reduced the efficiency of sprinkler systems. A decrease in water availability threatens the viability of horticultural and irrigated areas of public open space, which in turn poses threats to associated economic and social values (e.g. employment in water-reliant industries). Agriculture contributes about $175M in annual revenues (Marsden Jacob Associates, 2006). However, the overall impact to WA of a reduction in local agricultural production could be much higher when multiplier effects and food security concerns are taken into account.

Multiplier effects relate to the repercussions of a unit of demand created by the sector on the industries that provide it with input, and the subsequent net demands generated by these industries on the entire economy including agriculture itself. This is the ‘backward’ multiplier effect. A ‘forward’ multiplier effect arises when an extra unit of agricultural output stimulates further output on the sectors dependent upon it. When both backward and forward multiplier effects are accounted for, the contribution of the local agricultural sector could be much more significant to the economy of WA. Multiplier effects occur for other land and water uses as well (e.g. drinking water supplies, commercial forestry, recreation, etc).

The possible reallocation of existing horticulturalists to a dedicated precinct area and supplying them with treated wastewater for irrigation would result in increased production and establishment costs, which in turn would impact on business viability unless the government is willing to subsidise certain costs (Science Matters 2008;
Elmahdi and McFarlane 2008). Some crops require a seasonal workforce to be viably grown, so moving to districts with more affordable land and available water can incur costs of transporting workers to the new location (if there is a location available). Also, with estimated increases in fuel and energy prices in the future, this could lead to an increase in the crop price, which in turn could affect the social welfare of consumers.

The Wanneroo area therefore has natural advantages in terms of available infrastructure, closeness to markets, a suitable climate and a ready labour force. Against this is the decreasing availability of water and urban encroachment, with many farmers wanting to realise the capital gain in their land by selling to urban developers.

Horticultural areas distant from Wanneroo find it hard to compete for perishable crops (e.g. fresh leafy vegetables) and tend to grow lower-value crops or maintain pasture for grazing. If given an opportunity they may be able to switch to urban vegetables and get better returns on their land and water assets. Under climate change, the most suitable climate for Wanneroo crops may be located south of Perth, which may also be closer to the central vegetable and fruit markets at Canning Vale.

An absence of suitable soils and affordable water can reduce horticultural yield and diminish the potential of relocation of horticultural to some areas (e.g. clayey soils in the Harvey irrigation district). Urbanisation of peri-urban land may create some employment opportunities but probably not as much as horticulture itself. Consolidating urban areas will reduce the cost of commuter travel compared with retaining rural enclaves within the city however so the ‘food miles’ advantage can be more than offset by ‘commuter miles’.

6.2 From Changes in Land and Water Management

With declining groundwater levels and limited capability to make sudden changes in land use to increase recharge, land management regimes are considered a short-term alternative to increasing groundwater recharge. Land management regimes include increasing the frequency of bush-burning, adopting low leaf area index (LAI) land use after pine removal, switching to crops that require less water (crop factor in irrigation needs assessments) and improving the efficiency of irrigation water use.

The most critical parameter affected by land management regimes is net recharge from rainfall, less transpiration and evaporation. Improving land management regimes can help increase net recharge in the short term, and planning can help in the longer term. With commercial timber plantations, the management choice is thinning. Thinning regimes to increase recharge need to take into account the economic impact on long-term timber production and wood quality. Of similar significance is the choice of type of post-pine re-vegetation, and the intensity and frequency of bush-burning. Increased burning frequency to increase recharge needs to be cost-effective and may result in excessive smoke blowing into populated areas. It may also have an adverse biodiversity impact. To find the acceptable balance over time is complex due to community perceptions of risk (e.g. from wildfires) that changes depending on the time since the last major fire.
Water abstraction for private and public use is also of importance to management considerations. While many public uses may be deemed higher value (e.g., drinking) to society in general, there are often alternative sources available to a public authorities that may not be available to landholders. When most of the groundwater zones on the GGS are over-allocated, this not only threatens the security of public water supply and irrigation of crops, but also threatens the GDEs. The amount of environmental water provision, in this case, will be guided by societal valuation of the GDEs and an understanding the potential consequences of losing threatened ecosystems.

When there are uncertainties associated with future land use management, it could result in adverse economic consequences for the agricultural sector. Water supply and land use uncertainty impacts investment decisions by farmers who may be considering investing in water-saving technologies, further expansion of output, and changes to crop mix. When information related to future water-use and land-use policies is not forthcoming, the sunk costs associated with capital investment create option values of waiting for more information, thereby significantly delaying investment. In other words, farmers would rather not invest in efficient irrigation technology as they may be unsure of whether their land would be rezoned in the future and result in their investments becoming redundant. The repercussions of such delays could mean that farmers persist with water-inefficient technologies, thereby further aggravating the water scarcity situation. Water trading and appropriate water pricing might help avoid farmer resistance by encouraging the most efficient water users to adopt better irrigation technology.

6.3 Climate Change

Climate change is threatening the extinction of valuable ecosystems all over Australia. Elmahdi et al. (2008) noted that under the current climatic changes in the Lower Murray Darling region of Australia, the low inflows have become an ongoing issue. This is especially true given the uncertainty of climate change and its impact on water allocation, flow variability and hydrological parameters such as water table levels and evaporation rates on the floodplain or by native bush. Consequences include diminished irrigation, reduced yield, deteriorated drinking water quality, and damaged floodplain and ecosystem health. This is also true elsewhere (e.g., the Colorado River Basin, parts of Pakistan) where increasing water scarcity under drought conditions represents a major natural resource management challenge. In most cases, preserving or restoring these affected ecosystems requires continued efforts that come at a significant economic, social and environmental costs to society.

Land-use options available for the GGS are invariably linked to future climate change scenarios. However, consideration of long-term effects of climate-change-related impact on species diversity requires identifying the types of species that would be most adaptable to such climatic fluctuations and therefore suitable for re-vegetation. Fitzpatrick et al. (2008) studied the climate change related impacts on 100 species of banksia in WA and estimated that 66% of banksia species are projected to decline in all the climate change scenarios they considered. Moreover, between 5–25% of the species are projected to suffer losses up to 100% by 2080.
Climate change also influences the susceptibility of native forests by making them more prone to some invasive pests. Climate-change-induced migration of native forests causes stress in terms of sub-optimal soil type, elevation and terrain, thereby increasing the forests’ susceptibility to pathogens (Chakraborty et al. 1998). Phytophthora cinnamomi may spread through the banksia woodlands on the GGS as a result of increased soil temperature. The loss from such an infestation is predicted to be as high as 95% for biomass and 60% for species diversity (P. Brown. pers. comm.)

6.4 Land and Water Use Options for Climate Change Mitigation

Land and water management on the GGS poses challenging questions regarding the future price of energy, the cost of transportation from increased urban sprawl, and carbon footprints. For instance, any cost-benefit analysis of removing the horticultural precinct away from the urban fringe to accommodate urban expansion needs to incorporate the externalities of the increased transportation costs of delivering fruit and vegetables into the city, as well as the effects of urban sprawl by not enabling the land conversion to take place. However, technological options present certain optimistic scenarios as well. The Perth Seawater Desalination Plant (PSDP), currently the biggest single source water source for IWSS, produces 45GL of water per annum, which accounts for as much as 17% of Perth’s water needs (Crisp 2006). The plant uses about 21.1MW of energy per year, which is equivalent to the annual electricity consumption of 30,000 households, or one-third of the amount of energy used by a Boeing jumbo flying continuously (Crisp 2006). However, most of its energy needs are currently being generated by a wind farm.

On 11 March 2008, Australia’s ratification of the Kyoto Protocol came into effect, which binds it to reducing its carbon emission to 8% above its 1990 emission levels by 2008–2012. Australia is planning to adopt an emission trading scheme by 2010. In light of this policy, future land- and water-use options cannot ignore the opportunity cost of carbon sequestration or added costs of carbon emissions. Pine plantations on the GGS sequester significant amounts of carbon. For instance, Pinus pinaster in Gingin can sequester about 165 tonnes of CO₂ equivalent per hectare over a period of 15 years (DEH 2006). Given that currently the certified emissions reduction credits trade between $8 to $14 per tonne of carbon in the developing countries, the value of carbon sequestered amounts to $154 per hectare per year at the price of $14/tonne. This is still low compared to the value of water that could be recharged through the replacement of the pines with a high recharge land use (e.g. grassland or low-density banksia woodland).

Land use dedicated to urbanisation is an attractive option for enhancing recharge, but ignores the impact of urban sprawl, or low-efficiency or duplication of infrastructure, which is costly in the long run. Urban sprawl leads to additional commuting time and energy requirements, and has also been blamed for health impacts such as obesity. A World Bank study compared 37 studies across the world and ranked Perth as the most inefficient city in the world in terms of transportation infrastructure (McCrudden et al. 1998). Perth spends about 17% of its combined private and public wealth on passenger transport. With wider urbanisation along the north-west and north-east corridors, this
trend could worsen. Urbanisation should ideally be concentrated around employment nodes. When new areas are re-zoned for urbanisation without regard to their ability to generate a high level of employment self-sufficiency, such regions may not be sustainable in the long term and can only lead to more infrastructure and additional energy consumption.

6.5 Section Conclusions

There are significant links between climate change and land- and water-use options, but little guidance or experience from other jurisdictions about how to incorporate climate change mitigation and adaptation options into land- and water-use policies. The viability of a possible land-use or management option under the likely future climate needs to be considered, especially for long-term (e.g. 40-year commercial tree plantations) and ‘irreversible’ decisions (e.g. urbanisation).

The impact of urban sprawl on energy requirements must be weighed against the gain in water recharge through expanding the urban area. Similarly, the choice of revegetation with native species for increasing biodiversity needs to consider the threats of climate change and global warming to the survival of these flora and fauna. Temperatures, drought, relative humidity and fire are all expected to change in the future. The migration of invasive pests that may be induced by global warming could threaten not only communities like the banksia woodland, but also destroy the biodiversity that they support.

Renewable resources such as wind energy to power water abstraction from well fields located in grasslands, which maximise recharge, may offer an option to simultaneously meet water needs without increasing the carbon footprint.

Urbanisation on the GGS should not be mainly for the purpose of groundwater recharge, as the impact of urban sprawl can be costly to society and the environment. Ensuring there is efficient infrastructure design and sufficient locally generated employment in each urban node is also crucial to the decision to urbanise.

7. CONCLUSION, DISCUSSION AND RECOMMENDATIONS

Based upon the above sections, the following key conclusions are reiterated:

- In land-use and land-management planning, one option for incorporating the value of social and environmental assets into decision-making is to bring the assets into a common denominator; in other words, representing the value of such assets in monetary terms.

- As presented in section 2, there is a significant body of existing theoretical literature to guide us through the process of selecting the appropriate tool to measure the economic and ecological values of the assets associated with the GGS in monetary terms. However, not all values can be monetised to the satisfaction of those within the community who hold strong social values.
towards an environmental asset or lifestyle that may be lost due to the loss of the asset.

- In these circumstances, alternative evaluation frameworks such as BCA, CUA, CEA, MCA or ecological value ranking may be used to prioritise the importance of environmental assets using an ordinal scale system. Nonetheless, these methods have their own limitations. It is therefore advisable to choose the technique that best suits the policy question at hand, as well as the availability of data and funding.

- Section 3 presented a number empirical work that has tried to value urban and environmental assets on the GGS. In the context of groundwater, there are those that stand to gain and lose from restricting abstraction. Some may have higher costs than others if water-use restrictions are applied. This is demonstrated through studies that have estimated the societal welfare loss from sprinkler restrictions to the community from not being able to maintain private and public gardens and lawns. The impact of sprinkler restrictions also passes through to industries that rely on gardens and lawns, such as the nursery and lawn mowing industries, by causing lower profit margins and job losses, as well as local councils that may have stranded assets from no longer being able to use their bores or reticulation systems.

- Nonetheless, high-value urban wetlands and surrounding property owners stand to gain from restricting groundwater abstraction if this were to result in more water going into the wetlands. The benefits would also be felt by the Yanchep cave visitors as water adds to the aesthetic qualities of the caves. The ecological system, groundwater dependent ecosystems (GDEs) and species that depend on wetlands would benefit from more water.

- The growing value of urban land on the GGS will have significant implications for the environment, as demonstrated through the higher property price premium of urban wetlands as compared to peri-urban wetlands. Assuming that the preference for the environment rises with income, the value of the environment in the vicinity of these settlements should increase in the future.

- Although commercial forestry is known to extinguish recharge to the aquifer and there are plans to remove the pines over the GGS, the forestry sector provides other social services, such as the maintenance of roads and bushfire prevention worth around $1.75M/yr. This societal contribution from the forestry sector should not be overlooked when making decisions regarding sustainable land-use decisions.

- The literature summarised here gives us some idea of the value of urban and environmental assets on the GGS, as well as the value of water to different users. Whether water be provided to the highest-value user or not is one key question that needs careful consideration. Taking water away from other users may result in significant social and environmental impacts that may not be properly reflected in economic terms. Some of the findings presented here will
be incorporated into the DST in order to help policy-makers answer such questions and make better-informed decisions.

- The level of state funding invested in direct management interventions for improving ecological outcomes is an indicator of government commitment to retain environmental assets and their ecological and social services. Nonetheless, some efforts will be in vain, as the effect of the drying climate is overriding the efforts by the community, as demonstrated in the case of artificially maintaining wetlands. Shift in priority over certain restoration projects may reflect a gradual change in community values towards certain environmental conditions as the memory of the previous environment values is lost with changing generations.

- Some ecological systems, however, cannot be overlooked, particularly when invasive species such as EHB are of concern. Public risks associated with invasive pests are usually much larger than the private risks, and therefore cost benefits considerations need to incorporate the full costs of pest spread on a much wider area in the long term.

- There are significant links between climate change and land- and water-use options but there is little guidance available from other areas on how best to incorporate future climate change mitigation and adaptation options into land- and water-use policies. Impacts of urban sprawl on energy requirements must be weighed against the gain in water recharge through expanding urbanisation. Similarly, choice of re-vegetation in future needs to incorporate the threats faced by flora and fauna from climate change.

- Renewable resources such as wind energy present potentially low cost options to simultaneously meet the energy needs to operate well fields located in grasslands, which increase recharge rates without increasing the carbon footprint.

- Urbanisation options should not be water-centric and should incorporate the impact of urban sprawl, the ability to sustain employment and to avoid duplication of infrastructure and social ills.

This report brings together the existing knowledge on economic, ecological and social values on GGS. It also highlights the economic costs associated with maintaining some of the ecological services provided by the GGS. The economic value of the groundwater may not appear higher than the price of securing unlimited water from the sea. However, the advantage of pumping fresh groundwater near the demand centre (e.g. north-west corridor) is attractive from both cost and energy perspectives.

Due to the declining water levels of the GGS, the economic, ecological and social values of the GGS have been compromised. For example, water levels have fallen around the Yanchep caves and have led to unique cave-dwelling fauna being threatened with extinction and the need to develop expensive systems to augment groundwater levels. Water levels have also fallen in many conservation category wetlands affecting the ecological services they provide. Some of these wetlands also
have artificially maintained water levels. An attempt was made to protect important wetlands by requiring groundwater levels in their vicinity to be maintained as a Ministerial Condition of groundwater abstraction for public water supplies. However, the drying climate has resulted in declining groundwater levels even after bores have been switched off. As a consequence, 43 shallow bores near environmentally sensitive wetlands have been shut down. The capital investment in well fields and associated water treatment and distribution system are currently redundant. This adds extra cost to society by requiring groundwater for public water supply to be replaced by other sources (including other groundwater schemes) and ultimately resulting in householders paying higher water prices.

There is evolving concern about food security and food mileage impacts of declining groundwater table and the potential of rising energy prices to make them real. Currently, there is a shortage of large-scale models that incorporate the impact of rising fuel prices on predicting the net impact on a particular sector. However, partial equilibrium models that considers the impact of fuel prices on transportation costs only when predicting the costs of importing vegetables from the eastern states or abroad may give misleading results. Consequently, there is a need to further explore this area.

The impact on the ecosystems is equally important and their value to society must not be evaluated in a static environment that ignores the changing future ecological value of a species or landscape. The current societal value of such species or landscapes may not be high, but a growing urban population may place a higher value on the existing ecological stock around Perth and the value of those species and landscapes may become increasingly higher. There is a limited understanding about how social norms and preferences evolve over time when faced with resource scarcity and extinction of certain environmental goods that were previously deemed a necessity. Intergenerational shifts in valuation and preferences may render certain assets useless or less desirable, thereby shifting society's focus over what to preserve and what to let go. Such considerations, coupled with the fact that ecosystems are prone to exhibit non-linear dynamics, such as resilience and hysteresis, make inter-sectoral water allocation policies a much more difficult exercise. An enhanced understanding of these phenomena would help towards policy choices that would allow for smoother transition towards water-scarce environments in future.

In order to overcome the shortcomings in our current knowledge of social values attached to major land uses on the GGS, CSIRO will conduct a 'sense of place' study that would be a survey of community attitude towards land uses, including the pine plantation, native bush, conservation parks, and wetlands. The objective is to ascertain the broad community's feelings and views towards different types of land uses, such as geographical significance, aesthetical qualities, recreational uses, intrinsic (bequest and existence) values, and reasons for having or not having certain types of land uses. Findings from this survey will help policy-makers better understand the community's views on whether there exists a strong resistance towards letting go of a particular type of land use and whether the problem can be overcome by simply providing a substitute location.

Urbanising new areas, as well as increasing the density of inner suburbs, as preferred policy options needs to be revisited. Growing urbanisation may seem to have a much
higher value than other land uses on which it depends, specifically horticulture and the environment. However, if urbanisation threatens the availability of other land uses, its own growth could eventually be constrained. This effect multiplies when the carbon offsets of a bigger environmental region in Perth are considered. There are no current studies to guide us through these questions.

The pattern of urbanisation is also important. Urban sprawl is associated with many economic, environmental and social issues, but owning their own stand-alone home and associated garden remains a goal of property buyers if expansion of suburban areas is an accurate guide. Yet social valuation aspects that depend upon peoples’ preferences for lifestyle choices fail to incorporate this endogeneity in preference formation in the long run. People’s preferences may be resilient to revision and the market may not serve as a good servant to lead us through a sustainable path. Therefore, in order to tackle a problem with a global nature and scale, further exploration is needed in the realms of institutional mechanism design that could overcome the above limitation. Such avenues are being explored for optimal management of the GGS.

It has become evident from this exercise that there are significant shortcomings to our understanding of the key economic, ecological and social existing and potential future values. Failure to fill this gap in understanding could be detrimental to the objective of providing a sustainable strategy for the GGS and for Perth consequentially. The existing literature on the impact of water restrictions provides a valuable guideline for considering land-use management trade-offs. However, further research is needed to overcome some of the limitations of ‘multiplier analyses’ in order to be able to make more accurate predictions that capture substitutability between inputs and the ability of the industries to adapt to water limitations. A computable general equilibrium analysis (CGE) approach may offer a better alternative to evaluate these trade-offs.

Finally, it is important to identify the key stressor on the GGS. It is clear from this study that climate change considerations would impact possibly every aspect of land- and water-use decision options in future for the GGS. Failure to incorporate realistic climate change scenario may cause significant irreversible societal impacts.
REFERENCES


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