Gnangara Sustainability Strategy

An across-government initiative

Groundwater – Biodiversity – Land use

Ideal nutrient and water practices on a green-fields horticultural site at Carabooda – opportunities and constraints

July 2009

Investigation and report by Peter Eckersley in collaboration with Department of Agriculture and Food WA Horticulture team and Doug Hall of Irrigation Australia. *Project funded by Department of Water for the Gnangara Sustainability Strategy.*

Department of Water
Department of Agriculture and Food WA
Department for Planning and Infrastructure
Department of Environment and Conservation
GOVERNMENT OF WESTERN AUSTRALIA
WATER CORPORATION
CSIRO
Forest Products Commission WESTERN AUSTRALIA

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Objective

The objective of this report is to identify the circumstances (e.g. water price and regulatory environment) under which vegetable growers in the Shire of Wanneroo might be expected to adopt socially desirable water use efficiency and nutrient management, given the opportunity to relocate to a designated horticulture precinct at Carabooda.

Summary of findings

This report identifies the circumstances under which vegetable growers are likely to adopt best practice water and nutrient management if given the opportunity to relocate to a designated horticulture precinct.

The study uses a spreadsheet bio-economic model of a vegetable growing farm business in Carabooda to estimate the impact of water price and the use of good irrigation and fertiliser practices on net farm returns and the return on total capital invested.

Based on the level of profitability normally required to attract and/or retain investment in the vegetable industry, it is concluded that:

- It is economic for a grower to adopt best practice water management if the changes in Distribution Uniformity are made when an old system is fully depreciated. Best practice water management also achieves improvements in nutrient management/cost
- It is not viable for a grower to adopt best practice, pay $88c/kl, plus a cost of 40c/kl for water storage at a new site.
- It is unlikely to be more expensive to produce and transport vegetables from 150km as the additional cost of freight is balanced by the lower capital cost of land. (Assuming other costs/availability such as labour are equal)
- Growers would be unable to pay any rent for leasehold land if the cost of water is $88c/kl and there are storage costs
- A combination of bore and recycled water could be economic, the percent of recycled water possible being driven by potential reductions in fertilizer costs and increases in yield. Augmentation of bore water with recycled water could enable current growers at Carabooda to maintain production despite reductions in bore water allocations. This

may be a more efficient use of recycled water compared with developing a new horticultural precinct on former pine land
- Increasing cost of water will drive an increase in hydroponic production.

The report provides evidence that, if the potential nutrient savings associated with improved distribution uniformity and use of compost were proven to be realisable in a commercial setting, economically, environmentally and socially sustainable vegetable growing could be achieved on the Gnangara mound.

Background for study

Combined allocations of groundwater in the Gnangara Mound are believed to total 20 per cent more than the sustainable yield [1]. There are also public concerns about nitrate pollution of groundwater caused by leaching of compounds from fertiliser applied by irrigators ("Manure 'poisoning' bore water", The West Australian Monday 16 March 2009 page 5).

The management framework (both legislation and policy) for the Gnangara Mound has been unclear (Water Corporation 2009). The Gnangara Sustainability Strategy (GSS) taskforce is a cross-Government initiative and includes all agencies responsible for the management of land and water within the Gnangara groundwater system. The GSS aims to achieve a water and land management framework for the Gnangara groundwater system that is socially acceptable, economically viable and environmentally protective. This Strategy is built on existing knowledge, updated groundwater modelling and studies in biodiversity, horticulture, land use planning, forest management, future uses of Crown land and prescribed burning.

This study is designed to build on the recommendations in the report to DAFWA for the GSS "The Feasibility of a New Horticulture Precinct on the Gnangara Mound" (Science Matters 2008).

Intensive horticultural precinct

Land currently used for horticulture in the East Wanneroo area is proposed for urbanisation (East Wanneroo Land Use and Water Management Strategy). The GSS is considering the feasibility of an intensive horticultural precinct close to Perth would replace part, or all, of the East Wanneroo groundwater management area horticultural zone.

Doug McGhie ("Science Matters") and his team completed a report "The Feasibility of a New Horticulture Precinct on Gnangara Mound" (Science Matters 2008). This report considered that it was important to retain productive capacity for some lines of perishable produce close to Perth and supported a potential precinct on Crown land (ex pine plantation) at Carabooda. A further benefit of such a precinct is that it matches the availability of, with the need for, labour for high value and high labour crops, especially tomatoes and strawberries and also intensive 'small' crops such as spring onions and silverbeet.

[1] Gnangara Sustainability Strategy (In press)

This Carabooda land had been identified in planning studies for this purpose. The challenge is that:

- water in the area is fully or over allocated,
- currently recycled water which could be available in the future is deemed by growers to be too expensive, and
- government policy currently requires that recycled water compete with other sources of water i.e. no subsidy for recycling, and that irrigators be required to pay the same price as other water users.

There are a range of reasons why growers may not have adopted efficient water and nutrient practices. These include technical capacity, uncertain tenures and low cost of water compared with capital cost for best practice infrastructure. A green-fields site offers an opportunity to require good practice.

The purpose of this study is to bring together studies and experience within the Department and externally to inform the economics of ideal water and nutrient management for a green-fields site.

Completed studies

Research, development and extension have cumulatively investigated, proven and communicated many aspects of water and nutrient management in the vegetable industry on the Swan Coastal Plain over many years. Examples of the significant publications and tools produced by DAFWA are:-

- Crop irrigation requirement calculator (DAFWA 2004). – a program which uses crop factors and long term weather data to calculate the irrigation requirements of a range of crops;
- Phosphorus and nitrate loss from horticulture on the Swan Coastal Plain. (Lantzke, 1997)
- Principles of vegetable nutrition on sandy soils of the Swan Coastal Plain. (Phillips et al 2001).
- Survey of Irrigation Efficiencies on Horticultural Properties in the Peel-Harvey Catchment (Milani 2001) reveals the potential for improvement in the industry.
- Compost production and use in horticulture (Paulin & O'Malley 2008) indicates how compost improved soil moisture levels, reduced nitrogen leaching and increased marketable yield of lettuce and broccoli.
- Irrigation and fertiliser guidelines for strawberries on sandy soils (Phillips and Reid 2008) - Webnote

Current DAFWA projects

One of DAFWA's goals is an economically viable vegetable industry on the Swan Coastal Plain with minimised off-site environmental impacts. To encourage Swan Coastal Plain vegetable growers to adopt improved land, fertiliser and water management practices DAFWA is delivering:

1. Guidelines and extension activities relating to current best practice for land, fertiliser and water management

2. A software/internet based expert system for use by growers to determine irrigation

3. Products used to replace groundwater abstraction, to reduce nutrient leaching and to improve soil management

The above DAFWA projects incorporate about 10 externally funded projects involving field experiments to test specific hypotheses.

Objectives for water and nutrient management on a green-fields site

Creation of a green-fields precinct using a leasehold tenure system (DAFWA 2008) would potentially allow Government to determine specific rights and obligations in respect of water and nutrient use. The objectives this could satisfy would depend upon the form of these rights and obligations.

One objective that has long term appeal is to conserve water by substituting recycled water for the groundwater currently extracted by irrigators. The water conservation impact would be reinforced by pricing the recycled water as closely as possible to it's opportunity cost i.e. the value of that water in it's highest value alternative use.

This could simultaneously satisfy the further objective of limiting (to a sustainable level) accessions of nitrate from horticulture to groundwater. Quantifying this objective would require both an adequate understanding of the groundwater system and a monitoring system capable of accurately measuring these nitrate accessions.

Growers have already been told that poultry manure will be banned throughout the year from 2011 onwards.

Relevant characteristics of horticultural businesses operating on Gnangara mound

Agriculture on Gnangara Mound is extremely diverse in both type and scale.

The Department of Water uses 57 different descriptors within the eight categories of licensed agricultural water uses in Gnangara Mound (Marsden Jacob Associates 2006). Almost 50 different crops which fit the descriptor 'vegetables' were produced in Gnangara Mound in 2005-06 (ABS 2008).

There is a correspondingly wide range in both the economic value of water and users' individual capacity to pay for water. Indicative estimates of 'water margin' for 16 crops (Marsden Jacob Associates *op cit*) ranged from $-616 to $+2,108, showing how the viability of users will have varying degrees of sensitivity to the cost of water.

The GSS should take this into account, as it can help us improve economic and social outcomes.

Horticultural farmers in Carabooda operate farms ranging from small (<4ha) and medium (4ha to 20ha) to large (> 20ha) and have a range of enterprises including vegetables, strawberries, avocadoes and nurseries (DAFWA, 2008).

Most vegetables produced in WA with highly mechanised systems requiring large parcels of land (e.g. potatoes, onions and carrots) are grown in other parts of south west Western Australia. Four relatively distinct combinations of vegetable crops at different scales can be found on Gnangara Mound (Phillips 2009 pers comm). Phillips describes these as:

1. Bulky supermarket lines of leafy vegetables (iceberg lettuce, celery, broccoli, cabbage and Chinese cabbage) grown on farms in the order of 40 ha in Carabooda or Baldivis.
2. Fruiting crops such as tomato, capsicum and egg plant, sometimes grown in combination with strawberries or lettuce.
3. Gourmet salads such as fancy lettuce, spinach and red beet grown for processors, grown on farms of typically 4 ha.
4. Specialty crops such as radish, spring onions, snow peas, silver beet and beetroot and strawberries, all of which are labour intensive and are typically grown on even smaller parcels of leased land, closer to urban areas.

Of the above farm types No. 1 uses the most land, hence has the largest requirement for land to replace properties being redeveloped for residential and industrial purposes in East Wanneroo. Phillips considers that specialist strawberry growers have even more reason to take up land in the dedicated horticulture precinct under consideration here, with around 60% of WA strawberry production being currently located in East Wanneroo.

The need for labour is a major reason for horticulture businesses locating within the Perth metropolitan region. Market gardens such as type No. 1 above typically employ about 800 hours of labour per hectare per year (Gartrell *op cit*). Total labour employed on strawberry farms is approximately 1,600 hours per hectare per year (Phillips pers comm.).

Of the above types of horticulture business, while all are potential occupants of the precinct considered by McGhie, those most likely to do so are those with the highest returns per hectare and the highest use of labour.

If the cost of water rises for any reason, the small but increasing greenhouse sector of the industry will have greater capacity to pay than field-based growers. Greenhouse production is often linked with hydroponic practices. Hydroponic practices allow higher production per unit of water and per unit of land. In many other parts of the world, the greenhouse and hydroponic sector is very large and gaining in market share (John Burt pers comm.). It can be expected that, with predicted climate change, this sector will continue to increase its market share in Perth.

Good practice water and nutrient management – parameters and constraints

Maintaining an adequate level of moisture in plant tissues is critical to plant health and production. As this must be achieved in a highly variable environment the horticulture industry requires water at varying flow rates and a supply system with significant storage capacity.

Good practice water management in vegetable growing is essentially about achieving the most economic level of sprinkler distribution uniformity (DU), scheduling and monitoring of crops and environmental conditions (atmospheric and soil). Brennan and Calder (2006) show how the optimal quantity of water use per hectare decreases substantially as distribution uniformity is improved. There is a halving of water use as distribution uniformity is increased from 52% to 91%.

What is "most economic" needs to be considered from both private and social perspectives i.e. the market gardener needs to achieve a return that is competitive with alternative investments; society needs to achieve fair priced and healthy food plus good environmental and social outcomes.

Brennan and Calder (2006) quantify some crucial relationships:

- between capital investment (in sprinkler system design) and mean DU (%);
- between mean DU (%) and net economic return ($ per crop ha);
- between economic gain from adopting the sprinkler system with the highest DU ($ per crop ha) and mean DU, in both green-fields and "sunk capital" situations;
- between mean DU and water saved (ML per crop ha); and
- between DU and nitrogen leached (kg per crop ha).

Good practice irrigation entails use of a sprinkler system that achieves 85 per cent DU, and uses sensors and live micro-climate information (e.g. on-site precipitation and evaporation rates) and weather forecasts to schedule waterings. Based on modelled water use, and using evidence of nitrogen leaching associated with different water application rates, Brennan and Calder estimated that increasing DU from 65 per cent to 90 per cent reduces nitrogen leached by about 16 per cent. Nitrogen fertiliser is responsible for about one third of total fertiliser cost, so this increase in DU allows a fertiliser cost reduction of 5 per cent.

Good practice nutrient management on the sandy soils of the Swan Coastal Plain is about providing adequate plant nutrition without jeopardising long term sustainability (vegetablesWA 2007). The vegetablesWA Good Practice Guide is an excellent resource for farmers. The chapter on nutrient management explains the need and techniques for soil, tissue/sap and water testing. These enable growers to select the best nutrient sources, and rates and timing of application. The grower's aim is to maximise marketable yield per unit of inputs, and the proportion of applied nutrients that are used by the crop rather than "leaking" to the environment.

Designers of any regulations to achieve a socially acceptable level of pollution (or nutrient "leakage") need affordable means of measuring, and a target level of, nutrient loss to groundwater, or percentage utilisation of applied nutrients in product sold.

Constraints

The major constraints to good practice water and nutrient management are:

1. Absence of a water market, which is needed to communicate the opportunity cost of water;
2. The capital cost of replacing inefficient irrigation equipment with a system that achieves adequate distribution uniformity;
3. The cost of farmers acquiring the knowledge and skills needed to manage their irrigation and production systems efficiently.

Synopsis and economic implications of good practice water and nutrient studies in the horticulture industry on Swan Coastal Plain

Synopsis

Good practice water studies include those undertaken on:

- Irrigation uniformity
- Web Based System for Vegetable Irrigation (Chris Denby & Vegetables WA)
- Improving lettuce quality through adoption of sustainable production practices – HAL project VG97083. This project extended DAFWA findings on scheduling irrigation of carrots and broccoli, to lettuce and provided an optimal mineral fertiliser schedule for lettuce. Recent unpublished work suggests that daily deeper irrigation limited to 10mm has the potential to use water more efficiently without compromising yield. (Peter O'Malley)
- Enhancing fertiliser use efficiency for transplanted vegetables – HAL project VG04018. This project produced mineral fertiliser guidelines for lettuce, celery and selected brassica crops on sandy soils
- Sustainable strawberry production – HAL project BS97003. Project includes research on irrigation and nutrition schedules for strawberries
- Commercialising Australian bred strawberry varieties in Western Australia – HAL project BS01006. Project further develops irrigation and nutrition guidelines.
- Facilitating the development of the strawberry industry in Western Australia - HAL project BS05001. Project demonstrates irrigation and nutrition guidelines to growers on a commercial scale over three seasons.
- HAL project VG08020 Optimising Water & Nutrient Use On Vegetable Farms (Peter O'Malley) - funding approved Dec 2008
- Developing guidelines for Environmentally Sustainable Use of Mineral Fertilisers - HAL project VG07036. Currently underway this project is producing step by step blueprints for vegetable nutrition in the absence

of soil amendment with organics and testing methods to effect widespread adoption.

- Develop Compost Based Vegetable Production Practices (Bob Paulin)

Economic implications

Sprinkler distribution uniformity studies have shown that to achieve an acceptable standard requires design by a competent irrigation system designer and installation of a system capable of that level of performance. Both of these can increase cost, but that may be offset by higher returns due to increased yield and reduced water and power consumption, depending upon the pricing of water and power (electricity or fuel).

Brennan and Calder (op cit) report that expenditure above $10,000 per hectare is generally associated with higher DU, but there are many sprinkler systems that have high DU with substantially lower investment cost. Over the cost range $5,000 to $7,000, there is substantial variation in mean DU between different systems.

Brennan and Calder (op cit) concluded that twice as much lettuce could be grown with the most efficient system for the same amount of water, and (net) returns would increase by $1,500 to $2,000 per hectare per crop, compared to the least efficient system studied. The extent to which these increased returns are realised by farmers depends on the existence of a water market (i.e. water price greater than zero), whether farmers are aware of this opportunity for efficiency gains, and whether farmers are paid by weight or volume.

Over the next few decades, the economic incentive to improve efficiency of water use and fertiliser use is likely to be reinforced by anticipated higher energy and fertilizer costs due to climate change policies (Australian Government, 2008) and oil depletion (Akehurst, 2002).

Certification and monitoring

Irrigation Australia offers certification for irrigation professionals in all sectors of the industry – operator, manager, installer, contractor, agronomist, retailer and designer.

Use of certified irrigation professionals should help to raise the efficiency of water use. Requiring irrigators to do so would be a useful mechanism to apply in a green-fields precinct.

Balancing private and public costs and benefits

The establishment of a green-fields horticulture precinct as described above is a new concept that requires testing and evidence before it will gain the support of community, industry, other stakeholders and, ultimately, the elected government.

Part of the evidence required involves estimates of the economic impacts, on market gardeners, of implementing good practice water and nutrient management. Others will need to estimate the economic, social and environmental impacts on other stakeholders before government can weigh up all these factors.

This paper now reports on a desk-top study to estimate the economic impacts on market gardeners and Perth consumers.

The precinct proposal requires market gardeners to substitute re-cycled water (from the Water Corporation's planned Alkimos wastewater treatment plant) for self-supply pumping from Gnangara Mound groundwater. The full cost of the recycled water has been estimated at $0.88 per kilolitre (Science Matters 2008), which is an order of magnitude greater than the cost of extracting groundwater.

A crude estimate is made of the economically optimal combination of investments in water, irrigation equipment, soil conditioners and fertilisers. An estimate is also made of the level of public subsidy that would be needed to leave market gardeners neither better nor worse off after making a shift to the proposed precinct with certain conditions attached.

Economic model of a Carabooda market garden

An Excel spreadsheet model "VegoutSwanA.xls" (Gartrell 1998) was modified to create an economic model of a market garden business that would be reasonably representative of the industry, as discussed in page 4 above (VegoutCarabooda2.xls).

The model was designed to test the sensitivity of net farm returns to water price, irrigation equipment cost (as a proxy for DU, hence water use efficiency), vegetable prices, fuel & electricity prices etc.

The aim was to identify the conditions of water price, sprinkler distribution uniformity and irrigation system capital cost under which market gardeners in the City of Wanneroo might be expected to adopt socially desirable water use efficiency and nutrient management.

The combination of enterprises is based partly on a combination of agricultural statistics (Australian Bureau of Statistics, 2008), water/bore licensing information (Marsden Jacob Associates, 2006) and advice from experienced horticulture professionals about the types of enterprise most likely to want to locate in a green-fields horticultural precinct at Carabooda (Dennis Phillips pers comm.).

Water use is based on that shown in Gartrell (1998), but responds directly to a specified level of DU. Assumptions about the average level of DU (hence water use efficiency) in current industry practice, and in a 'good practice' scenario, were based on advice from Vegetable Development Officer Rohan Prince.

Input prices are those in Gartrell (1998), projected to 2009 using agricultural indices for respective farm input categories (chemicals, fertiliser, fuel, labour etc) (ABARE 2009).

The farm selected has a total area of 33 hectares, of which 1.5 hectares are occupied by infrastructure or otherwise unusable. In a full year the crops produced are lettuce (42 ha), broccoli (21 ha), celery (16.8 ha) and cabbage (4.2 ha). Lettuce is alternated with any one of the other three crops, and on average a total of 2.67 crops is grown on each hectare in one year. This level of cropping intensity can be exceeded by good managers, but is a compromise between good practice and what is typical of the industry at present. Extension research shows that adoption of best practice is usually a drawn out process; unless the changes in practice are simple, low-cost, low-risk and soon increase cash returns, it may take a decade or two before the majority of the industry has made the changes.

Scenarios

A base case scenario is selected in which

- DU is 65 per cent, which equates to 72 per cent of what is achievable with ‘good practice’ (an efficient but affordable irrigation system);
- Total water consumption is 13.8 ML per reticulated hectare; the licensed application rate for vegetables is 15.5 ML/ha/a, and for winter vegetables is 5 ML/ha/a (Marsden Jacob Associates *op cit*).
- The irrigation system costs $6,000 per hectare to purchase and install;
- Water is delivered to the crop from a bore; electricity consumption is the amount required to move water through a total head of 100 metres (static head + friction losses + delivery pressure);
- Zero volumetric charge for the water used;
- Land valued at $150,000 per hectare;
- Buildings valued at $500,000;
- Machinery and equipment valued at $323,750;
- Net income split 50:50 between the two partners in the farm business;
- Income tax at rates applying in 2008-09.

The base case scenario produces, after tax, a net return of $18,642 per year, which equates to 0.3 per cent on total capital invested, excluding capital appreciation. Equivalent returns to total capital in broadacre industries have averaged 0.6 per cent in Australia during the last six years, 2002-03 to 2007-08 (ABARE 2005, 2008). The range of values has been from -0.4 to 1.5 per cent. In the long run, return on capital (before capital appreciation) in the vegetable industry is not very different to that for broadacre industries, except that vegetable industry returns are likely to be lower to the extent that capital appreciation is higher in a peri-urban region due to urban expansion.

Sensitivity of farm returns to changes in practice, water supply and location

Sensitivity analyses were conducted by entering different values in the whole farm sheet of the Excel workbook “VegoutCarabooda2.xls “ and manually recording the resulting net farm returns or return on capital. Break even analyses were done by selecting the combinations of values for input variables which resulted in the same return on capital.

The following analyses are designed to estimate the financial implications, for a market gardener, of

A. Converting the farm's irrigation system from one currently typical of the industry, as represented in the base case above, to a system that achieves 90 per cent distribution uniformity, or

B. Relocating to the proposed horticulture precinct in which he is required to use recycled water and good practice water and nutrient management.

A. Adoption of best practice DU

The irrigation system most representative of current industry practice, achieving DU of 65 per cent, is estimated to have a capital cost of $6,000 per hectare at 2009 prices. Using the values in Brennan and Calder (2006), and allowing for inflation, it can be confidently assumed that an irrigation system currently priced at $11,000 per hectare is capable of 95 per cent DU. Thus the additional investment required to convert from an average to a best practice irrigation system is estimated to be $5,000 per hectare at 2009 prices. It is assumed that the farmer is able to finance the $11,000 per hectare investment when the old system is replaced by the high quality sprinkler system.

This analysis excludes any allowance for any other costs incurred in changing to good practice water and nutrient management.

Recognizing that these cost factors might be significant in some circumstances, the model departs from Gartrell's model in that it assumes irrigation equipment is depreciated over 10 years, not 20 years. This in effect simulates the premature replacement of irrigation equipment and any associated training cost to enable use of two other elements of good practice – monitoring and scheduling.

The net effect of adopting best practice DU is an $8,000 per year increase in net farm returns. An alternative expression of this effect is an increase from 0.32 per cent to 0.46 per cent return on capital. This excludes any additional benefit through reduced leaching of fertiliser nitrogen or increased marketable yield. If this improved DU reduced expenditure on fertiliser by 1 per cent and simultaneously raised marketable yield by 1 per cent, net farm return would rise by $23,000 per year and return on capital from 0.32 to 0.72 per cent.

B. Relocation to horticulture precinct as well as best practice DU

If a farmer represented by the base case scenario above relocates to the proposed horticulture precinct, initial assumptions are –

- The piped supply of recycled water from Alkimos water treatment plant would be delivered under pressure at a flow rate sufficient to meet average daily needs of the crops without any need for the farmer to pump it;
- The irrigator purchases this water from the Water Corporation for $0.88 per KL;
- There is a need for storage capacity on or close to the farm, as this supply is at a relatively constant flow rate, whereas total farm water requirement varies substantially due to fluctuations in weather, crop growth stage and area planted;

- To meet peak irrigation needs in hot windy weather, it is assumed the farmer needs storage capacity sufficient for 2 average days' irrigation;
- Storage could be provided by an underground aquifer or by some above ground structure;
- If stored in the aquifer the cost of water storage is assumed to be the cost of recovery by pumping through 100 m head, i.e. in the order of 20 cents per KL used, plus 20 cents per KL used to compensate for assumed seepage/evaporation losses of 50 per cent, i.e. total 40 cents per KL used;
- If stored in a purpose-built facility, depending whether that were a fully sealed earth dam at a capital cost in the order of $10 per KL of storage capacity, or an above-ground tank at a capital cost of $100 per KL of capacity, the cost would be within the range $0.50 to $10 per KL used;
- This analysis uses the lower of the above alternatives i.e. 40 cents per KL used;
- the farmer would invest $11,000 per hectare in design and installation of a sprinkler system that will achieve 90 per cent DU (i.e. an increase of $5,000 per hectare relative to the base case).

This analysis excludes any allowance for the direct cost of moving from an existing market garden to the proposed horticulture precinct (it is assumed that the farmer relocates at a time when irrigation and other infrastructure is due for replacement). It also excludes any change in the cost of employing staff as a consequence of relocating to the proposed precinct.

To be no better or no worse off, the farmer would need financial support equating to:

- A $1.08 per KL subsidy on water; or
- A $1.01 per KL subsidy on water PLUS a 100 per cent subsidy of the sprinkler conversion; or

If the farmer needed to pump through a total head of 20 metres, to break even he would need

- A $1.12 per KL subsidy on water; or
- A $1.05 per KL subsidy on water PLUS a 100 per cent subsidy of the sprinkler conversion; or

If the improvement in distribution uniformity reduces the requirement for fertiliser by 5 per cent, and the farmer incurs no pumping cost, to break even he would need

- A $1.03 per KL subsidy on water; or
- A $0.97 per KL subsidy on water PLUS a 100 per cent subsidy of the sprinkler conversion;

If the improvement in water use efficiency increased marketable yield by 5 per cent, and the farmer incurs no pumping cost, to breakeven he would need

- A $0.84 per KL subsidy on water; or

- A $0.77 per KL subsidy on water PLUS a 100 per cent subsidy of the sprinkler conversion;

To break even without any subsidy, in order for farmers to be able to pay $0.88 per KL for water, would need a 19 per cent reduction in fertiliser use PLUS a 19 per cent increase in marketable yield. These very large efficiency gains may be achievable on many commercial farms with current technology, but it would be unrealistic to expect industry-wide adoption in the short term.

The above analysis allows us to conclude that, to accommodate a 10 cent per KL increase in water price, the farmer using an efficient sprinkler system would need

- A 59 metre reduction in pumping pressure head, or
- A 10 per cent reduction in fertiliser rate, or
- A 2 per cent increase in marketable yield

If it were feasible and practical to do so, best practice irrigation using a combination of bore water and recycled water would break even with the base case under the following circumstances:

- If no reduction in fertiliser use or increase in yield, the break even combination would be 3 per cent recycled water, 97 per cent bore water;
- If a 1 per cent reduction in fertiliser use plus a 1 per cent increase in yield, the break even combination would be 8 per cent recycled water, 92 per cent bore water;
- If a 2 per cent reduction in fertiliser use plus a 2 per cent increase in yield, the break even combination would be 13 per cent recycled water, 87 per cent bore water.
- If a 5 per cent reduction in fertiliser use plus a 5 per cent increase in yield, the break even combination would be 29 per cent recycled water, 71 per cent bore water.

The costs of obtaining produce from sources other than Gnangara Mound

If less vegetables were produced on the Gnangara Mound, it is most likely that the shortfall in Perth metropolitan markets would be filled by produce from growers north or south of the metropolitan region at similar prices to consumers.

The principal differences in the cost of supplying produce to Perth outlets are likely to be the opportunity cost of land and the cost of transport from farm to market. Land in suitable[2] areas between 100 km and 200 km from Perth has a market value that is perhaps $50,000 per hectare below the Carabooda area. At 5 per cent of market value, the difference in opportunity cost of land is $2,500 per hectare per year. If the additional distance travelled to market is 150 km and freight cost $0.20 per km per tonne of marketable product, then for farmers producing 80 tonnes of marketable crop per hectare per year, the

[2] It is assumed that "suitable" includes availability of labour

extra freight cost is $2,400 per hectare per year. The combined net effect on cost is small.

Leasehold option

A survey of local growers, conducted by Allan Price for Science Matters, found that most growers were receptive to the idea of leasing land for market gardening. Most of the smaller growers already lease some land. The larger growers were more inclined towards obtaining freehold land.

Land rental paid in the wheatbelt typically approximates 5 to 6 per cent of market value, which in turn is primarily related to the productivity of the land.

In a peri-urban situation, market value is more strongly related to it's potential subdivision for residential or industrial use, and market gardeners cannot pay rent equivalent to 5 per cent of market value. Indeed, the above analysis indicates growers would be unable to afford any rent whatsoever if they were required to pay the full cost of recycled water ($0.88 per KL plus storage as required).

Advertising the opportunity to lease publicly owned land for 5, 10, 15 or 20 years, with an associated right to purchase recycled water at $0.88 per KL, would be a way of eliciting growers' willingness to pay for water.

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Appendix I

Base case of model farm – whole farm summary
(shaded cells are entered values)

Carabooda Market Garden	**Total**	**Lettuce**	**Broccoli**	**Celery**	**Cabbage**	**Total crops**	1	ha infrastructure
Land (ha)	33	42	21	16.8	4.2	84	0.5	ha waste land
rotation length incl fallow (months) #		4.5	4.5	4.5	4.5		2.67	Crops/year on cropland
annual land use by crop (ha)	31.50	15.75	7.88	6.30	1.58		100%	cropping intensity (%max)
crop share of overheads	100%	50%	25%	20%	5%		90%	target distribution uniformity
INCOME							**Irrigation**	
Local market	2,735,917	1,346,625	609,797	677,376	102,119	mm applied	mm aver. crop need per watering	
TOTAL INCOME	2,735,917	1,346,625	609,797	677,376	102,119	6.9	5	Lettuce (Crop 6)
EXPENSES						6.9	5	Broccoli (Crop 4)
Fertiliser	414,021	215,636	91,935	90,492	15,958	6.9	5	Celery (Crop 5)
Seed & seedlings	307,292	126,000	81,332	82,320	17,640	6.9	5	Cabbage (Crop 1)
Herbicides, insecticides & fungicides	154,963	90,861	27,421	34,842	1,838		72%	of achievable efficiency
Fuel	113,294	67,894	13,616	27,898	3,886		65%	distribution uniformity (DU)
Water for irrigation	0	0	0	0	0	Water price	$0.00	/kL
Irrigation power	61,788	30,894	15,447	12,358	3,089		100	m total head
Repairs & parts	44,016	25,620	5,901	10,366	2,129			
Labour	453,257	242,137	55,702	139,136	16,282	Water use	436	ML/year/farm
Marketing expenses	874,772	393,642	258,906	191,359	30,865		13.8	ML/yr/ha reticulated
Interest on working expenses	41,970	21,088	9,712	9,542	1,629		0%	Fertiliser change
TOTAL COSTS	2,465,374	1,213,772	559,973	598,312	93,317		0%	Mktble yield change
GROSS MARGIN PER ENTERPRISE		132,853	49,824	79,064	8,802			
GROSS MARGIN PER HECTARE	8,198	3,163	2,373	4,706	2,096			
Overheads	31,220	15,610	7,805	6,244	1,561	Irrigation system capital investment		
Equipment replacement	112,836	59,706	23,124	24,731	5,275	$6,000	/ha	
TOTAL COSTS	2,609,430	1,289,088	590,901	629,287	100,153			
Operating Surplus/Deficit	$126,486	$57,537	$18,895	$48,089	$1,966			
interest on long term debt	$0	$1,370	$900	$2,862	$468	surplus/deficit per crop hectare		
management fee (owner/manager)	$80,000	$264	$173	$551	$90	net margin per ML water applied		
net tax	$27,844			Land value:	$150,000	/ha	**Lease option**	
After tax "profit"	**$18,642**			Buildings:	$500,000		3%	of land & building value
Capital (land, buildings, equip't)	$5,773,750			Machinery:	$323,750		$4,955	/ha/yr land rental
Return on capital	**0.32%**							