DARWIN REGIONAL WATER SUPPLY
AND LAND MANAGEMENT STRATEGY
1988
SUMMARY REPORT-AUGUST 1988

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4. ECONOMIC ANALYSES OF DAMSITES

Prepared by a Working Party comprising representatives of the
Power and Water Authority and the Department of Lands & Housing
-August 1988
OBJECTIVES

The main objective of the study is to provide the Minister for Mines and Energy, and the Minister for Lands and Housing, with a strategy for future water supply development in the Darwin Region to the year 2040. A secondary objective is to provide a view to the longterm future when the population capacity of the region might be reached.

BACKGROUND

A public seminar in November 1986 addressed broad-scale issues of future land use and water supply in the Darwin Region. The findings of this seminar are summarised in an information paper titled Darwin Region Land and Water Development - Planning Perspectives (May 1987).

The information paper sets out a programme of investigations required to resolve the choice of sources for the next stage of augmentation of the regional water supply system. This strategy study had been undertaken as part of the programme.

In conjunction with the development of this strategy study, a series of public meetings were held within the region and displays mounted at several locations as part of a public information exercise.

APPROACH

The strategy has been derived by first projecting urban, agriculture and aquaculture water requirements to the year 2040. For the purposes of the study, a 3.5% per annum population growth rate was adopted.

Next, all potential major supply sources within the region have been investigated, including costs (at final quarter 1987 levels) and environmental and social factors. Consideration has been given to regional planning constraints and opportunities.

The conclusions and recommendations drawn from the study are based on the best available data, some of which remains subject to detailed confirmation. The strategy therefore relies to a degree on subjective judgement until the completion of further studies.
CONCLUSIONS

1. At high growth rates, it is concluded that:-

(a) Water supply demands in the region will increase to the following levels by 2040:-

<table>
<thead>
<tr>
<th>Category</th>
<th>Demand (ML/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>206 000</td>
</tr>
<tr>
<td>Agriculture</td>
<td>38 000</td>
</tr>
<tr>
<td>Aquaculture</td>
<td>18 000</td>
</tr>
</tbody>
</table>

(freshwater only)

TOTAL 262 000 ML/year

-with demands continuing to grow well beyond 2040.

(b) The population in the region is projected to reach about 500 000 by 2040 with a population capacity well in excess of one million occurring sometime after 2100.

(c) The existing regional water supply sources of Darwin River Reservoir, McMinns Borefield and Manton Reservoir (emergency use only) are projected to be fully utilized by 1992.

(d) Relatively small new sources will be required for urban water supply, irrigation and aquaculture prior to 2000. A major new damsite will be needed by about 2006, primarily for urban water supply, but also for field irrigation and freshwater aquaculture.

(e) For the period to year 2000, freshwater aquaculture and irrigation supplies will be most appropriately developed through close liaison between PAWA, Department of Lands and Housing, Department of Industry and Development and private developers based on Lambells Groundwater, portion of Howard East Groundwater and Manton Reservoir. Each of these sources is closely associated with land considered suitable for irrigated agriculture, although detailed land surveys are only completed for the Lambells Lagoon Area.

(f) Future augmentation of potable water supply from Howard East Groundwater and Manton Transfer System, including interaction with proposed recreational use of the reservoir, is adequately covered by current planning programmes within PAWA.
(g) Marrakai, Mount Bennet or Warrai damsites could each satisfy the projected growth in demand for water for some 50 years hence, while their joint total supply capacity should be adequate for at least 100 years into the future. All three are of major strategic importance to the long-term prospects for regional growth.

(h) The present values of staged development of Marrakai, Warrai and Mount Bennet Damsites over the planning period to 2040 fall within the narrow range of $47M to $49M. Consequently, none of these options has a clear economic advantage.

2. Acacia Gap and Tumbling Waters Damsites offer only small development potential relative to overall regional requirements and would cause considerable community dislocation. As a consequence, it is concluded that they can be discarded from further consideration.

3. Batchelor Damsite was provisionally withdrawn from consideration in November 1987 on socio-economic grounds. In view of the study showing the three remaining damsites of Marrakai, Mount Bennet and Warrai to be more attractive, it is concluded that Batchelor Damsite should not be considered further.

4. Marrakai, Mount Bennet and Warrai Damsites require detailed geotechnical and engineering work before they can be regarded as technically proven. This is estimated to cost a total of $1.0M over a two year period. Aboriginal sacred site issues need to be resolved for Warrai and Aboriginal land issues may arise for Mount Bennet damsite.

5. Pending confirmation of technical and environmental feasibility, Warrai, Marrakai and Mount Bennet Damsites should be recognised as the future major water resources of the region.
6. Land management in each of the selected damsites would depend upon whether the catchment is to be closed or remain open.

Warrai catchment would be closed and land management would be the responsibility of PAWA. Marrakai and Mount Bennet catchments would be open and their development monitored using existing regional planning referral mechanisms to avoid conflict with water supply objectives.

Mining and quarrying are currently carried out in Marrakai and Mount Bennet catchments, with Marrakai catchment considered very prospective for mineral development. Accelerated exploitation of mineral prospects within the impoundment area should be encouraged so that known prospects are exhausted before development of the damsite.

Ordinary pastoral, agricultural, recreational and rural-residential use of Marrakai and Mount Bennet catchments would be permitted but would be monitored and controlled using existing regional planning mechanisms to safeguard these major future water supply options.

No legislative changes or new planning instruments are considered necessary at this stage.

7. The whole of Warrai catchment would be acquired at an estimated current cost of $600 000. For Marrakai and Mount Bennet damsites, the impoundment area and an approximate 0.5 km buffer of land around the reservoir would be acquired. The estimated current cost of acquisition for Marrakai damsites is $1.7M and for Mount Bennet $850 000.
RECOMMENDATIONS

It is recommended that:-

1. Endorsement, in principle, be given to the following strategy for regional water supply and associated land management:

   (a) base the development of irrigation and freshwater aquaculture on water supplies from Manton Dam, Lambells Groundwater and Howard East Groundwater;

   (b) develop Manton Transfer System and portion of Howard East Groundwater as the next two stages of augmentation to potable supply;

   (c) relinquish Acacia Gap, Tumbling Waters and Batchelor damsites as regional water source planning options;

   (d) adopt Warrai, Marrakai and Mount Bennet damsites as preferred longterm water source options, subject to confirmation of engineering feasibility and satisfactory environmental assessment of each damsite, and agreement with Aboriginal traditional custodians regarding sacred sites affected by Warrai Damsite and special arrangements for Aboriginal land affected by Mount Bennet Damsite.

2. In order to finalize selection of the preferred next regional dam, detailed engineering feasibility and environmental impact investigations be completed for Warrai, Marrakai and Mount Bennet damsites in 1988/89 and 1989/90 at an order of cost of $1.0M.

3. No legislative changes or planning instruments be instituted at this stage in relation to land use management in the Warrai, Marrakai, and Mount Bennet Damsite catchments.

4. The strategy for water supply and land management be reviewed on the basis of the findings of the feasibility studies referred to in Recommendation 2.
POTENTIAL SOURCES RECOMMENDED FOR DEVELOPMENT

HEG - HOWARD EAST GROUNDWATER
LG - LAMBELLS GROUNDWATER
MD - MARRAKAI DAMSITE
WD - WARRAI DAMSITE
MBD - MOUNT BENNET DAMSITE
MTS - MANTON TRANSFER SYSTEM

POTENTIAL SOURCES NOT RECOMMENDED FOR DEVELOPMENT

BD - BACHELOR DAMSITE
TWD - TUMBLING WATERS DAMSITE
AGD - ACACIA GAP DAMSITE

1988 SOURCES

McMB - McMINNS BOREFIELD
MnR - MANTON RESERVOIR
DRR - DARWIN RIVER RESERVOIR

STRATEGY FOR MAJOR WATER SUPPLY DEVELOPMENT IN THE DARWIN REGION
## DARWIN REGIONAL WATER SUPPLY & LAND MANAGEMENT STRATEGY-OVERVIEW

### SMALLER SOURCES TO AUGMENT WATER SUPPLY BEFORE YEAR 2000

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>LAMBELLS WATER</th>
<th>HOWARD EAST WATER</th>
<th>MANTON TRANSFER</th>
<th>WARRAI DAMSITE</th>
<th>MARRAKAI DAMSITE</th>
<th>MT. BENNET DAMSITE</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIRST NEEDED</td>
<td>1988</td>
<td>1993</td>
<td>1993</td>
<td>2006</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>FULL USE BY</td>
<td>2025</td>
<td>2010</td>
<td>2003</td>
<td>2037</td>
<td>0</td>
<td>2047</td>
</tr>
<tr>
<td>ML/YR IN 2040</td>
<td>?</td>
<td>5,000</td>
<td>15,000</td>
<td>122,000</td>
<td>146,000</td>
<td>146,000</td>
</tr>
<tr>
<td>-URBAN:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-IRRIGATION:</td>
<td>13,000</td>
<td>11,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>-AQUACULTURE:</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>-UNUSED:</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>294,000</td>
<td>54,000</td>
</tr>
</tbody>
</table>

### COSTS (1987$)

<table>
<thead>
<tr>
<th>TOTAL WORKS</th>
<th>$1M (PRIVATE FARMS)</th>
<th>$12M (PUBLIC POTABLE SUPPLY)</th>
<th>$181M</th>
<th>$433M</th>
<th>$262M</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAND:</td>
<td>NIL</td>
<td>NIL</td>
<td>$0.6M</td>
<td>$1.7M</td>
<td>$0.8</td>
</tr>
<tr>
<td>$/ML/YR SAFE YIELD</td>
<td>$80 (PRIVATE FARMS)</td>
<td>$800 (PUBLIC POTABLE SUPPLY)</td>
<td>$1490</td>
<td>$990</td>
<td>$1315</td>
</tr>
</tbody>
</table>

### STRATEGIC ISSUES FOR LAND & WATER MNGT

**EXPANDING HORTICULTURAL INDUSTRY TO BE SUPPORTED BY PRIMARY DEDICATION OF LAMBELLS GROUNDWATER TO PRIVATE FARM DEVELOPMENT, ALLOWING FOR POSSIBLE SHARE OF WATER RESOURCE FOR URBAN AND AQUACULTURE SECTORS.**

**FURTHER EXPANSION OF IRRIGATION TO BE SUPPORTED BY DEDICATION OF UP TO 7,000 ML/YR RELEASE FROM MANTON DAM, AND ALSO APPROX. 70% OF HOWARD EAST GROUNDWATER TO PRIVATE FARMS, LEAVING 30% FOR URBAN SECTOR. SUBJECT TO IRRIGATION AND URBAN NEEDS, SOME SUPPLY TO AQUACULTURE MAY BE POSSIBLE.**

**ALTHOUGH SECURITY BUFFERS WILL BE NEEDED AROUND POTABLE SUPPLY BORES THE BALANCE OF LAND IN THE GROUNDWATER AREAS WILL BE AVAILABLE FOR GENERAL AGRICULTURE. NO CONTROLS ON PRIVATE BORES ARE ENVISAGED BEYOND PLANNING FOR THE RATIONAL AND EQUITABLE SHARING OF AVAILABLE WATER RESOURCES.**

**MANTON TRANSFER SYSTEM OR HOWARD EAST GROUNDWATER WILL AUGMENT URBAN SECTOR SUPPLY BEFORE YEAR 2000.**

**MAJOR DAMS WILL BE NEEDED BEYOND 2006 TO AT LEAST SATISFY POTABLE DEMAND BY URBAN SECTOR. COMBINED SUPPLY POTENTIAL FROM MOUNT BENNET MARRAKAI AND WARRAI DAMSITES IS ADEQUATE FOR FORECAST DEMANDS FOR AT LEAST THE NEXT 100 YEARS. LACK OF GEO-TECHNICAL INFORMATION AT EACH DAMSITE PREVENTS FINAL CONCLUSION ON ENGINEERING FEASIBILITY FOR THE PRESENT.**

**WARRAI CATCHMENT IS USED FOR LOW INTENSITY PASTORAL ACTIVITY AND CAN BE CLOSED WITH LITTLE SOCIO-ECONOMIC IMPACT TO ACHIEVE LOW-COST WATER QUALITY MANAGEMENT. WARRAI CATCHMENT WOULD BE CLOSED TO RECREATION USE, BUT CONTROLLED USE SHOULD BE PERMITTED IN MARRAKAI AND MOUNT BENNET CATCHMENTS.**

**THERE ARE NO KNOWN CONSTRAINTS DUE TO ABORIGINAL LAND ISSUES FOR MARRAKAI DAMSITE, BUT FLOODING OF SACRED SITES IN WARRAI DAMSITE AND PART OF FINNISS RIVER LAND CLAIM IN MOUNT BENNET DAMSITE NEEDS TO BE NEGOTIATED.**
## COMPARISON OF POTENTIAL DAMSITES

<table>
<thead>
<tr>
<th></th>
<th>ACACIA GAP</th>
<th>TUMBLING WATERS</th>
<th>WARRAI</th>
<th>MARRAKAI</th>
<th>MOUNT BENNET</th>
<th>BATEHELOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>ML/YEAR SUPPLY</td>
<td>32 000</td>
<td>32 000</td>
<td>122 000</td>
<td>440 000</td>
<td>200 000</td>
<td>57 600</td>
</tr>
<tr>
<td>HECTARES FLOODED</td>
<td>2 900</td>
<td>2 500</td>
<td>8 200</td>
<td>26 000</td>
<td>13 300</td>
<td>3 500</td>
</tr>
</tbody>
</table>

**WATER QUALITY FACTORS**
- Stormwater runoff and sewerage overflows from Batchelor to Mount Bennet, Batchelor and Marrakai damsites. Marrakai Dam site also receives Adelaide River Township stormwater and sewerage overflow.
- Stuart Highway within Acacia Gap & Marrakai Damsite catchments.
- General overland flow of rural-residential wastewaters possible for Acacia Gap, Marrakai & Tumbling Waters damsites.
- Several existing & potential mines upstream of Marrakai Dam site.
- Small tin and tantalum mines in Tumbling Waters catchment.
- Pastoral use in all catchments, intensive agriculture in Marrakai, Acacia Gap & Tumbling Waters catchments.
- All catchments suffer erosion to varying degrees.
- Noxious Mimosa pigra present in Acacia Gap, Marrakai & Mount Bennet catchments and suspected in others, Salvinia & Water Hyacinth present in past in Warrai & Marrakai catchments; potential threat to all.
- Management of Litchfield Park potentially beneficial for erosion and weed control in Mount Bennet and Warrai damsites.

<table>
<thead>
<tr>
<th>NUMBER OF LANDHOLDERS AFFECTED</th>
<th>60</th>
<th>64</th>
<th>3</th>
<th>18</th>
<th>16</th>
<th>285</th>
</tr>
</thead>
</table>

**MINING POTENTIAL**

**ABORIG'N LAND ISSUES**
- Dry Season, Wet Season, Dry Season, Dry Season, Dry Season, Nil
- Camping, Swimming, Camping, Camping, Fishing & Fishing, Rare Plants, Species, Crocodile Breeding.

**DEVELOPMENT COSTS (1987$)**
- Land: $2.75M
- Total Works: $60M
- Dam: $29M
- Pipeline: $16M
- Treatment: $15M
- $6.4M
- $181M
- $38M
- $9M
- $15M
- $0.6M
- $433M
- $47M
- $9M
- $12M
- $1.7M
- $262M
- $71M
- $122M
- $0.85M
- $50M
- $190M
- $61M
- $6.0M
- $145M
- $90M
- $43M
- $12M

**LEAD TIME FOR ALL WORKS (YEARS)**
- 7
- 7
- 8
- 9
- 9
- 5
ECONOMIC ANALYSES OF DAMSITES

The economics of augmentation have been assessed by taking into account all costs associated with the staging of each damsite in alternative augmentation programmes. This gives predicted cost flows of new surface water supplies from 1990 to 2040. The augmentation schedules are based on an assumed rate of growth in population of 3.5% per annum.

All capital costs for each source, including land acquisition and preparation, construction of dams, pumpstations, pipelines, water treatment plants where necessary, and appertinent works for access and power supply were accounted for, as well as the ongoing annual costs of operation to deliver water into the public supply system. All cost streams were adjusted for an inflation rate of 6.5% per annum. Borrowings for land acquisition and construction works were assumed to be repaid in fixed annual amounts over 25 years at interest rate of 13.5% per annum.

As a measure of economic merit for each augmentation programme, total cost flows to year 2040 were converted to their present value as at 1988. The present values thus obtained should be considered in the light of capital debts which will continue beyond the year 2040, while the different costs for operation of each of the alternative augmentation programmes should also be taken into account for a complete picture of economic merit.

Twenty-two alternative programmes for staging new damsites into the regional water supply system were assessed. The seven lowest cost programmes are presented below. All costs are expressed in 1988 money values.

<table>
<thead>
<tr>
<th>SOURCES</th>
<th>PRESENT VALUE OF ALL COSTS TO YEAR 2040</th>
<th>CAPITAL DEBT REPAYMENTS AT YEAR 2040</th>
<th>OPERATING COSTS AT YEAR 2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>MARRAKAI</td>
<td>46.6</td>
<td>11.7</td>
<td>9.3</td>
</tr>
<tr>
<td>ACACIA GAP, THEN MT. BENNET</td>
<td>46.9</td>
<td>14.0</td>
<td>9.8</td>
</tr>
<tr>
<td>WARRAI, THEN MOUNT BENNET</td>
<td>47.4</td>
<td>18.9</td>
<td>6.6</td>
</tr>
<tr>
<td>ACACIA GAP, THEN MARRAKAI</td>
<td>47.8</td>
<td>15.9</td>
<td>9.3</td>
</tr>
<tr>
<td>MOUNT BENNET</td>
<td>48.8</td>
<td>12.5</td>
<td>10.2</td>
</tr>
<tr>
<td>TUMBLING WATERS, THEN MARRAKAI</td>
<td>49.9</td>
<td>12.3</td>
<td>8.9</td>
</tr>
<tr>
<td>ACACIA GAP, THEN TUMBLING WATERS, THEN WARRAI</td>
<td>50.9</td>
<td>19.9</td>
<td>6.0</td>
</tr>
</tbody>
</table>
DARWIN REGIONAL WATER SUPPLY
AND LAND MANAGEMENT STRATEGY
1988

CONSOLIDATED REPORT
(August 1988)

Prepared by a Working Party comprising
representatives of the Power and Water Authority
and the Department of Lands and Housing
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INTRODUCTION

The aim of the strategy is to describe long term planning pathways for water supply development and land management policies in the Darwin Region. For the purposes of the strategy, the Darwin Region is that area bounded by the Adelaide River and Finnis River.

Three perspectives are encompassed by the strategy:
- identification of sources best matched to regional growth to the year 2000;
- recommendation of preferred source options for development between year 2000 and year 2040;
- the view beyond 2040 through comparison of water supply potential with population capacity for the region.

A public seminar in November 1986 was the starting point for the strategy. The findings of the seminar, as summarised in the information paper "Darwin Region Land and Water Development - Planning Perspectives (May 1987)", included a programme of investigations for augmentation of the regional water supply system. The present strategy arises from that programme.

Fundamental to the strategy is the projection of demand for water in three separate sectors: urban centres; irrigated agriculture; and large-scale aquaculture. Also important is the re-appraisal of water yield, development costs and environmental issues for all sources, enabling comparison of options on a consistent basis.

The starting point adopted for meeting rising demands was to seek sources which could be wholly dedicated to each of the three separate sectors of demand. With the needs of each sector thus satisfied, any unused water supply capacity was made available, as appropriate, to other sectors. In this way, full and efficient use of sources between competing sectors was achieved.

It is stressed that the price of water to consumers in each sector was not taken into account as a factor affecting the levels of demand. Cash flows which reflect capital debt burdens and operating costs were, however, assessed and will form the basis of more detailed economic analysis in the continuing implementation of the strategy.
POTENTIAL SOURCES

HEG - HOWARD EAST GROUNDWATER
LG - LAMBELLS GROUNDWATER
MD - MARRAKAI DAMSITE
WD - WARRAI DAMSITE
MBD - MOUNT BENNET DAMSITE
MTS - MANTON TRANSFER SYSTEM
BD - BATCHelor DAMSITE
TWD - Tumbling Waters DAMSITE
AGD - Acacia Gap DAMSITE

1988 SOURCES

McMB - McMinns BOREFIELD
MnR - MANTON RESERVOIR
dRR - DARWIN RIVER RESERVOIR

MAJOR WATER SUPPLY SOURCES IN THE DARWIN REGION

Figure 1
FORECASTS OF DEMAND FOR WATER

Overview

Three broad sectors are analysed for water demand to the year 2040. They are: urban sector; irrigated agriculture; and large-scale aquaculture. Forecasts for the urban sector and irrigated agriculture encompass high and low growth projections. A single growth projection applies for aquaculture.

The accuracy of forecasts is heavily dependent on the validity of projections of factors which influence growth in each sector. Consequently, the forecasts derived for the urban centres are considered to be firmer than those for irrigated agriculture which are, in turn, firmer than those for aquaculture. It seems certain, nevertheless, that water supply to the urban sector will comprise approximately 70% of the total demand on regional water supply over the period to year 2040.

High projection of growth for the urban sector between year 1988 and year 2040 indicates a seven-fold increase in water demand, while the low growth projection will bring a three-fold increase.

A ten-fold rise in water demand accompanies the high growth projection for irrigated agriculture, with low growth resulting in a six-fold rise.

For the purposes of planning for water supply to both the urban and irrigated agriculture sectors, high growth projections for demand are presented. This may provide a safety margin in the timing of planning decisions should lower growth rates occur. On the other hand, the dynamics of water demand in each sector make it quite possible for the high growth projections to be achieved.

Growth in aquaculture is the most difficult to define precisely, however it is projected that demand for freshwater from this sector may be at least half that of the irrigation sector by year 2040.
**Urban Sector**

Two broad consumer areas comprise the urban sector:
- closely settled city and town areas as typified by Darwin and Palmerston;
- rural residential areas as typified in the Howard Springs and Humpty Doo areas.

**Town and City**
By far the largest overall demand for water in town and city areas is accounted for by household use. With no known growth in demand from other users expected, at this stage, to alter this position of dominance it is considered valid to project town and city water demand on the basis of population growth. Annual growth rates ranging from 2% to 3.5% are used, with adjustments made to account for changes in local Defence Force numbers. Statistics for water consumption in Darwin between 1976 and 1986 are applied to the population growth projections to provide scenarios for total water demand. High levels of water demand are based on 3.5% annual population growth and the highest annual per capita consumption rate; low level demand is based on 2% annual population growth and the mean per capita consumption rate. The high level demand projections are adopted for planning purposes.

**Rural Residential**
Statistics for 1986/87 are suitable for analysis of demand on the public water supply system in the rural centres. These demonstrate that residential use accounts for half of the total demand. Small-scale irrigation and commercial enterprises constituted the remainder of demand, along with supply to Channel Island Power Station which is considered, by virtue of its location, to be in the rural area. A continuing demand of 800 ML/year for potable water is projected for these non-residential consumers in the rural area. Approximately 30% of rural residents were connected to the public water supply system in 1986/87. It is assumed that this rate of connection will be maintained into the future without variation, as will the per capita consumption rate as measured in 1986/87. Population growth rates between 2% and 3.5% per annum are used for the rural area, until a ceiling population of 20,000 after which 1% annual growth is adopted. For planning purposes, the highest growth projection is adopted.

**Longterm Regional Population**
The combined town and city and rural residential population at year 2040 will be almost 500,000 under the assumed highest growth rate. Continued high growth would reach the region's population capacity of around one million before the turn of the twenty second century.
FORECAST OF WATER DEMAND
DARWIN REGIONAL URBAN SECTOR

Figure 2
Irrigated Agriculture

The Department of Industries and Development provided forecasts of irrigated crop areas expected 5 years, 10 years and 20 years beyond 1987, as well as estimates of development possible at year 2040. The forecasts encompassed high and low growth prospects. In addition, water demand and total land utilisation rates were given for each crop. Projections of total farm areas and water demand are based on these data.

Land unit mapping confirms that even the high growth projections for total farm areas could be accommodated on suitable land within the Darwin Region. Approximately 90% of information applies to the northern third of the region, with 5% of total information available in the Batchelor area and 5% in the Adelaide River area. For the purpose of planning it is assumed that major irrigation development will occur in the region north of Darwin River Dam, however this does not preclude the possibility of development elsewhere. More importantly, it is confirmed that sufficient land is available for projected irrigation growth in the Darwin Region as a whole.

Projections of growth are considered to be firmest for intensively farmed horticultural crops. These projections indicate that there could be a six-fold increase in the total horticultural area in the region between year 1987 and year 2040, with total farm area expected to increase by 3 to 5 fold within the next 20 years. Projected growth is less firm for extensive irrigated cropping, such as for grain and pasture production. The highest growth potential could see a remarkable 80-fold increase in irrigated field cropping between year 1987 and year 2040, while low growth projections indicate a lesser but still significant 10-fold increase.

Applying water consumption rates for the various crops shows:

For low growth projections: total demand for water will first double by 1993, and double again by 1999, by which time the growth in demand for water levels off such that by year 2040, irrigation water demand is approximately 6 times that of 1987.

High growth projections, however, suggest first doubling in demand at 1992, second doubling by 1995, then once more by 2002, before levelling to a demand at 2040 approximately 10 times that of 1987.

The high growth projections are adopted for planning purposes.
<table>
<thead>
<tr>
<th>IRRIGATION SECTOR</th>
<th>1987</th>
<th>2000</th>
<th>2005</th>
<th>2015</th>
<th>2040</th>
</tr>
</thead>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HORTICULTURE OR FIELD</td>
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<td>12.9</td>
<td>13.6</td>
<td>15.2</td>
<td>19.2</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>SUPPLEMENTARY</td>
<td>0.05</td>
<td>1.8</td>
<td>4.1</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>DRY SEASON</td>
<td>0.14</td>
<td>4.5</td>
<td>6.3</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>PASTURE</td>
<td>0.7</td>
<td>5</td>
<td>6.7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>TOTAL</td>
<td>3.49</td>
<td>24.2</td>
<td>30.7</td>
<td>34.2</td>
<td>38.2</td>
</tr>
</tbody>
</table>

**EXPECTED UPPER LIMIT OF IRRIGATION SECTOR WATER DEMAND**
- THOUSANDS OF MEGLITRES PER YEAR -

**FORECAST OF WATER DEMAND BY DARWIN REGIONAL IRRIGATION SECTOR**

Figure 3
Large-scale Aquaculture

Preliminary forecasts of potential growth of aquaculture were provided by the Department of Industries and Development, encompassing freshwater, brackish and saline systems. Development of large-scale commercial aquaculture farms in the Darwin Region is generally considered to be highly prospective.

There is the potential for establishment of up to 500 ha. of freshwater aquaculture ponds based at either the Middle Point Area or the Tumbling Waters area. Up to 1600 ha. of brackish ponds can be accommodated in the Hope Inlet coastal area, while the Point Stephens coastline is potentially suitable for 500 ha. of brackish ponds plus 200 ha. of saline ponds.

Anticipating the rates of development in each sector of the aquaculture industry is difficult at this stage. For planning purposes, however, it is assumed that saline aquaculture will be established within 5 years to the full potential available at Point Stephens. For the brackish aquaculture sector it is assumed that the full potential area at Point Stephens will be developed within 10 years, followed with full development possible at Hope Inlet over the following 10 years. Freshwater aquaculture is assumed to achieve full development in the region within 5 years.

Close control on water quality is identified as an essential factor for the success of all types of aquaculture. The simplest expedient of regularly discarding degraded, untreated pond waters and replacing with clean supplies is an option for saline systems. This is not feasible for either the freshwater or brackish systems, however, as the potential demand levels exceed the capacity for supply from the region's total water resources.

It is assumed that technological processing for control of water quality will prove feasible at the required scales, so that water demand for aquaculture will be required only to compensate for losses through evaporation, seepage and the treatment process itself. Brackish aquaculture ponds could receive make-up from either brackish groundwater sources or a mixture of fresh water and sea water. For planning purposes, it is assumed that fresh water supplies will not be necessary for brackish aquaculture. Makeup for freshwater aquaculture ponds, however, must be of freshwater quality to minimise treatment costs. Water demand for 5, 10 and 20 years ahead are presented for aquaculture.
### Forecast of Water Demand by Aquaculture in the Darwin Region

The table below shows the forecasted water demand for different sectors of aquaculture in the Darwin region for the years 1982, 1987, and 2007.

<table>
<thead>
<tr>
<th>Aquaculture Sector</th>
<th>Required Quality of Water Supply</th>
<th>Thousands of Megalitres Per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater</td>
<td>Fresh</td>
<td>18.0 18.0 18.0</td>
</tr>
<tr>
<td>Brackish</td>
<td>Brackish</td>
<td>7.8 25.7 100</td>
</tr>
<tr>
<td>Saline</td>
<td>Sea</td>
<td>480 480 480</td>
</tr>
</tbody>
</table>

**Figure 4**
SOURCES OF WATER

Overview

The region is generally well endowed with groundwater resources and potential damsites. Water resources of major water supply potential are those with yields exceeding 10 000 ML/year. Topographic and geologic factors result in a distinct separation in the location of major water resources:

- groundwater resources of greatest supply potential occur in the northern one-third of the Darwin Region;
- the major damsites are found in the southern two-thirds of the region

The existing public water supply to Darwin, Palmerston and their rural hinterland is drawn from two surface reservoirs and a small borefield with combined yield capacity of 49 000 ML/year.

It is possible for up to an additional 15 000 ML/year to be drawn from the existing surface reservoirs by means of transferring to Darwin River Reservoir that water which would otherwise spill from Manton Reservoir. Additional groundwater supply is assessed, at this stage, at up to 30 000 ML/year. Six potential damsites are assessed to offer an aggregate yield of up to 878 000 ML/year. Total water supply potential, then, from all known major resources in the Darwin Region is 972 000 ML/year.

All potential sources have been assessed to the same level of detail with regard to hydrology, engineering and development costs, environmental factors and social issues. Detailed assessments are yet to be undertaken, particularly in regard to final engineering feasibility studies. Nevertheless, the work completed to this stage is considered satisfactory for input to aid valid planning decisions.
Hydrology

Groundwater
McMinns Borefield is the major developed source of groundwater in the Darwin Region, drawing on the Coomalie Dolomite aquifer system. Field investigations have confirmed two other areas of potential for major groundwater supply from this aquifer system. These are in the Lambells Lagoon area and to the east of the Howard River. Generally, the criterion applied in deciding major groundwater potential in the region is the capability of successfully operating individual bores at a delivery rate of at least 30 L/second.

The annual supply potential for each of the major groundwater sources is assessed at:

- Howard East Groundwater : 16 400 ML/year
- Lambells Groundwater : 13 900 ML/year
- McMinns Borefield : 5 000 ML/year

The weathered layer at the top of the otherwise impervious Coomalie Dolomite provides zones of large water yield potential. This weathered layer lies at around 50m depth and is fed by water seeping through the overlying soils. Wet season rainfall provides direct annual recharge to the system. While the high yield potential for water supply is directly associated with the Coomalie Dolomite, the complete aquifer system also incorporates the overlying soil profile.

The groundwater drawn from the Coomalie Dolomite aquifer has been found to be suitable for drinking water supplies without treatment. While contact with the weathered dolomitic surface results in elevated hardness in the water, this is of potential health benefit and also offers opportunity to counteract the slightly corrosive nature of water supplied from the main surface reservoirs.

The potential exists for the Coomalie Dolomite groundwater resource to be degraded by contaminated seepage from occupation and use of the land overlying the aquifer system. Sewerage, fertilisers, pesticides and herbicides are possible major pollutants connected with rural residential and agricultural development. A degree of natural filtration is provided by the overlying soils as water percolates down through the aquifer system, however this effect can reduce over long periods with continuous seepage of contaminated waters. The major implication of degradation in groundwater quality would be the cost and effectiveness of treatment to ensure safe drinking supplies.
Surface Water

All surface water resources in the Darwin Region capable of supplies in excess of 30 000 ML/year have been considered. Six potential damsites are described, and the performances of both existing reservoirs, at Manton Dam and Darwin River Dam, are also updated. Consistently adequate streamflow information is available for each site, but there is wide variability in topographic mapping for the potential reservoirs. Nevertheless, the likely water supply capabilities are:

- Marrakai Damsite : 440 000 ML/year
- Mount Bennet Damsite : 200 000 ML/year
- Warrai Damsite : 120 000 ML/year
- Batchelor Damsite : 54 000 ML/year
- Darwin River Reservoir : 37 000 ML/year
- Tumbling Waters Damsite : 32 000 ML/year
- Acacia Gap Damsite : 32 000 ML/year
- Manton Transfer System : 15 000 ML/year
- Manton Reservoir : 6 700 ML/year

The effect of joint operation of reservoirs on the same stream has not been accounted for in the yields quoted. Some reduction in yield would be expected at Marrakai and Mount Bennet damsites due to operation of Warrai and Batchelor damsites respectively. This effect would be greater for Mount Bennet Damsite, while the much larger catchment for Marrakai Damsite would render the effect of Warrai Reservoir insignificant.

The assessments conducted for all damsites were aimed at maximising yields without attention to water quality management of the reservoirs. An important factor in this regard may be the need to allow reservoirs to overflow more regularly, with consequent lowering of the yield potential. This will be least significant for Marrakai Damsite, where catchment runoff causes spill from the reservoir in at least 50% of all years.

In conjunction with the volume of runoff relative to reservoir capacity, land use in the catchments will affect the quality of impounded waters, with implications for water treatment in the case of drinking supplies. Warrai Damsite is the least affected in terms of land use, while the greatest intensities of development occur at Batchelor, Mount Bennet and Marrakai damsites. The costs of treatment compared to land acquisition, indicate that Warrai and Batchelor reservoirs would be most economical with closed catchments. For all other potential damsites, leaving the catchments open is most economical.
### TABLE 1: COMPARISON OF POTENTIAL DAMSITES

<table>
<thead>
<tr>
<th>ML/YEAR SUPPLY</th>
<th>ACACIA GAP</th>
<th>TUMBLING WATERS</th>
<th>WARRAI</th>
<th>MARRAKAI</th>
<th>MOUNT BENNET</th>
<th>BATCHelor</th>
</tr>
</thead>
<tbody>
<tr>
<td>32 000</td>
<td>32 000</td>
<td>122 000</td>
<td>440 000</td>
<td>200 000</td>
<td>57 600</td>
<td></td>
</tr>
</tbody>
</table>

| HECTARES FLOODED | 2 900 | 2 500 | 8 200 | 26 000 | 13 300 | 3 500 |

**WATER QUALITY FACTORS**
- Stormwater runoff and sewerage overflows from Batchelor to Mount Bennet, Batchelor, and Marrakai damsites. Marrakai damsites also receives Adelaide River township stormwater and sewerage overflow.
- Stuart Highway within Acacia Gap and Marrakai damsites catchments.
- General overland flow of rural-residential wastewaters possible for Acacia Gap, Marrakai & Tumbling Waters damsites.
- Several existing & potential mines upstream of Marrakai damsite.
- Small tin and tantalum mines in Tumbling Waters catchment.
- Pastoral use in all catchments, intensive agriculture in Marrakai, Acacia Gap & Tumbling Waters catchments.
- All catchments suffer erosion to varying degrees.
- Noxious Mimosa pigra present in Acacia Gap, Marrakai & Mount Bennet catchments and suspected in others, Salvinia & Water Hyacinth present in past in Warrai & Marrakai catchments; potential threat to all.
- Management of Litchfield Park potentially beneficial for erosion and weed control in Mount Bennet and Warrai damsites.

| NUMBER OF LANDHOLDERS AFFECTED | 60 | 64 | 3 | 18 | 16 | 285 |

<table>
<thead>
<tr>
<th>MINING POT’L</th>
<th>MODERATE</th>
<th>SLIGHT</th>
<th>SLIGHT</th>
<th>VERY GOOD</th>
<th>SLIGHT</th>
<th>SLIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABORIG’L LAND ISSUES</td>
<td>FLOODS LARRAKEYAH RESERVE</td>
<td>SACRED SITES, SACRED SITES,</td>
<td>REGISTERED</td>
<td>nil</td>
<td>FINNIS RIVER</td>
<td>FINNIS RIVER</td>
</tr>
<tr>
<td>CON’S’N VALUES</td>
<td>DRY SEASON</td>
<td>SEASON</td>
<td>SEASON</td>
<td>CAMPING SEASON</td>
<td>CAMPING SEASON</td>
<td>CAMPING SEASON &amp; FISHING</td>
</tr>
<tr>
<td>&amp; FOSSICKING</td>
<td>CAMPING FOREST POCKETS</td>
<td>SEASON RARE PLANT SPECIES</td>
<td>MONSOON CROCODILE BREEDING</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| DEVELOPMENT COSTS (1987$) | Land | $2.75M | $6.4M | $0.6M | $1.7M | $0.85M | $6.0M |
| Total Works | $60M | $62M | $181M | $433M | $262M | $145M |
| - Dam | $29M | $38M | $47M | $71M | $50M | $90M |
| - Pipeline | $16M | $9M | $122M | $190M | $151M | $43M |
| - Treatment | $15M | $15M | $12M | $172M | $61M | $12M |

| LEAD TIME FOR ALL WORKS (YEARS) | 7 | 7 | 8 | 9 | 9 | 5 |
Comparison of Sources

In comparing sources, three broad planning factors of cost; social, cultural and environmental impact; and development potential are used. Each factor is measured in different units:

- the **cost factor** is obtained when total development cost of a source is divided by its safe annual water supply yield;
- **social, cultural and environmental impact** is measured in terms of displacement of human land use and disruption to natural habitats;
- the stand-alone safe annual yield of a source measures its **development potential**.

After measuring each planning factor for all sources, a simple numerical ranking is applied to indicate relative standings from best to worst. This allows all eleven source options to be compared in terms of the three independent planning factors. An overall comparison is then provided for all factors by summing all rank numbers for each source and standardising into a new ranking from best to worst. The convention used in assigning numbers is for 1 to represent the best, or most preferred option, and for eleven to represent the worst option.

**TABLE 2: SOURCE PLANNING FACTORS**

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>PLANNING FACTOR RANKINGS</th>
<th>ALL FACTORS</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Cost</td>
<td>Social And Env'l</td>
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<tr>
<td>Lambells Groundwater</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>- all private farm supplies</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Howard East Groundwater</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>- all public potable supply</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Manton Transfer System</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Marrakai Damsite</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Mount Bennet Damsite</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Warrai Damsite</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Tumbling Waters Damsite</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Acacia Gap Damsite</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Batchelor Damsite</td>
<td>11</td>
<td>6</td>
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</tbody>
</table>
OVERALL RANKING OF NEW SOURCE
1 - BEST, 11 - WORST

<table>
<thead>
<tr>
<th>GROUNDWATER</th>
<th>DAMSITES</th>
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<tbody>
<tr>
<td>LAMBELLS</td>
<td>HOWARD EAST</td>
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<td>PRIVATE</td>
<td>GROUNDWATER</td>
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<td>MANTON</td>
<td>TRANSMIT</td>
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<td>PUBLIC</td>
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<td>DAMSITES</td>
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<td>DAMSITE</td>
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<td>TUMBLING</td>
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<td>WATERS</td>
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</tr>
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<td>ACACIA GAP</td>
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<td>BATCHelor</td>
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</tr>
<tr>
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</table>

RANKING OF NEW SOURCES FOR CONSTRAINTS AND BENEFITS

<table>
<thead>
<tr>
<th>COST</th>
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<th>1</th>
<th>3</th>
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<td>SOCIAL AND</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>7</td>
<td>9</td>
<td>8</td>
<td>11</td>
<td>10</td>
<td>6</td>
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<td>ENVIRONMENTAL IMPACT</td>
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<td>OVERALL</td>
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<td>2</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>8</td>
<td>11</td>
<td>10</td>
<td>9</td>
</tr>
</tbody>
</table>

NEW SOURCES RANKED AGAINST PLANNING FACTORS

Figure 5
PLANNING ISSUES

Overview

The safe yield available from all current major water supplies in the Darwin Region is 49 000ML/year. Under high growth projections, the total demand will reach this level in year 1991. The only potential sources which can be brought into the water supply system by this time are Manton Transfer System, Howard East Groundwater and Lambells Groundwater.

These three sources fall, coincidentally, within the top ranked sources considering cost, social and environmental impacts and development potential. Their combined safe yield will meet the projected high growth in total demand until beyond year 2000. They are presented, therefore, as the preferred options for sequential augmentation to the region's water supply within the short-term perspective.

All remaining options are surface water damsites with larger yield potential, capable on their own or in staged joint operation of meeting possible growth in regional water demand to beyond year 2040.

Total regional demand is composed of three sectors which compete for shares of the water supply source options. This competition is the most important factor in planning for additional sources to augment regional water supply. Based on the accuracy of demand projections, the urban sector is given top priority in allocating potential sources, followed by irrigated agriculture, with aquaculture receiving lowest priority.

Within this overall priority system, sources are matched to demand sectors according to their ability to match short-term demand projections. The matching is then refined to minimise the distance between source and demand sector, and then to maximise the capacity for sharing of sources between demand sectors. This, in effect, results in the nominal dedication of sources to specific sectors of water demand.

Issues of land use planning are discussed for the options available for augmentation programmes. These issues are concerned with securing access to land for the purposes of accommodating development works and also with protecting source water quality through control over land use in catchment areas and recharge zones.
WATER SOURCES & DEMAND SECTORS IN THE DARWIN REGION

KEY TO DEMAND SECTORS

- URBAN
- IRRIGATION
- AQUACULTURE

Figure 6
Source Development Before Year 2000

Urban Sector
Darwin River Reservoir, Manton Reservoir and McMinns Borefield are the existing sources for water supply to the urban sector. While their combined yield is 49 000ML/year, only Darwin River Reservoir and McMinns Borefield are continuously used, so that the longterm supply available to the urban sector is 42 000ML/year.

Due to high costs for pumping from Manton Reservoir, this source is used as an emergency standby. For planning purposes it is assumed that Manton Reservoir does not contribute to year round water supply to the urban sector. Planned recreational use of the reservoir in the near future reinforces this decision. Design and operation of the system will ensure that there will be no conflict from recreational activity on the reservoir.

The total safe yield of Darwin River Reservoir and McMinns Borefield will satisfy urban sector demand until 1992 under high growth projections. Options for development of a new source within this time-frame are limited to Lambells Groundwater, Howard East Groundwater and Manton Transfer System; the lead times needed to complete construction of all others exceed the time available up to 1992. For both Lambells Groundwater and Howard East Groundwater there will be competing demand for water supply from the agricultural sector before the year 1992. Consequently, no supply will be available to the urban sector from Lambells Groundwater and the long-term urban supply from Howard East Groundwater will be restricted to one third of the total yield potential.

Manton Transfer System, then, arises as the best ranked option for short-term augmentation to urban water supply. This system enhances the yield available from Manton Reservoir by picking up the spill overflow, which represents about 70% of the flow through the reservoir. It offers a yield in excess of that available from Manton Reservoir as presently constructed but, calling only on spill overflow, does not change the behaviour of the water storage below overflow level throughout the year. This means that no conflict with recreational use of the reservoir is expected. Addition of Manton Transfer System to water supply available from Darwin River Reservoir and McMinns Borefield will be adequate for urban sector demand to year 2002.
Irrigated Agriculture
It is considered that the firmest prospects for growth in irrigated agriculture centre on the expansion of horticulture in the Lambells Lagoon area. At the highest growth projections this area will require approximately 80% of the potential yield from Lambells Groundwater by year 2000. Given this scenario, it seems appropriate for planning purposes, at this stage at least, to nominally allocate Lambells Groundwater as a dedicated source for horticulture.

Projected growth of other irrigated crops seems less certain. Nevertheless, suitable land for broad-acre field irrigation occurs near Manton Reservoir and the Howard East Groundwater area. High growth projections indicate that, by year 2000, some 65% of the water which could be safely released from Manton Reservoir and 62% of the potential yield of Howard East Groundwater could be required by irrigation in the vicinity of each source. Careful planning is required in the case of Manton Reservoir to ensure that competing needs for transfer to urban supply, minimum water level for recreational use and releases for irrigation are all equitably met.

Subject to other competing demand sectors attaining higher priority, then, it would be appropriate to tentatively plan for the dedication of Manton Reservoir releases and portion of Howard East Groundwater to broad-acre irrigation.

Aquaculture
While lowest priority is given to provision of water supply to aquaculture in planning considerations, this will affect only the freshwater component of the industry. It is assumed that seawater and brackish groundwater will provide satisfactory supply for development of aquaculture in the Hope Inlet and Point Stephens areas.

With the nominal allocations so far made to urban and irrigated agriculture sectors in tentative planning to the year 2000, the remaining potential yield from Howard East Groundwater is only about 30% of the projected requirement for freshwater aquaculture.

Rather than plan for the development of a major regional water source in response to this shortfall, it is considered appropriate that freshwater supply for development of aquaculture in the short-term is to be achieved as a trade-off against the similarly lowly placed broad-acre irrigation sector. In working towards this trade-off, it will be worthwhile investigating the possibility for irrigation to utilise the nutrient enriched wastewater produced from aquaculture ponds.
Source Development Beyond Year 2000

Urban Sector
Following the addition of Manton Transfer System to urban water supply, continuing high growth in demand will require another source of supply in year 2003. Subject to the allocations which may have been made to irrigation and aquaculture, the best option at this time is the remaining 30% of potential yield from Howard East Groundwater. This additional supply to the urban sector will require augmentation in 2006, at which time a choice of six damsites is potentially available.

From year 2006 to year 2040, the annual water demand from the urban sector may increase by 149,500ML. Only Marrakai and Mount Bennet damsites offer yields which can exceed this increase in demand; they are also the best ranked damsites for overall merit. Warrai Damsite is capable of matching high growth in demand until year 2037, when another source would be required.

The remaining three damsites - Acacia Gap, Tumbling Waters and Batchelor - offer a combined yield similar to that of Warrai alone, and less than either Marrakai or Mount Bennet damsites.

When the region has developed to its full capacity, it is expected that water supply of 430,000ML/year will be required by the urban sector alone. Marrakai Damsite is the only single source with yield potential of this magnitude, while the combined yields of Mount Bennet and Warrai damsites would also meet this requirement.

The economics of augmentation have been assessed by taking into account all costs associated with the staging of each damsite in alternative augmentation programmes. This gives predicted cost flows over the period from 1990 to 2040.

The augmentation schedules are based on an assumed rate of growth in population of 3.5% per annum. All capital costs for each source including land acquisition and preparation, construction of dams, pumpstations, pipelines, water treatment plants where necessary, and appertinent works for access and power supply are accounted for, as well as the ongoing annual costs of operation to deliver water into the public supply system. All cost streams are adjusted for an inflation rate of 6.5% per annum. Borrowings for land acquisition and construction works are assumed to be repaid in fixed annual amounts over 25 years at interest rate of 13.5% per annum.
As a measure of economic merit for each augmentation programme, total cost flows to year 2040 are converted to their present value as at 1988. The present values thus obtained should be considered in the light of capital debts which will continue beyond the year 2040, while the different costs of operation of each of the alternative augmentation programmes should also be taken into account for a complete picture of economic merit.

The results of analyses conducted are presented below for the 7 augmentation programmes which encompass all practicable options. All costs are expressed in 1988 money values.

**TABLE 3: ECONOMIC ANALYSES OF DAMSITES**

<table>
<thead>
<tr>
<th>SOURCES</th>
<th>PRESENT VALUE OF ALL COSTS TO YEAR 2040 $M/YEAR</th>
<th>CAPITAL DEBT REPAYMENTS AT YEAR 2040 $M/YEAR</th>
<th>OPERATING COSTS AT YEAR 2040 $M/YEAR</th>
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<tbody>
<tr>
<td>MARRAKAI</td>
<td>46.6</td>
<td>11.7</td>
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<tr>
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<td>9.8</td>
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<tr>
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<td>15.9</td>
<td>9.3</td>
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<tr>
<td>MOUNT BENNET</td>
<td>48.8</td>
<td>12.5</td>
<td>10.2</td>
</tr>
<tr>
<td>TUMBLING WATERS, THEN MARRAKAI</td>
<td>49.9</td>
<td>12.3</td>
<td>8.9</td>
</tr>
<tr>
<td>ACACIA GAP, THEN TUMBLING WATERS, THEN WARRAI</td>
<td>50.9</td>
<td>19.9</td>
<td>6.0</td>
</tr>
</tbody>
</table>
Horticulture
Sustained high growth in horticulture, focussed in the Lambells Lagoon area, will fully utilise the local water and land resources by around year 2017. This will see the accommodation of the major part of all currently projected growth for the industry; only a further 3,300 ha. is currently forecast to be required after this to year 2040.

Satisfactory land of this area is located in the northern vicinity of Darwin River Dam. Staging the development of horticulture in this area could be designed around the criterion of drawing only 10% of the available safe yield from Darwin River Reservoir, this level of demand being the supply required when the full 3,300 ha. is irrigated. Some water demands in this area could be met from local groundwater, however the resource here is generally quite restricted.

The prospect is also recognised that other land, yet to be surveyed for suitability, could be irrigated in the vicinity of the major dams site chosen for development to meet urban water demand at around 2006.

Broad-acre Irrigation, Aquaculture
Long-term planning for water supply to broad-acre irrigation and large-scale freshwater aquaculture remains uncertain. The high growth projection of water demand from each sector is similar at between 18 000 and 19 000 ML/year.

This level of demand, from either sector, can be accommodated with the short-term dedication of all releases from Manton Reservoir and 70% of the potential yield from Howard East Groundwater. Reduced short-term growth in each sector is possible through trade-off in their competition for these sources. Full-scale growth in both broad-acre irrigation and large-scale freshwater aquaculture can arise in association with augmentation to urban sector water supply after year 2006.

The full-scale level of water demand from either of these two competing sectors would represent approximately 10% of the supply at year 2040 to the urban sector.
Land Use Planning For Water Source Development

Urban Sector
Only one source is proposed for development to meet growth in urban sector demand prior to year 2000. This is Manton Transfer System, which will require the construction of intake works and pump station on Manton Reservoir and a pipeline link to Darwin River Reservoir. All works will be located on Government land within the catchments of Manton and Darwin River reservoirs, so that no acquisition of private land will be involved. The most important issue for land use planning related to Manton Transfer System will be to ensure that the proposals for recreational development on Manton Reservoir are compatible with the successful operation of a public potable water supply. This will require careful planning of all works associated with the transfer system, as well as equally careful planning and control of both land and water based activities for all recreational pursuits in the Manton Reservoir catchment.

The next source to be developed for urban water supply augmentation after Manton Transfer System is that portion of Howard East Groundwater available for use at around year 2003, considering the possible competition for share of this resource from irrigation and aquaculture. The primary land use planning issue with this stage of augmentation to urban water supply is to achieve, as far as practicable, the separation of the public system borefield from the other use sectors. At this stage, this seems best capable of being achieved through the dedication of the southern area of the Howard East Groundwater area for urban water supply. Such a location is most compatible with linking to the existing McMinns Borefield, while also leaving the better agricultural areas of the northern part of the groundwater area free for development. The development of a new public water supply borefield in the southern part of Howard East Groundwater Area will require the setting aside of land parcels to accommodate 50ha buffer zones around each of the four to five production bores which will be required, as well as the securing of easements for access roads, power supply and pipelines and the site for a central storage tank and transfer pump station.
Beyond year 2006 urban water supply will require the addition of one of the major damsites of the region. Six damsites are considered to offer potential for development as regional water supplies. Two of these are on the Finniss River, with Batchelor Damsite upstream of Mount Bennet Damsite. Two are on the Adelaide River, with Warrai Damsite upstream of Marrakai Damsite. The remaining two potential sources are Tumbling Waters Damsite on the Blackmore River and Acacia Gap Damsite on the Manton River.

The most significant uncertainties in land planning for the damsites are connected with the granting of land under the Aboriginal Land Rights Act and the possible constraints on development due to Aboriginal Sacred Sites.

Parts of the Finniss River Land Claim which have been recommended for grant lie within the catchments of the Mount Bennet Damsite and Batchelor Damsite. The recommendation concerning the Mount Bennet Damsite is currently under review, while the area recommended for grant within the catchment of Batchelor Damsite apparently remains in limbo - so that future status of land ownership within these catchments is uncertain. While this uncertainty persists it will be difficult to effect land planning decisions for both damsites. In the case of Acacia Gap Damsite, the Larrakeyah Aboriginal Reserve extends into the potential reservoir area. It is recognised that the Northern Territory Government would at best face lengthy negotiation for agreement to develop these damsites. At worst, negotiation may not be possible at all. It is pointed out, however, that positive and costructive contact has been initiated with the Northern Land Council in regard to the Mount Bennet Damsite.

Sacred sites are registered in the catchment of Warrai Damsite. Contact with Traditional Custodians for these sites has been initiated and indicate that no constraints upon development are likely. Sacred sites have been recorded, but not registered, in the catchment of Tumbling Waters Damsite. Their potential constraint upon development of the damsite is not known at this stage. Both Mount Bennet and Batchelor damsites have sacred sites associated with the Finniss River Land Claim. No sacred sites have been recorded or registered for Marrakai Damsite to this point in time.
Levels of settlement and development in the catchments bring another set of constraints upon the potential for each damsite. Generally speaking, the damsites may be classed into two groups, according to their relative size: larger and smaller. The smaller sites are Acacia Gap, Tumbling Waters and Batchelor. The larger damsites are Marrakai, Warrai and Mount Bennet. Different issues of land use planning attach to the two classes by virtue of the intensity of current and possible future land use in their catchments.

All of the smaller damsites have experienced a greater level of development by private landholders. They are occupied by relatively large numbers of residents and rural producers. The larger damsites, on the other hand, are sparsely occupied and developed. In terms of development opportunity, only Marrakai Damsite offers important prospects as a mineral and agricultural area. These issues of existing and potential land use are important factors for each damsite, as the imposition of large reservoirs carries significant impact for regional economic and social planning. The creation and operation of a reservoir, of course, precludes land-based occupation and economic development of the flooded area.

Beyond the direct effects on land use which accompany the conversion of land areas into reservoir storage areas, there may be wider effects which accompany land use controls throughout the catchment areas. By restricting the types of land use pursued in the catchments there may be large savings in the extent of water treatment necessary. These savings, however, must always be compared with the costs of land use control, including the direct costs of acquisition and the indirect costs of preventing alternative land use possibilities. Here again, the smaller damsites have catchments for which these costs are greater compared to the larger damsites.

On balance, the appropriate planning decisions for catchment land use controls seem to be for Acacia Gap, Tumbling Waters, Batchelor and Warrai damsites to be developed with closed catchments (requiring the displacement of all existing landholders through compulsory acquisition), while for Marrakai and Mount Bennet damsites, as the result of both the size of areas involved and their low levels of occupation and development, the catchments would remain open for continuing use, subject to oversighting to ensure that no risk to public water supplies would arise.

Apart from these issues of restricted land use in the impoundment areas and some of the catchment areas, there is also the less vexed question of securing easements for access roads, power supply and pipeline routes.
Irrigated Agriculture

The major issue of land use planning for irrigated agriculture in the Darwin Region is to protect the areas which have been identified as offering the best prospects for supporting the expansion of the industry.

There will be competing pressure on rural lands throughout the Darwin Region for residential development, with the possibility that sizing and occupation of subdivisions will be unsuitable or costly for subsequent conversion for agricultural development. It is most likely that the demand for rural residential subdivision will proceed at a more rapid rate than agricultural subdivision, so that market forces may not prove adequate mechanisms to realise the full development potential for agriculture in the region.

Existing statutory controls for land-use planning in those areas identified as particularly suited to agriculture will need amendment. Regional land use zoning may be the most appropriate means of achieving a desired level of control. With land use zoning in place, it may then be appropriate to encourage initial growth of the industry on the broadest front encompassing all suitable areas. This would aim to achieve long-term regional potential for agriculture in the face of pressures for competing non-agricultural land development.

An important element in this approach to land use control will be the completion of detailed land surveys to confirm the best prospects for agriculture, as well as identifying possible conjunctive land use for residential subdivision.

Detailed land surveys have been completed in the Lambells Lagoon area, however careful planning of the initial stages for the north-east portion is required to avoid saline intrusion. Rates of groundwater extraction within this portion of the area will determine the risk of saline intrusion. Within the currently recognised limitation of safe groundwater extraction rate, the different irrigating schedules of each crop type will allow full development of the north-easterly portion under either melons/cucurbits alone or mixes of all crop types. If extensive fruit tree crops alone are grown, then only two-thirds of this portion can be safely developed for irrigation; with intensive fruit tree crops the safe area to be developed falls to one-third of the portion. These constraints on development potential of the north-east Lambells Lagoon area need to be taken into account in both the release of farm blocks and in ongoing land-use management.

Broad-acre irrigation of field crops, both with supplementary and full season watering is the second sector of agricultural potential with
significant requirements for land and water. Prospects for growth in the Darwin Region are less firm than is the case for horticulture. This could disadvantage the industry when competing for land, although the type of land required will not generally be attractive for residential subdivision. A more important competitive factor may arise in terms of the trade-off between broad-acre irrigation and large-scale freshwater aquaculture for a share of the water resource base. In the short-term this trade-off is expected to require conjunctive development of both industries, with effluent discharge from aquaculture representing a major supply option for irrigation. The land planning issue in this case will be to encourage complimentary siting of the two industries on the most appropriate land systems to encourage economical sharing of water supplies.

Aquaculture
Development of saline aquaculture carries no perceived problems in regard to regional water supply planning, assuming that the sources most suitable are either seawater or brackish groundwater resources - both of which will be subject to little competition for use in regional growth.

Freshwater aquaculture, however, has the potential of requiring large water supplies in comparison with other demand sectors. Its long-term level of demand is similar to that for broad-acre irrigation. In light of the relative uncertainties in growth projections for both freshwater aquaculture and broad-acre irrigation, planning at this stage is tentatively based on a trade-off between both industries for access to water supply. Apart from uncertainties in projecting growth of aquaculture through interplays in the market-place, there is some uncertainty in the land requirements for freshwater aquaculture. Current projections indicate that 500 ha of ponds may be developed in the long-term, and sites in the Southport and Middle-Point areas have been nominated. Both these areas are not considered to offer feasible water supply prospects due to higher priority allocation to either the urban sector or horticulture.

If development of freshwater aquaculture proceeds in conjunction with broad-acre irrigation, then the suitability of land in the vicinity of Howard East Groundwater Area and/or Manton Dam needs to be assessed. Both these areas offer the prospect of achieving about half the individual growth projections for each industry in the short to medium term perspective through the sharing of the available and potential water supplies. In the longer term, both areas could be fully developed from the first major augmentation to regional water supply with completion of the next surface reservoir.
THE STRATEGY

Overview

Growth in the Darwin Region to the year 2000 will rely on increasing water supplies to the urban, agricultural and aquacultural sectors. To the present, only the urban sector has brought consistently growing demand to major water supply sources. Irrigation can be considered an active fledging industry with reasonably strong prospects for continuing expansion in the region. Aquaculture is at embryonic stage with speculative prospects for quite dramatic expansion. It is expected that both irrigation and aquaculture will bring increasing competitive pressures for access to major water sources in the lead up to year 2000.

In recognition of the spatial distribution of major water resources, the disparate locations of each sector of demand and the varying reliability of projections for growth in demands from each sector, the strategic planning for development of new water supplies is based on initially assigning discrete sources to each sector. After this initial dedication of sources to demand sectors, the strategy then examines conjunctive use of sources to maximise efficiency of regional water supply. Consideration is also given to flexibilities in the access to water sources to allow for possible shortfall in growth projections used for each demand sector.

Projections of population growth indicate that the existing potable water supply system drawn from Darwin River Reservoir, McMinns Borefield and Manton Reservoir will need to be augmented by around year 1993. Only the Manton Transfer System and Howard East Groundwater can be developed within this time-frame.

Potable water supply from the groundwater option faces competition from irrigation and aquaculture sectors, to the extent that only some 30% of the assessed yield may be available for the urban sector. An element of competition also exists for Manton Transfer System in terms of the proposed opening of the reservoir to controlled recreational use. It is considered, however, that multiple use of the reservoir can be managed to avoid detriment to potable supply delivered by the Manton Transfer System.

The strategy recommends that final planning for the next two stages of augmentation to potable water supply should be based on Manton Transfer System and 30% access to Howard East Groundwater. These two sources will meet demand from the urban sector at least until the year 2006.
Irrigated horticulture in the Darwin Region is expected to undergo strong growth. The strategy identifies the Lambells Lagoon Area as the prime focus for horticulture, since the land and groundwater resources available here match projected growth to year 2017. Privately operated farm bores are seen as the best option for water supply to irrigation in this area.

Broad-acre irrigation of field crops is also projected to expand in the Darwin Region, however the prospects are less firm than is the case with horticulture. Supplementary irrigation up to 40 000ha could develop in the region to the west of the Adelaide River. At this scale, the water supply required will be equivalent to 70% of the assessed yield of Howard East Groundwater, which lies in the western portion of the potential irrigation area. Water supply will be required at the end of each growing season to supplement late wet season rainfall.

The strategy recommends that water supply be drawn from Howard East Groundwater for broad-acre irrigation, allowing for the share of this resource with the urban sector. Privately operated farm bores would supply irrigation water in the western portion, but a central borefield and transmission system would be needed to deliver water to the Adelaide River Floodplains in the eastern portion.

In addition to supplementary irrigation, there is also some growth expected in year-round field cropping. The projected growth can be fully accommodated on land identified in the northern vicinity of Manton Dam, utilising water released from the reservoir. At full projected growth the irrigation requirement would be equivalent to the safe yield from Manton Reservoir, accounting for operation of the Manton Transfer System and recreational requirements on the reservoir. Water supply for irrigation in this area would require a transmission pipeline to be taken off the Manton Dam Pipeline. Farms would then tap into the transmission pipeline. The strategy recommends that water releases from Manton Reservoir should be dedicated to field irrigation.
Three types of aquaculture are considered to offer prospect in the region. Two of these, the saline and brackish types, would draw on non-freshwater resources provided in abundance by the sea and brackish groundwater on Gunn Point Peninsula. Their access to these waters would not be affected by competition from other users.

Planning for large-scale freshwater aquaculture, however, is difficult in terms of potential impacts on regional water resources.

The primary impact is one of demand for water supply. Without in-situ treatment of water quality in ponds the potential rate of demand for water is very large; at the projected growth ceiling for freshwater aquaculture this demand exceeds the assessed total yield of all water sources in the Darwin Region. In-situ control of water quality will, in principle, reduce the demand for water supply to the ponds. This reduction could be managed to achieve a water supply demand rate within the capacity of known major resources.

The secondary impact on regional water resources from freshwater aquaculture ponds is the effluent wastewaters they generate. Here again, water treatment could, in principle, be managed to remove the need for any wastewater effluent. This would, however, deny the possibility for re-use of the nutrient enriched waste-waters. It may be feasible for these potentially valuable waste-waters to be used for irrigation. Slight modification to the treatment process used in freshwater aquaculture ponds could result in conjunctive development of irrigation. The mix of freshwater aquaculture and irrigation actually realised would depend on both competing economics and the relative rates of growth in each industry. It is possible, for example, that 50% of the full projected potential for both freshwater aquaculture and broad-acre irrigation could be achieved from the assessed yield of Manton Reservoir and 70% of the assessed yield of Howard East Groundwater.

The strategy recommends that these sectors of the irrigation and aquaculture industries compete in the short to medium term future for Manton Reservoir Releases and 70% of the assessed yield for Howard East Groundwater. Such a trade-off could achieve half of the projected long-term projections for freshwater aquaculture and broad-acre irrigation. In the short-term, however, 70% of the projected growth in the irrigation sector to year 2000 could be met.
For the strategic allocation of water supply sources recommended thus far:

- Potable water supply to the urban sector will be met to year 2006 from Darwin River Reservoir, McMinns Borefield, Manton Transfer System and Howard East Borefield (30%).

- Expansion of irrigated horticulture to year 2017 can be met in the Lambells Lagoon area through the dedication of the local groundwater resource to the industry.

- Either broad-acre irrigation or freshwater aquaculture may develop to full projected scale using Howard East Groundwater (70%) and Manton Reservoir. Conjunctive use of these water sources could satisfy 50% of the projections for long-term development in each industry. In terms of projections to the year 2000, the conjunctive use of the sources could achieve, respectively, 50% and 70% of the level of development, respectively, for aquaculture and broad-acre irrigation.

The strategy for water supply augmentation to this stage enables a degree of flexibility to be exercised in the overall allocation of water sources to demand sectors. It is recognised that projected rates of growth in demand for other than the urban and horticultural sectors may not be achieved. If growth rates for either broad-acre irrigation and aquaculture are less than allowed for in the strategy then the opportunity would arise for re-allocation of Howard East Groundwater and releases from Manton Reservoir to the dominant remaining sectors.
Beyond the turn of the century, the only major augmentation to regional water supply will be the construction of a dam, primarily to meet rising demand for potable water supply from the urban sector. There may also be additional water supply capacity needed for irrigation and aquaculture. Current projections place these demands as small proportions of the requirement for potable water supply.

Six damsites are capable of providing major water supplies. While detailed engineering and environmental investigations are yet to be undertaken, evaluation of all important regional planning issues places Marrakai, Warrai and Mount Bennet damsites in the top rankings. Issues of cost efficiency, social impact and development potential relegate Batchelor, Acacia Gap and Tumbling Waters damsites to the lower rankings.

With each of the top three ranked damsites - Marrakai, Warrai and Mount Bennet - capable of meeting demand for potable water supply to year 2040 and beyond, the strategy recommends that all other optional damsites - Batchelor, Tumbling Waters and Acacia Gap - should be relinquished from consideration as regional source options.

Placing the Marrakai, Warrai and Mount Bennet damsites within the horizon beyond 2040 reveals their strategic importance to the region. Their combined yield, in conjunction with currently developed sources and those recommended for development before year 2000, is assessed to be capable of meeting the demand for water when the region's population capacity of 1 million is attained.

In consequence of their strategic importance, and considering the need to achieve early resolution of all issues necessary to finalise their place in a regional development strategy plan, including the completion of land acquisition programmes, the strategy recommends that detailed geotechnical investigations and environmental assessments should proceed immediately at Marrakai, Warrai and Mount Bennet damsites.
Conclusions

1. At high growth rates, it is concluded that:-

(a) Water supply demands in the region will increase to the following levels by 2040:-

<table>
<thead>
<tr>
<th></th>
<th>206 000 ML/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>206 000 ML/year</td>
</tr>
<tr>
<td>Agriculture</td>
<td>38 000 ML/year</td>
</tr>
<tr>
<td>Aquaculture</td>
<td>18 000 ML/year</td>
</tr>
</tbody>
</table>

(freshwater only)

TOTAL 262 000 ML/year

(with demands continuing to grow well beyond 2040.

(b) The population in the region is projected to reach about 500 000 by 2040 with a population capacity well in excess of one million occurring sometime after 2100.

(c) The existing regional water supply sources of Darwin River Reservoir, McMinns Borefield and Manton Reservoir (emergency use only) are projected to be fully utilized by 1992.

(d) Relatively small new sources will be required for urban water supply, irrigation and aquaculture prior to 2000. A major new damsite will be needed by about 2006, primarily for urban water supply, but also for field irrigation and freshwater aquaculture.

(e) For the period to year 2000, freshwater aquaculture and irrigation supplies will be most appropriately developed through close liaison between PAWA, Department of Lands and Housing, Department of Industry and Development and private developers based on Lambells Groundwater, portion of Howard East Groundwater and Manton Reservoir. Each of these sources is closely associated with land considered suitable for irrigated agriculture, although detailed land surveys are only completed for the Lambells Lagoon Area.

(f) Future augmentation of potable water supply from Howard East Groundwater and Manton Transfer System, including interaction with proposed recreational use of the reservoir, is adequately covered by current planning programmes within PAWA.
(g) Marrakai, Mount Bennet or Warrai damsite could each satisfy the projected growth in demand for water for some 50 years hence, while their joint total supply capacity should be adequate for at least 100 years into the future. All three are of major strategic importance to the long-term prospects for regional growth.

(h) The present values of staged development of Marrakai, Warrai and Mount Bennet Damsites over the planning period to 2040 fall within the narrow range of $47M to $49M. Consequently, none of these options has a clear economic advantage by this measure.

2. Acacia Gap and Tumbling Waters Damsites offer only small development potential relative to overall regional requirements and would cause considerable community dislocation. As a consequence, it is concluded that they can be discarded from further consideration.

3. Batchelor Damsite was provisionally withdrawn from consideration in November 1987 on socio-economic grounds. In view of the study showing the three remaining damsites of Marrakai, Mount Bennet and Warrai to be more attractive, it is concluded that Batchelor Damsite should not be considered further.

4. Marrakai, Mount Bennet and Warrai Damsites require detailed geotechnical and engineering work before they can be regarded as technically proven. This is estimated to cost a total of $1.0M over a two year period. Aboriginal sacred site issues need to be resolved for Warrai and Aboriginal land issues may arise for Mount Bennet damsite.

5. Pending confirmation of technical and environmental feasibility, Warrai, Marrakai and Mount Bennet Damsites should be recognised as the future major water resources of the region.
6. Land management in each of the selected damsites would depend upon whether the catchment is to be closed or remain open.

Warrai catchment would be closed and land management would be the responsibility of PAWA. Marrakai and Mount Bennet catchments would be open and their development monitored using existing regional planning referral mechanisms to avoid conflict with water supply objectives.

Mining and quarrying are currently carried out in Marrakai and Mount Bennet catchments, with Marrakai catchment considered very prospective for mineral development. Accelerated exploitation of mineral prospects within the impoundment area should be encouraged so that known prospects are exhausted before development of the damsite.

Ordinary pastoral, agricultural, recreational and rural-residential use of Marrakai and Mount Bennet catchments would be permitted but would be monitored and controlled using existing regional planning mechanisms to safeguard these major future water supply options.

No legislative changes or new planning instruments are considered necessary at this stage.

7. The whole of Warrai catchment would be acquired at an estimated current cost of $600 000. For Marrakai and Mount Bennet damsites, the impoundment area and an approximate 0.5 km buffer of land around the reservoir would be acquired. The estimated current cost of acquisition for Marrakai damsite is $1.7M and for Mount Bennet $850 000.
Recommendations

It is recommended that:-

1. Endorsement, in principle, be given to the following strategy for regional water supply and associated land management:

   (a) base the development of irrigation and freshwater aquaculture on water supplies from Manton Dam, Lambells Groundwater and Howard East Groundwater;

   (b) develop Manton Transfer System and portion of Howard East Groundwater as the next two stages of augmentation to potable supply;

   (c) relinquish Acacia Gap, Tumbling Waters and Batchelor damsites as regional water source planning options;

   (d) adopt Warrai, Marrakai and Mount Bennet damsites as preferred longterm water source options, subject to confirmation of engineering feasibility and satisfactory environmental assessment of each damsite, and agreement with Aboriginal traditional custodians regarding sacred sites affected by Warrai Damsite and special arrangements for Aboriginal land affected by Mount Bennet Damsite.

2. In order to finalize selection of the preferred next regional dam, detailed engineering feasibility and environmental impact investigations be completed for Warrai, Marrakai and Mount Bennet damsites in 1988/89 and 1989/90 at an order of cost of $1.0M.

3. No legislative changes or planning instruments be instituted at this stage in relation to land use management in the Warrai, Marrakai, and Mount Bennet Damsite catchments.

4. The strategy for water supply and land management be reviewed on the basis of the findings of the feasibility studies referred to in Recommendation 2.
# TABLE 4: DARWIN REGION WATER SUPPLY & LAND MANAGEMENT OVERVIEW

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>LAMBERTS GWATER</th>
<th>HOWARD EAST GWATER</th>
<th>MANTON TRANSFER</th>
<th>WARRAI DAMSITE</th>
<th>MARRAKAI DAMSITE</th>
<th>MT. BENNET DAMSITE</th>
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</tr>
<tr>
<td>- TOTAL WORKS:</td>
<td>$1M (PRIVATE FARMS)</td>
<td>$1M (PRIVATE FARMS)</td>
<td>$12M (POTABLE SUPPLY)</td>
<td>$181M</td>
<td>$433M</td>
<td>$262M</td>
</tr>
<tr>
<td>- LAND:</td>
<td>NIL</td>
<td>NIL</td>
<td>NIL</td>
<td>$0.6M</td>
<td>$1.7M</td>
<td>$0.8</td>
</tr>
<tr>
<td>- $/ML/YR</td>
<td>$80</td>
<td>$80</td>
<td>$800</td>
<td>$1490</td>
<td>$990</td>
<td>$1315</td>
</tr>
<tr>
<td>SAFE YIELD</td>
<td>1200 (POTABLE SUPPLY)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EXPANDING HORTICULTURAL INDUSTRY TO BE SUPPORTED BY PRIMARY DEDICATION OF LAMBERTS GROUNDWATER TO PRIVATE FARM DEVELOPMENT, ALLOWING FOR POSSIBLE SHARE OF WATER RESOURCE FOR URBAN AND AQUACULTURE SECTORS.

FURTHER EXPANSION OF IRRIGATION TO BE SUPPORTED BY DEDICATION OF UP TO 7,000 ML/YR RELEASE FROM MANTON DAM, AND ALSO APPROX. 70% OF HOWARD EAST GROUNDWATER TO PRIVATE FARMS, LEAVING 30% FOR URBAN SECTOR. SUBJECT TO IRRIGATION AND URBAN NEEDS, SOME SUPPLY TO AQUACULTURE MAY BE POSSIBLE.

MAJOR DAMS WILL BE NEEDED BEYOND 2006 TO AT LEAST SATISFY POTABLE DEMAND BY URBAN SECTOR. COMBINED SUPPLY POTENTIAL FROM MOUNT BENNET, MARRAKAI AND WARRAI DAMSITES IS ADEQUATE FOR FORECAST DEMANDS FOR AT LEAST THE NEXT 100 YEARS. LACK OF GEO-TECHNICAL INFORMATION AT EACH DAMSITE PREVENTS FINAL CONCLUSION ON ENGINEERING FEASIBILITY FOR THE PRESENT.

WARRAI CATCHMENT IS USED FOR LOW INTENSITY PASTORAL ACTIVITY AND CAN BE CLOSED WITH LITTLE SOCIO-ECONOMIC IMPACT TO ACHIEVE LOW-COST WATER QUALITY MANAGEMENT. WARRAI CATCHMENT WOULD BE CLOSED TO RECREATION USE, BUT CONTROLLED USE SHOULD BE PERMITTED IN MARRAKAI AND MOUNT BENNET CATCHMENTS.

THERE ARE NO KNOWN CONSTRAINTS DUE TO ABORIGINAL LAND ISSUES FOR MARRAKAI DAMSITE, BUT FLOODING OF SACRED SITES IN WARRAI DAMSITE AND PART OF FINNISS RIVER LAND CLAIM IN MOUNT BENNET DAMSITE NEEDS TO BE NEGOTIATED.

ALTHOUGH SECURITY BUFFERS WILL BE NEEDED AROUND POTABLE SUPPLY BORES THE BALANCE OF LAND IN THE GROUNDWATER AREAS WILL BE AVAILABLE FOR GENERAL AGRICULTURE. NO CONTROLS ON PRIVATE BORES ARE ENVISAGED BEYOND PLANNING FOR THE RATIONAL AND EQUITABLE SHARING OF AVAILABLE WATER RESOURCES.

MANTON TRANSFER SYSTEM OR HOWARD EAST GROUNDWATER WILL AUGMENT URBAN SECTOR SUPPLY BEFORE YEAR 2000.
POTENTIAL SOURCES RECOMMENDED FOR DEVELOPMENT
HEG - HOWARD EAST GROUNDWATER
LG - LAMBELLS GROUNDWATER
MD - MARRAKAI DAMSITE
WD - WARRAI DAMSITE
MBD - MOUNT BENNET DAMSITE
MTS - MANTON TRANSFER SYSTEM

POTENTIAL SOURCES NOT RECOMMENDED FOR DEVELOPMENT
BD - BACHELOR DAMSITE
TWD - TUMBLING WATERS DAMSITE
AGD - ACACIA GAP DAMSITE

1988 SOURCES
McMB - McMINNS BOREFIELD
MnR - MANTON RESERVOIR
DRR - DARWIN RIVER RESERVOIR

STRATEGY FOR MAJOR WATER SUPPLY DEVELOPMENT IN THE DARWIN REGION

Figure 7