Water Authority
of Western Australia

Next Major Public Water Supply Source for Perth (post 1992)

Environmental Review and Management Programme
Stage 1

Evaluation of Alternatives

Ian Pound & Associates Pty Ltd
January 1988

Water Authority
of Western Australia

WATER RESOURCES DIRECTORATE
Water Resources Planning Branch

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Environmental Review and Management Programme
Stage 1: Evaluation of Alternatives

The Environmental Protection Authority (EPA) invites people to make a submission on this proposal.

This Environmental Review and Management Programme (ERMP) Stage 1 for the evaluation of alternatives and selection of the next major public water supply source for Perth (post 1992) has been prepared for the Water Authority of Western Australia in accordance with Western Australian Government procedures. The report will be made available for comment for 10 weeks, beginning on 17 February 1988 and finishing on 27 April 1988.

Comments from Government agencies and from the public will assist the EPA to prepare an Assessment Report in which it will make a recommendation to Government.

The ERMP Stage 1 provides a detailed analysis of issues relevant to the selection of the next major water supply source for Perth. This will be followed by a Stage 2 report which will focus on the management of the environmental affects of the selected source development.

Why write a submission?

A submission is a way to provide information, express your opinion and put forward your suggested course of action including any alternative approach. It is useful if you indicate any suggestions you have to improve the proposal.

All submissions received will be acknowledged.

Developing a submission

You may agree or disagree, or comment on, the general issues in the ERMP Stage 1 or with specific proposals.It helps if you give reasons for your conclusions, supported by relevant data.

You may make an important contribution by suggesting ways to make the proposal environmentally more acceptable.

When making comments on specific proposals in the ERMP Stage 1:

- clearly state your point of view;
- indicate the source of your information or argument if this is applicable; and
- suggest recommendations, safeguards or alternatives.

Points to keep in mind

By keeping the following points in mind, you will make it easier for your submission to be analysed:

- Attempt to list points so that the issues raised are clear. A summary of your submission is helpful.
- Refer each point to the appropriate section, chapter or recommendation in the ERMP Stage 1.
- If you discuss different sections of the ERMP Stage 1, keep them distinct and separate, so there is no confusion as to which section you are considering.
- Attach any factual information you wish to provide and give details of the source. Make sure your information is accurate.

Please indicate whether your submission can be quoted, in part or in full, by the EPA in its Assessment Report.

Remember to include

- YOUR NAME
- ADDRESS
- DATE

THE CLOSING DATE FOR SUBMISSIONS IS 27 APRIL 1988.
SUBMISSIONS SHOULD BE ADDRESSED TO:

The Chairman
Environmental Protection Authority
1 Mount Street
PERTH WA 6000

Attention: Mr C. Murray

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Supporting Documents

DUNLOP, J. N. & ASSOCIATES AND NINOX WILDLIFE CONSULTING (1987). *A Fauna Assessment of Four Water Supply Sources in the Darling Ranges.* Report to the Water Authority of Western Australia.

FEILMAN PLANNING CONSULTANTS (1987). *Next Major Water Supply Source for Perth. Preliminary Assessment of Social/Recreational Impacts.* Report to the Water Authority of Western Australia.

HAVEL LAND CONSULTANTS (1987). *Flora and Vegetation of Four Alternative Water Resource Development Sites in the Northern Jarrah Forest, Western Australia.* Report to the Water Authority of Western Australia.

O'CONNOR, R. AND BENNELL, P. (1987). *Report on the Ethnographic Survey of Four Alternative Water Supply Sources.* Report to the Water Authority of Western Australia.

STONE, R. R. (1987). *Next Major Source for Perth.* Engineering Report. Water Authority of Western Australia, Report WP 72.

VETH, P. (1987). *A Report on the Significance of Aboriginal Archaeological Sites at the Mundaring, Canning, North Dandalup and South Canning Dam Sites.* Report to the Water Authority of Western Australia.

1. Summary

A new major water source will be required after the currently proposed Pinjar development to meet the increasing demand on the Perth water supply system.

The Water Authority's water conservation programme now being actively implemented will delay the need for the next major source as long as possible but demand may still necessitate development of a new major source as early as 1993.

After reviewing the full range of water supply options, four alternatives were identified as the most feasible for development as the next major source for the Perth metropolitan region. The four alternatives were: the raising of Mundaring Weir (referred to in this report as 'Raised Mundaring'), the raising of Canning Dam ('Raised Canning'), the construction of a dam at South Canning or the construction of a dam at North Dandalup near the site of the existing pipehead facility.

Selection of the most beneficial and environmentally acceptable source was based on consideration of key factors in the four broad areas (accounts) of water supply, economics, natural environment and social environment. Using these key factors to characterise and differentiate the four alternative source developments, the alternatives were ranked within each account on the basis of best satisfying nominated objectives:

- the **water supply** objective, which was to provide the most reliable and best quality water supply to meet the next increment in the metropolitan demand;
- the **economic objective** of providing the required additional water supply at minimum long-term monetary cost to the community;
- the **natural environment** objective of minimising impact on the environment; and
- the **social environment** objectives of minimising social costs and maximising social (recreational) opportunities without unduly adversely affecting any particular individual or sector of the community.

Engineering investigations and investigations of the natural and social environment were conducted for the four alternatives. These investigations entailed reviewing existing information and undertaking additional studies aimed at providing an appropriate basis for selecting the best new major public water supply source for Perth. Discussions with relevant agencies and community groups provided feedback on the approach and on community values.

On the basis of these studies, the Water Authority identified the North Dandalup Dam as ranking first in all four accounts and as being clearly the best alternative overall.

The review of North Dandalup Dam and its natural and social environment in the context of an assessment of alternative sources has not identified any individual or cumulative effect of the project, the nature or magnitude of which makes the project environmentally unacceptable.

Further investigation is required for detailed design to optimise the project within technical and economic constraints, minimising any adverse impacts on the environment and realising maximum social opportunity in both the project's construction and operation. The detailed implementation planning which follows this assessment will be directed to that purpose and the results of that planning, including commitments to implementing a programme of specific monitoring and management strategies, will be presented to the Environmental Protection Authority (EPA) in the Stage 2 Environmental Review and Management Programme (ERMP).

This Stage 1 ERMP:

1. demonstrates the need for a new source, possibly as early as 1993;
2. demonstrates that of the options available, and after a broadbased evaluation of the feasible alternatives, North Dandalup is the best source for development;
3. establishes that there are no adverse impacts, either locally or for the region, the significance of which would make the development of a new storage dam at North Dandalup environmentally unacceptable;

The Water Authority therefore seeks agreement in principle from the Environmental Protection Authority and the Minister for Environment that the development of a new storage dam on the North Dandalup River is environmentally acceptable.

Following such agreement in principle being given, the Water Authority will proceed with implementation planning and preparation of a Stage 2 ERMP that:

1. elaborates on planning and details of the proposed project;
2. refines predictions of impacts made in Stage 1, reviews measures for mitigation of adverse environmental effects and outlines means for realising the environmental benefits of the project;
3. includes the framework for and approach to be adopted in an active monitoring and management programme for the project, identifying systems and components of the environment which require ongoing attention.

2. Introduction

2.1 The water supply planning process

The Water Authority of Western Australia has statutory responsibility for the management and allocation of the State's water resources and the utility role of sourcing and distributing the public water supply.

The water supply planning process is outlined in the report 'Planning Future Sources for Perth's Water Supply' (Mauger, 1987). A diagram illustrating the planning and decision-making process is reproduced in Figure 1.

The first level of planning involves framework studies and developing policies to provide a broader basis for individual decisions on allocation and management of water resources. As part of this comprehensive basis for rational planning of water allocation and management, the Water Authority has recently completed, for the Water Resources Council, a preliminary review of the Perth/Bunbury region's water resources, their attributes, and the competing demands upon those resources. The study proposes a balanced allocation of preferred uses for individual regional water resources. The proposals have been published in the working paper 'A Strategy for Water Allocation in the Perth/Bunbury Region' (Western Australian Water Resources Council, 1987).

Within this developing context of strategy planning, the Water Authority has prepared, and regularly reviews, a Source Development Plan (SDP). The Source Development Plan seeks to match Perth's future water supply demands by developing sources which are most cost-effective within known and assumed environmental and social constraints. The SDP is, in effect, the anticipated long-term timetable for source development, reflecting the lowest-cost sequence of development of these sources. The current SDP (described in Mauger, 1987) provides three different source development timetables to meet 'maximum', 'most likely' and 'minimum' projections of increasing demand* on Perth's water supply over the next 25 years (see Figure 2). The 'most likely' timetable identifies the need for a new major source (after the currently proposed Pinjar project) for commissioning by 1993. Table 1 provides a revised 'most likely' timetable which takes account of recent refinements in source yield estimates, (see section 5.2.4 (iv)).

,*See Glossary

Although the Urban Water Conservation Programme will seek to delay the need for new sources (see section 3.2), planning and design must proceed sufficiently in advance of demand to ensure that source development can occur when it is required for continuity of Perth's water supply.

Having identified the need and likely timing of the next major source from the SDP, the next step in the planning process is the commencement of project planning. This is carried out in two stages:

- **assessment planning** to select a source and present the findings in an Environmental Review and Management Programme, or a Stage 1 ERMP in the case of a complex project where the Environmental Protection Authority considers a staged approach appropriate (see 2.2); and
- **implementation planning,** which involves preparation of detailed design and management plans for the selected source and presentation of a Stage 2 ERMP where a staged approach has been adopted.

The Water Authority has completed the review of alternatives in the assessment planning stage for the next major source after Pinjar and is now seeking agreement on the environmental acceptability of development of the favoured alternative so that detailed implementation planning may proceed.

2.2 The assessment planning stage

The objectives for the assessment planning stage for the next major source after Pinjar were:

1. to determine, from a broad-based assessment of the alternatives, the most satisfactory new public water supply source for commissioning as early as 1993 if required according to forecasts based on the observed growth in Perth's water supply demand;
2. to seek agreement as to the environmental acceptability of development of the recommended source, when required by demand growth, through preparation of Stage 1 of an Environmental Review and Management Programme to facilitate Environmental Protection Authority and public review of the evaluation of alternatives.

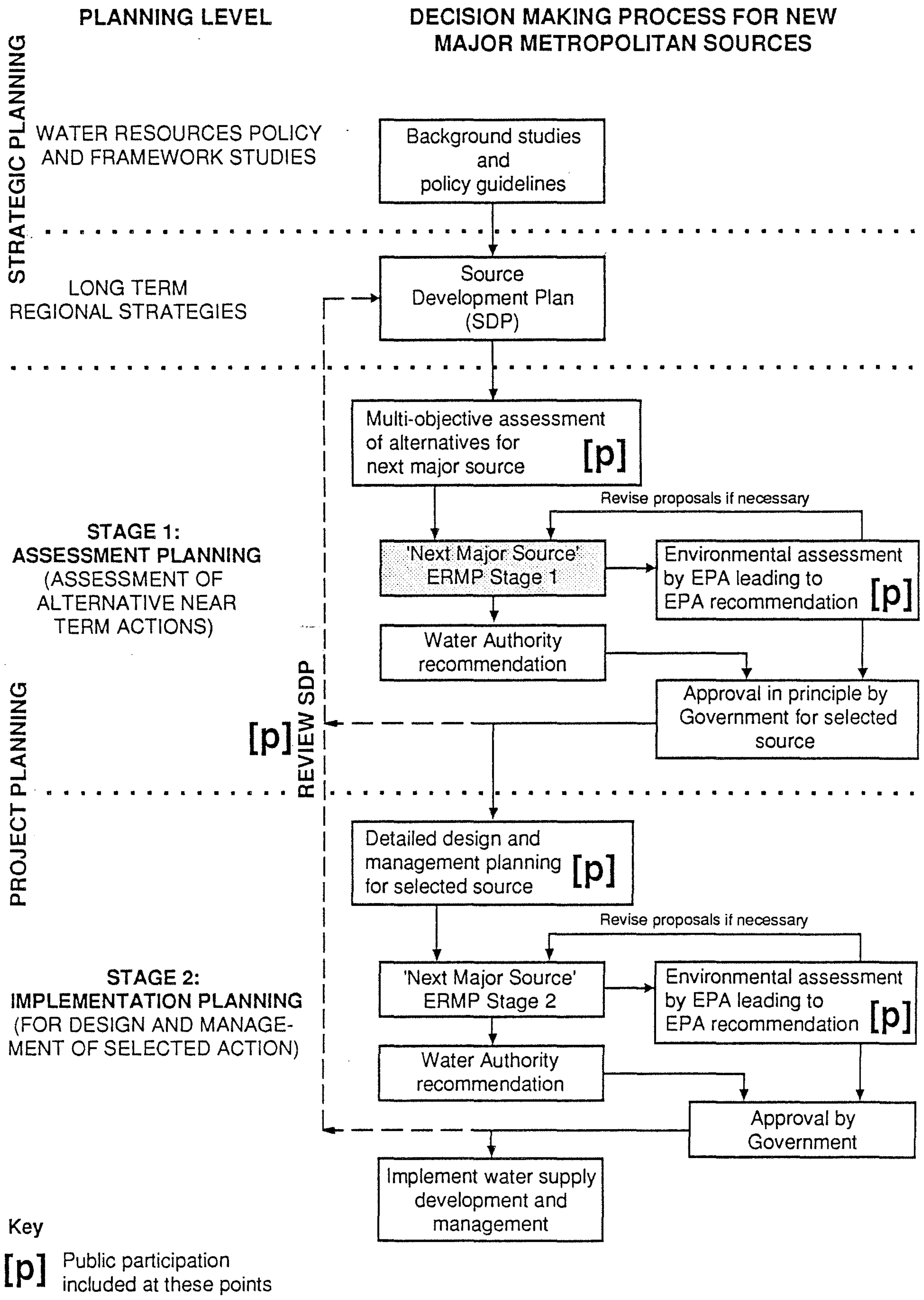

Figure 1: The Planning and Decision-making Process

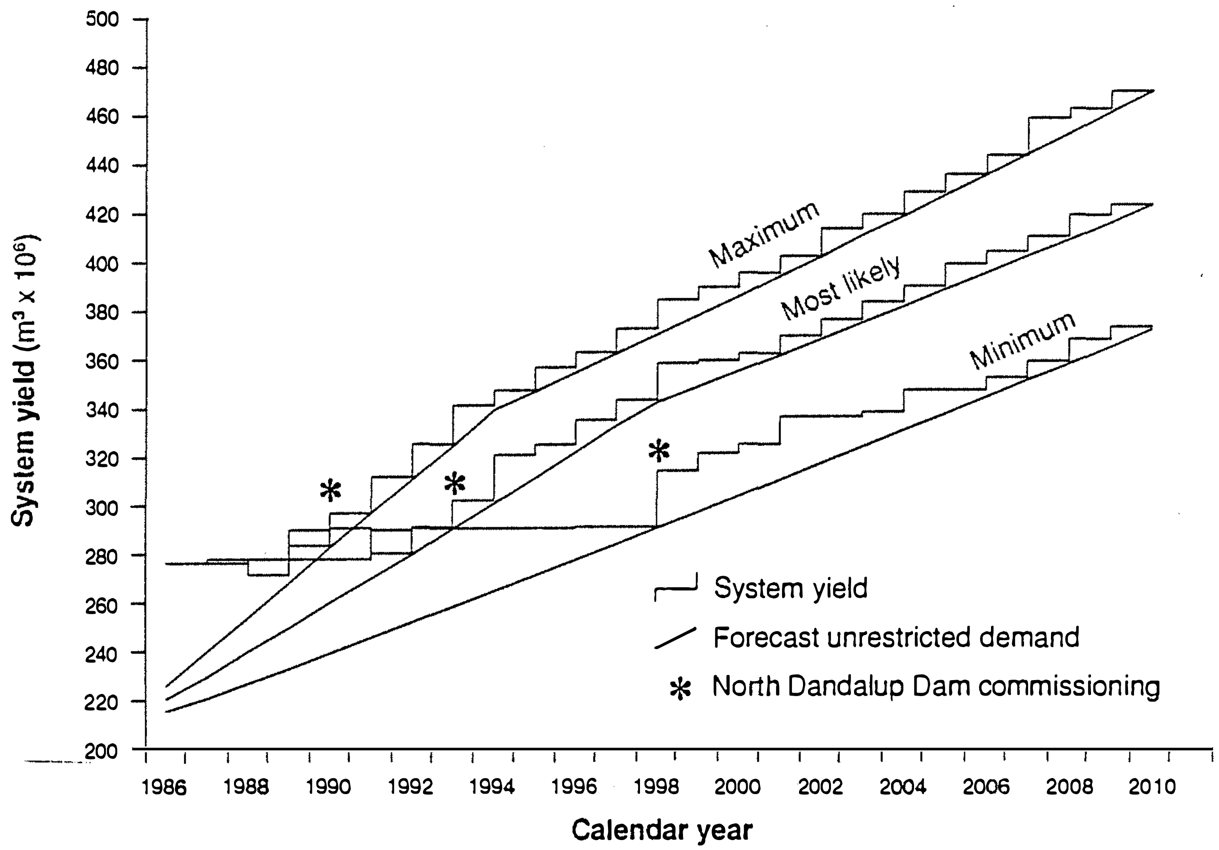

Figure 2: Source Development Timetables
(for 'maximum', 'most likely' and 'minimum' demand estimates)

The Source Development Plan (Mauger, 1987) current at the time of the evaluation being undertaken (February, 1987) identified North Dandalup Dam (a new storage dam to replace the existing pipehead dam on the North Dandalup River) as the most economically attractive option for the next major source. A wide range of water supply options was examined at the commencement of this evaluation to determine a smaller number of viable alternatives which could meet the same basic requirements as North Dandalup Dam (see sections 4.1 and 4.2). These viable alternatives (including North Dandalup) were then investigated and the results assessed in order to select the most suitable post-1992 water supply source augmentation for Perth. Water supply, economic, natural environment and social factors were considered in this assessment.

Discussions with relevant agencies and community groups have provided valuable feedback on the approach and on community values. The Water Authority held a workshop for invited representatives of government agencies and public interest groups in September 1986 and subsequent meetings refined the input from these and other parties. This input has been incorporated into the assessment and has assisted in determining which source development is considered of most benefit to the community as a whole.

The investigation and evaluation of the feasible alternatives has been described in the Water Authority's working report entitled 'Next Major Source for Perth - Evaluation of Alternatives' (Stone and Pound, 1987).

Selection and assessment of the next major source of water supply for Perth has involved consideration of a complex array of factors but has ultimately resulted in the recommendation of a source considered by the Water Authority to be clearly better than any of the other alternatives.

Table 1: Most Likely Source Development Timetable (includes G & AWS System)

All units millions of cubic metres per annum

D.A.W.=Deep Artesian Well G.W.=Groundwater Scheme P.H.=pipehead P.B.=pumpback St=stage

Year	Forecast unrestricted demand	Sources commissioned (operational)	Groundwater interim quota Scheme	Groundwater interim quota Total	System yield benefit	System yield	Surplus yield
1984/85	210.8	STORAGE RESERVOIRS:					
		Canning,Serpentine,					
		South Dandalup,Wungong					
		(restricted outlet)*,					
		Churchmans,Victoria, Mundaring.					
		PIPEHEADS/PUMPBACKS:					
		North Dandalup P.H.					
		Lower Helena P.B.					
		GROUNDWATER SCHEMES:					
		Gwelup	10.5				
		Mirrabooka	16.8				
		East Mirrabooka St 1&2	4.6				
		Wanneroo	21.2				
		Jandakot St 1	4.0				
		Deep Artesian	12.0	69.1		276.2	+65.4
1987/88	239.8	Wanneroo D.A.W.	1.5	70.6	1.5	277.7	+37.9
1988/89	249.4					277.7	+28.3
1989/90	259.9	Pinjar St 1 G.W.	10.2	80.8	11.9	289.6	+29.7
1990/91	269.7	Mundaring Integration			0.0		
		Wungong Outlet Main Amp.			1.1	290.7	+21.0
1991/92	279.7	Deletion of North Dandalup P.H.			-11.5		
		Cockleshell Gully D.A.W. (north)	1.1	81.9	1.1	280.3	+ 0.6
1992/93	290.3	Conjurunup Creek P.H.			5.2		
		Cockleshell Gully D.A.W. (south)	1.3		1.3		
		Jandakot St 2 G.W.	4.0	87.2	4.2	291.1	+ 0.7
1993/94	300.7	North Dandalup Dam (part)			11.0	302.0	+ 1.3
1994/95	311.2	North Dandalup Dam (add)			7.0		
		Pinjar St 2 G.W.	10.9	98.1	11.9	320.9	+ 9.7
1995/96	321.7	North Dandalup Dam (add)			4.0	324.9	+ 3.2
1996/97	332.6	Gooralong P.B.			3.2		
		North Dandalup Main Amp			3.0		
		North Dandalup Dam (add)			4.1	335.2	+ 2.6
1997/98	342.3	Cockleshell Gully D.A.W. (central)	1.3		1.3		
		Whitfords D.A.W.	1.5		2.0		
		Tamworth D.A.W.	1.5	102.4	2.0		
		Raise Mundaring Weir			0.0		
		(enlarged Helena Reservoir)					
		Lower Serpentine P.B. St 2			3.0	343.5	+ 1.2
1998/99	348.7	Pinjar St 3 G.W.	10.9	113.3	12.0		
		Raised Mundaring (part)			3.0	358.5	+ 9.8
1999/2000	355.1	Raised Mundaring (add)			1.0	359.5	+ 4.4
2000/01	361.7	Dirk Brook P.B.			3.0	362.5	+ 0.8
2001/02	368.3	Lexia G.W.	6.5	119.8	7.0	369.5	+ 1.2
2002/03	374.9	South Canning Dam			0.0		
		Araluen P.B.			1.8		
		Raised Mundaring (add)			3.0		
		Hamilton Hill D.A.W.	1.5	121.3	2.0	376.3	+ 1.4
2003/04	381.6	Marrinup Brook P.B.			5.3		
		Lake Thompson D.A.W.	1.5	122.8	2.0	383.6	+ 2.0
2004/05	388.4	Lower South Dandalup P.B.			4.4		
		East Mirrabooka St 3 G.W.	2.0	124.8	2.0	390.0	+ 1.6
2005/06	395.2	Yeal St 1 G.W.	7.8	132.6	9.0	399.0	+ 3.8
2006/07	402.0	Raised Mundaring (add)			3.0		
		South Canning Dam (part)			2.0	404.0	+ 2.0
2007/08	408.9	Jane Brook P.B.			6.1	410.1	+ 1.2
2008/09	415.9	Yeal St 2 G.W.	7.8	140.4	9.0	419.1	+ 3.2
2009/10	423.1	South Canning Dam (add)			4.0	423.1	+ 0.2

* Assumes Wungong Tunnel and outlet pipes completed to South West Highway.

2.3 The Stage 1 Environmental Review and Management Programme

Having determined, after a careful review of the options and broad-based evaluation of the alternatives, the most satisfactory new public water supply source, the Water Authority now submits the first stage of its ERMP to the EPA.

The two-stage approach to preparation of the ERMP was determined, in conjunction with the EPA, to benefit both the source development planning and the environmental review processes. This approach provides the opportunity for a full review and assessment of the range of available alternatives prior to a commitment to detailed planning for the source concluded to be the best for development as the next major source.

This document has been prepared to facilitate early EPA and public review of the evaluation process and the selected source.

This report briefly addresses the options reviewed, assesses in greater detail the alternatives which appeared feasible for development as the next major source and finally reviews the source concluded to be best. Some established management strategies for mitigating project impacts through design or construction practices are addressed in this report. The framework of the formal management programme for the proposed project will be developed and presented in Stage 2 of the ERMP together with further definition of the project as detailed design proceeds.

This Stage 1 ERMP has been kept as concise as possible, whilst conveying the information essential to decision-making. Readers requiring further details of particular aspects of the study are referred to the comprehensive supporting documents available from the Water Authority.

The Water Authority believes that this Stage 1 ERMP report

1. demonstrates the need for a new source, possibly as early as 1993;
2. demonstrates that of the options available, and after a broad-based evaluation of the feasible alternatives, North Dandalup is the best source for development;
3. establishes that there are no adverse impacts, either locally or for the region, which would make the development of a new storage dam at North Dandalup environmentally unacceptable;

and now proposes to proceed with detailed implementation planning and a Stage 2 ERMP for the preferred alternative. The Authority seeks EPA endorsement of this proposed course of action.

3. *The Need to Develop a New Major Water Source*

3.1 The demand for water

The report 'Planning Future Sources for Perth's Water Supply' provides details on historical and projected demand* for water from Perth's public water supply (Mauger, 1987). Broadly speaking, projected demand is controlled by two factors: population growth and increase in water use per person.

Three demand projections have been developed - 'minimum', 'most likely' and 'maximum'. The 'most likely' demand projection assumes that overall metropolitan water use per person will continue to increase until the late 1990s, up to the level of consumption per capita reached prior to the introduction of water restrictions in 1977, and will then remain constant at that level. Of the expected 4% per annum growth in the total metropolitan demand over this period, about half would be attributable to increased per capita demand, with the balance due to population growth. The 'minimum' demand projection assumes an increase close to the population growth figure of 2% per year. Based on 'most likely' demand predictions, a major new source of water supply will be needed in 1993.

3.2 Water conservation

The Water Authority's policy since 1987 has been to 'actively promote throughout the community the adoption of efficient practices in the utilisation of fresh water' (Water Authority, 1987). The Authority is committed to undertaking an active programme to produce a gradual and permanent reduction in the per capita demand for water from both public and private sources. Domestic consumers now pay for water used based on a tariff structure with progressively more expensive unit costs as consumption increases.

The initial conservation target for the Perth metropolitan area is to return the average per capita demand to the 1986/87 level of 190 kilolitres per annum by 1991/92, i.e. to prevent the current 2% per annum growth in the per capita demand for water. A detailed action plan has been prepared and is being progressively implemented. When the expected effects on future demand can be estimated with confidence, the current demand projections will be revised accordingly. Even then, it will take some years for the actual effects of the programme to be measurable.

*See Glossary

The Source Development Timetable is sensitive to small changes in the growth in demand. For instance, if average household water use could be kept at the current level and demand only varied by the population growth rate of 2% per year, demand would approximate the 'minimum' curve and, in general, projects in the Source Development Plan would be delayed by 10-12 years. The next major source would be delayed by at least 5 years.

While water conservation of the order discussed above can significantly delay the introduction of new sources, it cannot prevent the need for them altogether, due to the underlying population growth factor. Also, the more 'structural' water conservation proposals, such as the introduction of dual flush toilets, will take many years to become effective in established buildings and residences and hence will affect the timing of development of longer-term rather than near-future sources.

Thus, although the Water Authority is pursuing water conservation to help to delay the introduction of new sources for as long as possible, the rate at which the water conservation programme can achieve lasting changes to demand trends has not yet been determined and there is good reason to believe that sustainable changes may only be achieved slowly. Prudent planning needs to proceed to meet a commissioning date of 1993 should a new source be required at that time.

3.3 Climate change

The Water Authority is attempting seriously to address the long-term implications of the 'Greenhouse Effect' for water supplies in this region. Many scientists expect rainfall in the south-west to decline over the next 50 years. Although the effect is not yet quantifiable, there is a very real possibility that reduced water supply yield due to climate change will offset any benefits of the water conservation programme in deferring source development in this region. The Authority is actively researching this issue and considering its future strategic implications. There is an expectation that a slight reduction of the estimated yield of the metropolitan water supply system may already be appropriate following changes to climate averages caused by the succession of dry years in the 1980s.

3.4 The consequences of no development action

If water consumption continues to grow at the present rate, demand will exceed the design capacity of the water supply system by 1992 and require an additional 10 million cubic metres of water each year for the subsequent six years.

If no new sources were developed and unrestricted demand conformed to the 'most likely' timetable, the probability of restrictions to supply would increase from the normal design level of 10% to about 40% by 1998, i.e. nearly one chance in two of restrictions every year. The Water Authority believes that, although some review of restriction policy might be fruitful, such a high probability of restrictions of the present style would not be acceptable to the community or the government. The Authority also believes that a sustained water conservation programme is preferable to implementing restrictions to reduce water use. High levels of restrictions could induce a strongly increased demand for private bores with associated environmental implications. The effects of climate change could add to the above consequences of no development.

With lower levels of demand growth associated with water conservation, the process outlined above would take longer but the final result would be the same. Hence, 'no source development' is not considered a viable option but rather the emphasis should be on effectively balancing water conservation and supply development.

4. *Possible Water Supply Options*

4.1 Criteria for selecting the next major source

The requirements for a water source to be a feasible alternative for the next major source are:

1. **It must be a 'major' source, i.e. provide a system yield benefit* of more than about 10 million cubic metres of water per annum.**

   Current demand projections indicate a growth in demand of approximately 10 million cubic metres per year until the late 1990s. Hence a 'major' source is required to meet at least one year's growth in demand. The long planning and implementation lead times required for developing water supply sources make it impractical to deal with demand increments of less than one year's growth.

2. **It must be able to be developed and commissioned by 1993 if required.**

   Although urban water conservation strategies are intended to halt growth in per capita water use by the early 1990s, the measures may not be sufficiently effective to delay the timing of the next major source. Hence, at this stage, prudent planning requires that a source would have to be able to be commissioned by 1993 to be considered a viable alternative for the next major source.

3. **It must be financially feasible in the current political and economic climate.**

   The community expects efficient, low-cost public water supplies, particularly in the current economic climate. Hence there is a limit to the unit cost of water from a new public water supply source which would be considered acceptable to the community.

   All water supply sources (including desalination*) have some environmental impacts and it does not follow that more expensive sources have fewer environmental impacts than cheaper ones. For the purposes of this assessment, it was considered that all water supply sources within the 25 year time frame of the current Source Development Timetable were financially feasible alternatives for the next major source. Sources at the end of this time frame had costs approaching 35 cents per cubic metre, which is about double the estimated cost of water from the existing sources.

*See Glossary

4.2 Source development options

A large number of source development options were considered and evaluated according to the above criteria to determine viable alternatives for the next major source. These options are listed in Table 2, with the reasons for their rejection or acceptance. For more details of these sources, see Mauger (1987).

Sources due to be developed prior to 1993 (see Table 1) were not considered to be alternatives and hence were not included in the list. These are as follows:

- **Pinjar Stage 1** - due to be completed by 1990, source has environmental approval following EPA assessment of the Gnangara Mound ERMP.
- **Conjurunup Pipehead** - due to be completed by 1992, the source has environmental approval in principle but requires final clearance of the pipeline route.
- **Jandakot Stage 2** - groundwater* scheme - due to be completed by 1992, this is an extension of the existing scheme and although it has environmental approval in principle it is likely to require a more detailed assessment prior to development.
- **Cockleshell Gully deep artesian* wells** - shown for development in 1991, but tests of a trial well have indicated problems which may require deferral of this scheme.

Additional comments on some of the sources considered are warranted:

- **Desalination of seawater** - this is the ultimate source of water for Perth (post 2050) but the cost (about ten times the cost of current sources) is currently prohibitive. The high energy consumption also carries environmental penalties.
- **Murray River** - the 'Tributaries' development is large and within the financial margin, but water production has not been included as a purpose for the Lane-Poole Reserve and hence it is not an alternative; development outside the Lane-Poole Reserve is too expensive at a cost of 83 cents per cubic metre.
- **Forest thinning** - while this option has the potential to provide substantial additional yield from existing sources, further practical and environmental investigations are required. It is

expected to take at least 10 years before it can be determined whether forest thinning will be a practical option. Thus forest thinning does not meet the criterion of being able to be developed by 1993 and was eliminated as a viable alternative at this point in time.

- **Harvey River** - redevelopment of the existing dam to gain additional yield which could be used for metropolitan water supply is an attractive long-term proposition. Its cost estimate of 23 cents per kilolitre is based on delivering water to an expanded Mandurah area some time after the current 25 year programme.

  Redevelopment to supply Perth by 1993 would require extensive additional transfer main (pipeline) capacity and the cost would increase to approximately 36 cents per kilolitre. This cost is at the financial margin of 35 cents per kilolitre and construction of the extensive transfer mains required would be a major undertaking. This option is one which will probably require lengthy public evaluation to resolve water allocation issues and was eliminated as a serious alternative for the next major source.

- **Pinjar Stages 2 & 3** - these sources form part of a supply strategy to meet the future water supply needs of the North-West Corridor. This corridor continues to have one of the highest growth rates in the metropolitan area but is furthest from the traditional supply sources in the 'hills' to the south-east. The high cost of supplying the large transfer main capacity required to supply the corridor from the south makes the adjacent Gnangara Mound sources such as the proposed Pinjar, Lexia, Yeal and Barragoon developments the most economic sources of supply to the North-West Corridor.

  Pinjar Stage 2 is currently timed for completion soon after the next major source, and Stage 3 a few years later. To develop Stage 2 as the next major source would require the construction of additional transfer mains to carry the surplus supply capacity south to the rest of the supply system. The additional cost is not considered warranted.

- **Package of small pumpback* schemes** - the metropolitan water supply system requires a balanced combination of storage reservoirs and pumpback/pipehead* sources to gain maximum yield benefit. A new pipehead dam is due to be constructed on Conjurunup Creek prior to the next major source. Hence the development of a package of small pumpback schemes as the next major source would be inefficient. Their combined normal yield benefit would be significantly reduced due to the lack of sufficient reservoir storage in the water supply system.

*See Glossary

4.3 Viable alternatives for the next major source

The filtering process outlined above reduced the possible source development options to four viable alternatives. These are raising Mundaring Weir (Raised Mundaring), raising Canning Dam (Raised Canning), construction of a dam at South Canning and construction of a dam at North Dandalup (see Figure 3, Table 3).

All of the alternatives involve further development of existing supply sources to gain additional system yield benefit. The existing storage capacities of Mundaring and Canning Dams are not large enough to harness the full yield potential of their river systems and the existing small pipehead* dam at North Dandalup can only harness a part of the winter streamflow.

The following descriptions for each project are based on the economic optimum size for each dam. Final project specifications can be developed only during the detailed design phase (Stage 2 - Implementation Planning) at which time the detailed environmental management programme will also be prepared and submitted to the EPA.

The **Raised Mundaring** project (Figure 4) involves raising the existing Mundaring Weir by 11.5 metres by the placement of conventional mass concrete. The reservoir would be enlarged from a capacity of 77 million cubic metres to 200 million cubic metres, a surface area increase of 6.4 square kilometres. This would provide an additional system yield benefit of 11.0 million cubic metres per year.

The **Raised Canning** project (Figure 5) involves raising the existing Canning Dam by 11.5 metres by the placement of conventional mass concrete. The reservoir would be enlarged from 90 million cubic metres to 170 million cubic metres, a surface area increase of 3.5 square kilometres. This would provide an additional system yield benefit of 9.9 million cubic metres per year.

The **South Canning Dam** project (Figure 6) involves construction of a 37 metre high embankment dam on the Canning River. The new reservoir created, with a storage capacity of 215 million cubic metres and a surface area of 25 square kilometres, would be the largest in the metropolitan water supply system. The project

Table 2: Water Supply Development Options Considered for the Next Major Source

Category	Source: Name	System yield Benefit (Mm3/yr)	Able to be developed by 1993	Approx. cost (c/kL)	Reasons for rejection or acceptance as a viable alternative for the next major source
1. Non-feasible options.	• Ord River	>10	No	1020	
	• Icebergs	>10	No	very expensive	
	• Solar distillation	>10	No	very expensive	
2. Long-term options	• Desalination of sea water	>10	No	>150	Too expensive
	• Swan-Avon Trib. (Wooroloo, Brockman, Julimar, Red Swamp)	2 - 34	Yes	67 - 91	Too expensive
	• Murray River - Outside Lane-Poole	150	No	83	Too expensive
	- Tributary Devel.	21	No	32	Precluded by vesting of Lane-Poole Reserve
	• Forest thinning	>10	No	<10	Feasibility studies in progress but not able to be developed by 1993.
3. Medium term surface water options	• Helena River redevel. (Upper Helena, Darkin or Lower Helena)	9 - 13+	Yes	35 - 60	A number of alternative schemes were considered but found to be considerably more expensive and have greater engineering problems than the option of raising Mundaring Weir.
	• Victoria/Bickley redevelopment	3	Yes	51	Yield small and too expensive
	• Conjurunup Dam	3.3	No	40	Yield small and too expensive.
	• Lower Sth Dandalup Pumpback	4	Yes	30	Yield small (a full dam proposal was considered but was still small and was more expensive than the pumpback proposal).
	• Marrinup (Pumpback or Dam)	5 - 7	Yes	31 - 32	Pumpback and dam yield are small and the dam would flood a section of the Hotham Valley Railway.
	• Swan-Avon Trib. (Jane & Susannah pumpbacks)	1 - 6+	No	25 - 31	Yield small and could not be developed in time
	• Pumpback developmnts (Dirk, Gooralong, Lower Serp. St. 2)	3+	Yes	20 - 36	Individually too small. Yields depend on a new major storage dam and hence the three as a package would still be too small.
	• Harvey River	30	No	36	Expensive source timed to meet the expected growth in Mandurah demand post 2010. Resolution of water resource allocation issues prevent development by 1993.

Notes

Mm^3/yr = million cubic metres per year
c/kL = cents per kilolitre
\+ Yield for each source

Table 2: Water Supply Development Options Considered for the Next Major Source (continued)

Category	Source: Name	System yield Benefit (Mm3/yr)	Able to be developed by 1993	Approx. cost (c/kL)	Reasons for rejection or acceptance as a viable alternative for the next major source
4. Medium term groundwater	• Pinjar Stages 2 & 3	12+	Yes	>35	Development timed to meet local demand growth in the adjacent North-West Corridor. Additional cost involved in developing earlier would make them too expensive.
	• Barragoon, Yeal, Lexia	7 - 9+	No	40 - 50	As with Pinjar, these sources are timed to meet local demand growth in the North West Corridor and hence not able to be developed by 1993.
	• East Mirrabooka St 3	2	Yes	26	Yield small.
	• Jandakot South Stages I & 2	3+	Yes	45	Yield small and expensive
	• Dandalup	10	Yes	39	Too expensive.
	• Karnup	7	Yes	38	Yield small and expensive.
	• Deep Artesian Wells (7)	2+	No	12	The seven wells are individually small, and their development timing is dependent on an increased demand on adjacent service reservoirs to allow mixing. Hence theycould not be developed as a package by 1993.
5. Viable alternatives	• Raised Mundaring Dam	11	Yes	18	Large, can be developed in time and financially realistic.
	• Raised Canning Dam	10	Yes	28	Large, can be developed in time and financially realistic.
	• South Canning Dam	12	Yes	20	Large, can be developed in time and financially realistic.
	• North Dandalup Dam	14	Yes	19	Large, can be developed in time and financially realistic.

would provide an additional system yield benefit of 11.6 million cubic metres per year.

The **North Dandalup Dam** project (Figure 7) involves the construction of a 54 metre high embankment dam immediately upstream of the existing pipehead dam. The new reservoir would have a storage capacity of 75 million cubic metres and a surface area of 5 square kilometres. The project would provide an additional system yield benefit of 13.8 million cubic metres per year.

Table 3 presents the principal engineering and economic statistics for each alternative.

It should be noted that these projects, with the exception of Raised Canning, are all included in the current Source Development Plan. Thus, selection of one as the next major source is just that; it does not make any predictions on the suitability or acceptability of the others for future development. This activity will be undertaken as part of a similar planning exercise in the future. However, Raised Canning is a mutually exclusive alternative to South Canning, and selection of one of these as the next major source would eliminate the other as a possible future source.

It is also important to realise that each of the 'alternatives' is part of an alternative Source Development Timetable, and selection of one project as the next major source will have implications on the timing of the development of other sources.

Table 3: Key Parameters of the Alternatives for the Next Major Source (Economic optimum size if developed as the next major source)

Details	Raised Mundaring Weir	Raised Canning Dam	South Canning Dam	North Dandalup Dam
STRUCTURE				
Site	Present dam site	Present dam site	Approx 1.5 km NE of Eagle Hill, U/S of Scenic Drive Gauging Station	Approx 200 m U/S of Pipehead
Type of Structure	Concrete	Concrete	Embankment	Embankment
Dam Crest Level (m A.H.D.)	154	217.5	271	224
Dam Crest Length (m)	460	1250	580	660
Height of dam or Raising (m)	11.5	11.5	37	54
CATCHMENT				
Area (km^2)	1482	727	495	153
Mean rainfall (mm p.a.)	800	950	880	1300
Mean streamflow ($m^3 \times 10^6$)	48.6	57.5	23.1	29.9
RESERVOIR				
Full supply level (m A.H.D.)	150	216	267	219
Storage capacity ($m^3 \times 10^6$)	200	170	215	75
Additional storage ($m^3 \times 10^6$)	123	80	215	75
Surface area (ha)	1400	850	2450	505
Additional area (ha)	640	350	2450	505
System yield benefit ($m^3 \times 10^6$ p.a.)	11.0	9.9	11.6	Total 25.0[1] Net 13.8[1]
Mean system annual draw ($m^3 \times 10^6$ p.a.)	11.7	7.9	10.0	13.1
Mean annual draw of the source ($m^3 \times 10^6$ p.a.)	5.9	2.5	11.1[2]	12.9
Time to develop full yield (years)	10	7	16	4
STREAMFLOW UTILISATION[3]:				
Draw/Inflow	62% (54%)	77% (73%)	51% (0%)[2]	81% (40%)
Overflow/Inflow	27% (39%)	19% (25%)	17% (0%)	11% (60%)
Net Evaporation/Inflow	11% (7%)	4% (2%)	32% (0%)	8% (Minimal)
COSTS[4]:				
Capital Cost (Millions $)	22.4	36.4	23.2[5]	34.8
Operating Cost (Thousands $ p.a.)	200	130	174	222
Present Value Total (PVT) (Millions $)	25.6	38.5	26.0	38.4
PVT/Yield ($/$m^3$ p.a.)	2.33	3.89	2.24	2.78[1]
Cost (Cents/m^3)	18.2	29.1	20.3	18.6
PVT of development timetable (Millions $)	397.6	412.3	392.6	363.8
Sequence of major sources	RM > ND > SC	RC > ND > RM	SC > ND > RM	ND > RM > SC

1. The net system yield benefit of 13.8 for North Dandalup Dam is made up of a total yield benefit of 25.0 minus 11.2 for the deletion of the existing North Dandalup Pipehead, which must be demolished to make way for the construction of the dam. The quoted PVT/Yield for North Dandalup is based on the net yield benefit.
2. The draw for South Canning are releases, not releases plus overflow.
3. The streamflow utilisation shows the potential utilisation due to the proposed project and in brackets the existing utilisation. The inflow includes pumpback flows from the Lower Helena P/B. The P/B flow increases as the capacity of Mundaring is increased.
4. All costs are given in December 1986 dollars. Present value totals are calculated for a discount rate of 6%.
5. The capital cost of South Canning includes $650 000 for the realignment of an SEC power transmission line.

5. *Comparison and Evaluation of Feasible Alternatives*

5.1 Approach to comparison and evaluation of alternatives

Selection of the most beneficial and environmentally acceptable next major water supply source from the four feasible alternatives was based upon consideration of a number of key factors in the four broad areas (accounts) of: water supply, economics, natural environment and social environment. These key factors were used to characterise, differentiate and compare the four alternatives.

Choice of water supply and economic key factors used for evaluation was based on studies carried out by the Water Authority and consultation with appropriate staff of other government agencies. Selection of natural environment and social environment key factors was based on discussions with and reports by specialist consultants who were employed to carry out natural and social environment studies in the fields of planning, recreation, vegetation, fauna, landforms and soils, Aboriginal archaeology and Aboriginal ethnography.

The Water Authority studies, government agency consultations and consultants' reports were reviewed, summarised, and evaluated in a working report prepared for the Water Authority (Stone and Pound, 1987).

The underlying social and economic benefits to the community of improving the public water supply system to meet increased demand are substantial but difficult to quantify. They are directly related to the additional system yield benefit provided. Since this system yield benefit is the same for each of the alternative source development sequences, these common underlying benefits were not included in the evaluation.

The purpose of the following sections (5.2 to 5.6) is to present information relevant to comparing the four alternatives and to then determine the alternative which, on balance, is the most satisfactory having regard to all community interests. Because it is necessary to emphasise the differences between the alternatives, the results are not necessarily a balanced account of the merits of a particular alternative in an 'absolute' sense. A review of the 'absolute' acceptability of the alternative selected by this process is presented in section 6.

It is important to remember that the selection of one project as the next major source does not rule out the others as possible future sources for development at a later date. They would, however, be subject to a similar subsequent assessment process to select the most satisfactory alternative for development at that time.

The evaluation conducted for the Water Authority followed the general principles of the multi-objective planning approach, but the method of analysis was deliberately kept as simple and straightforward as possible.

For simplicity, a single size dam (the economic optimum) for each alternative was considered in the account evaluations. The environmental implications of a range of sizes for each project were reviewed, but alternative sizes were not found to provide any clear benefits over the optimum sizes.

Each account (water supply, economics, natural environment and social environment) had its own objective. For each account in turn, the key factors were reviewed and evaluated to determine the ranking of the alternatives. The relative weighting given to each of the key factors to determine the overall ranking of the alternatives is reflected in the discussion for each account.

An evaluation was then carried out between accounts (section 5.6). For each account, the alternative source developments were compared and a conclusion was drawn as to the most beneficial source overall.

5.2 Water supply considerations

5.2.1 The existing supply system

The Water Authority has the responsibility for managing the water resources of Western Australia for the continuing benefit of the community and for providing satisfactory public water supplies. The Metropolitan Water Supply Scheme (MWS) provides a water service of suitable quantity, quality and reliability for the population of the Perth metropolitan region, from Wanneroo to Mandurah.

The existing MWS has been carefully planned and developed to be operated as a single 'system' to gain maximum benefits. Thus 14 individual supply sources of different types (storage dams, pipehead dams, artesian bores and groundwater schemes) are harnessed together to meet the overall public water supply demands of the metropolitan population. The maximum demand that the system can sustain is called the 'system yield'.

Adding a new source to the system will increase the system yield and the increase is called the 'system yield benefit' of the proposed scheme. The yield benefit may be greater than the water produced from the new source if its inclusion results in greater overall efficiency of the system.

The MWS system is currently designed to allow for some level of general supply restriction in 10% of years. The system could be designed for no restrictions, but this would be considerably more expensive and require the development of a number of new water sources.

Mundaring Weir, the historical water supply source for the Goldfields and Agricultural Water Supply (G&AWS) scheme, has been progressively integrated into the MWS system over the last few years. This provides supply and reliability benefits to both the G&AWS and metropolitan consumers. The MWS system supplies both metropolitan and G&AWS consumers.

River sources currently supply about 70% of Perth's water. At present, the only treatment required before supplying this water to consumers is disinfection by chlorination.

The catchments of rivers currently supplying the MWS are all east of the Darling Scarp between Mundaring in the north and Dwellingup in the south. The catchments are almost totally covered by native forest, with small areas of pine plantations, orchards and pastoral land. The main commercial activities in the forest are timber production and bauxite mining, although there are many smaller industries which make use of the forest resources. The forest is also recognised for its conservation and recreation values. The rivers are currently generally fresh, but permanent clearing of forest in the drier parts of the catchment would certainly increase salinity.

MWS schemes for development of river resources for water supply can be generally classified as 'main dams', 'upper dams', 'pipeheads' and 'pumpbacks'.

- Main dams create a major reservoir in a valley. Water is delivered, after disinfection by chlorination and fluoridation, directly to consumers or to service reservoirs in the city.
- An upper dam creates a major reservoir on a river upstream of a main dam. Water is released from an upper dam to flow down the river into the main dam in order to maintain desirable water levels in the reservoir of the main dam.
- A pipehead is a small dam with minimal reservoir storage, only large enough to allow significant portions of mainly winter flow of the stream to be diverted into a pipe. The diverted water is supplied to consumers in the same way as water from a main dam.
- A pumpback uses the same type of small dam on a river to divert significant portions of mainly the winter streamflow, but instead of delivering the water for immediate use, the water is pumped through a pipeline into one of the major reservoirs.

The existing MWS has seven main dams (Mundaring, Victoria, Churchman Brook, Canning, Wungong, Serpentine and South Dandalup), two pipeheads (Serpentine Pipehead and North Dandalup Pipehead) and two pumpbacks (Lower Helena Pumpback and Araluen Pumpback). Of the four alternative new developments, three are main dams (Raised Mundaring, Raised Canning and North Dandalup) and one upper dam (South Canning).

The site and reservoir size of a dam are normally chosen to gain the most efficient use of the river's streamfow. Pipeheads and pumpbacks are less expensive than major dams but develop a smaller proportion of streamflow.

Shallow groundwater and artesian (confined) sources make up the remaining 30% of Perth's public water supply. Shallow (unconfined) groundwater is drawn from wells sunk below the water-table in the sandy aquifer which forms the surface layer over large areas of the coastal plain north and south of the Swan River. Artesian confined water is water occurring in sandy aquifers between layers of almost watertight material such as clay, usually at considerable depth below the ground surface. The water is usually under pressure and when a well is drilled into the aquifer, the water in the well rises and may even flow to the surface. Shallow groundwater and artesian water generally require treatment to make the water quality satisfactory for public water supply.

The existing MWS has four groundwater treatment plants at Mirrabooka, Gwelup, Wanneroo and Jandakot and 14 artesian wells (located at Bold Park, Melville, Mirrabooka, Mt Eliza and Yokine).

Service reservoirs are built near consumers to receive bulk supplies of water from the major sources via large trunk mains. The water is then distributed through smaller distribution and reticulation mains to the service connections of individual consumers.

5.2.2 Objective for the water supply account

The aim of the water supply account was to compare and rank the four alternatives on the basis of best satisfying the water supply objective which was to:

- provide the most reliable and best quality water supply to meet the next increment in metropolitan demand.

5.2.3 Approach

A number of studies on the four alternatives were conducted by the Water Authority to:

- refine previous system yield benefit estimates,
- evaluate their relative yield reliability,
- analyse source behaviour characteristics,
- evaluate their relative water quality.

The full study results are contained in the internal Engineering Report (Stone, 1987). The investigations and results are summarised in section 5.2.4.

System yield benefit estimates were determined for a range of size options for each alternative to establish the economic optimum size for comparison of the alternatives.

A number of approaches were then used to determine the relative reliability of the system yield benefit provided by each alternative under 'normal' (historical) and 'drier' climatic conditions.

In addition, an attempt was made to determine the relative level of confidence in the calculated yield estimates for the four alternatives. Variations in the net reservoir evaporation (reservoir evaporation minus direct rainfall) estimates can have a significant impact on the calculated yield benefit figures. This is particularly true for the Mundaring and South Canning Reservoirs, where net evaporation is large in proportion to either annual streamflow or yield benefit.

Source behaviour characteristics of each of the alternatives were analysed to provide input into the environmental investigations as well as to improve understanding of the nature of their benefit to the water supply system and their operating mode. Reservoir water level fluctuations were examined and graphs produced of the probabilities of flooding (or exposure) durations for various elevations. The reductions in downstream flows due to damming were examined and cumulative probability graphs for annual and seasonal flows produced. The water supply draws from each source before and after development were also examined and graphed.

A brief report examining the likely water quality behaviour of the alternatives prepared by the Authority's Principal Scientific Officer, Dr Rosich, is incorporated in the Engineering Report (Stone, 1987).

5.2.4 Characteristic and differential factors

Key factors which characterise and reflect the relative merits and performance of the four alternatives were considered to be:

- hydrology,
- climatic variations and yield reliability,
- catchment variations,
- yield benefit,
- reservoir characteristics,
- probability of restrictions,
- basin clearing,
- water quality,
- downstream flows,
- water supply system operation.

These factors are discussed below.

(i) HYDROLOGY

The large variation in the catchment* hydrology (rainfall and streamflow) of the alternatives affects their behaviour as supply sources (see Figure 3 indicating rainfall isohyets). North Dandalup has the highest and most consistent rainfall, followed by Canning, South Canning and Mundaring in that order.

The rain required to wet catchments before streams start flowing is a higher proportion of total rainfall in drier areas than in wetter areas. This accentuates the rainfall patterns, giving North Dandalup the highest and most consistent runoff* per unit of catchment area, followed by Canning, South Canning and Mundaring in that order.

(ii) CLIMATIC VARIATIONS AND YIELD RELIABILITY

Climatic variations can include long runs of above or below average rainfalls. Thus, ideally, a very long period of record is required to confidently determine long-term 'average' rainfall and streamflow values. However, reliable streamflow records are available only for the 76 year period 1911 to 1986 (inclusive).

The last 30 or 40 years have been generally drier than the full period since 1911. The significant reductions in mean streamflows in recent periods for each of the alternative dam sites are evident in Table 4. The table also indicates that the reduction in mean streamflows during a 'drier' period is

*See Glossary

much more severe at Mundaring and South Canning than Canning or the least severely affected, North Dandalup.

The sensitivity of each of the alternative source development programmes to a prolonged continuation of the current dry sequence was checked. The drier sequence caused the probability of restrictions to rise above the current design level of 10%. However, there was no discernable difference between the four alternative programmes.

In recent years the possibility of future climatic change has been raised and this was taken into account in evaluating the water supply alternatives. The indications are that the climate for the south-west of Australia will be drier, but the degree of change is unknown. It could be said that the climate of the last 30 or 40 years would provide a reasonable indication of the possible future 'drier' climate. Data from the period 1947 to 1980 were used to indicate the relative performance of the four alternatives under a possible drier climate. Data for the relatively 'dry' 1981 to 1986 period were not available at the time of the analysis, but are currently being added to the database.

Analysis of the 1947 to 1980 period produced streamflows about 7% less than the 1911 to 1980 period of record. This produced sizeable drops in the system yield benefit estimates for Raised Mundaring (11.0 to 8.3, or 24% reduction), South Canning (11.6 to 9.1, or 22%) and Raised Canning (9.9 to 8.7, or 12%). In contrast, there was no reduction in the estimated yield benefit of North Dandalup. Thus North Dandalup would perform substantially better than the other alternatives under drier climatic conditions.

These results are indicative of how the various alternatives would perform under a possible future drier climate. If the last 30 or 40 years (i.e. 1957 to 1986 or 1947 to 1986) were more representative of a possible future climate, the size of the yield reductions would be greater but the relative difference between the alternatives would be substantially the same.

(iii) CATCHMENT VARIATIONS

The catchment conditions of the four alternative sources will not necessarily remain constant over time and variations in catchment conditions could cause changes in source yields and quality. Bauxite mining, P.c. dieback (*Phytophthora cinnamomi*) and forest thinning could potentially cause significant changes to the catchment conditions.

Bauxite mining will affect the North Dandalup catchment in the foreseeable future, with some 30% of the area likely to be mined. Mined and rehabilitated areas are likely to produce greater runoff in the short term (10-15 years) until the revegetation is fully established. Increased salinity is not expected to be a problem because the catchment is largely in the high rainfall zone. In the long term, runoff from these areas may well be less than prior to mining, due to the density of the regrowth. Thinning would then be required to achieve optimum timber and water production. Hence the likely short-term gain in yields at North Dandalup due to the mining could be offset to some extent by the need to thin the regrowth at a later date to prevent a net loss.

Table 4: Mean Streamflows for Canning River, Helena River and North Dandalup River, 1911 to 1986

Period	Helena River (at Mundaring Weir)		Canning River (at Canning Dam)		Canning River (at South Canning)		North Dandalup River (at Pipehead Dam)	
	Mean flow ($m^3 \times 10^6$/yr)	% reduction from long-term mean, 1911-1980	Mean flow ($m^3 \times 10^6$/yr)	% reduction from long-term mean, 1911-1980	Mean flow ($m^3 \times 10^6$/yr)	% reduction from long-term mean 1911-1980	Mean flow ($m^3 \times 10^6$/yr)	% reduction from long-term mean 1911-1980
1911-1980 (70 yrs)	49.6	0	59.9	0	24.1	0	30.9	0
1947-1980 (34 yrs)	40.3	19	56.6	5	21.9	9	30.5	1
1911-1986 (76 yrs)	48.6	2	57.5	4	23.1	4	29.9	3
1937-1986 (50 yrs)	41.7	16	56.1	6	22.9	5	29.5	4
1947-1986 (40 yrs)	37.5	24	52.5	12	20.3	16	28.6	7
1957-1986 (30 yrs)	35.5	29	50.4	16	19.4	20	27.4	11

It is believed (E. Hopkins, CALM, personal communication) that the most severe impacts of 'dieback' on the northern Jarrah forest have already occurred, and future effects will be gradual and not as significant. Thus there is not expected to be any marked deterioration in the condition of the forest in the four catchment areas in the foreseeable future.

Forest thinning trials for enhanced timber production have been carried out as part of normal logging operations over the last few years. The potential of forest thinning to enhance water yield from existing sources is under investigation but, as mentioned previously, it will be many years before the practicality of this option can be determined. The catchments of North Dandalup, Canning Dam and Mundaring Weir have the potential to benefit from catchment thinning as it is currently proposed. This would not be the case for South Canning, however because the forest quality is incompatible with thinning.

(iv) YIELD BENEFIT

Individual source yield is related to mean annual streamflow, reservoir storage capacity and the variability of the streamflow. The more variable streamflows at Mundaring and South Canning require relatively larger reservoir storage capacities than North Dandalup to gain the same degree of regulation of the streamflow. Hence the supply system would require an additional storage of 122 million cubic metres at Mundaring or 210 million cubic metres at South Canning to gain a yield benefit of approximately 11 million cubic metres per year, whereas a storage of 75 million cubic metres at North Dandalup would gain a yield benefit of more than 13 million cubic metres per year.

Recent simulation analyses indicate that South Canning would take approximately 16 years to be able to contribute its full system yield benefit to the water supply system. This is a function of its large reservoir size in relation to its mean annual streamflow. The viability of South Canning as the next major source is therefore dependent on the subsequent development of a number of other water supply sources to make up the 'shortfall' until it develops its full yield. In particular, the pumpback schemes immediately following it in the Source Development Timetable (Gooralong, Lower Serpentine Stage 2 and Dirk Brook) are essential and could be considered as part of a South Canning 'package' supplying the necessary yield.

Raised Mundaring would take about 10 years to gain its full yield benefit, and Raised Canning about 7 years. In contrast, North Dandalup would provide its full yield benefit within 4 years of completion. The financial implications of these differences between the alternatives are taken account of in section 5.3.

The manner of obtaining the calculated system yield benefit varies between the alternatives. With North Dandalup, the bulk of the system yield benefit would be obtained from increased draw on the source itself, whereas with South Canning in the supply system, there would be a small reduction in the total draws from the Canning River system and the entire system yield benefit would be obtained from increased draws from other sources. Thus, when reservoir storages are generally high, the relatively large excess storage capacity at South Canning allows the other sources to be drawn more heavily to prevent overflow. When storages are generally low, the relatively large storage at South Canning allows it to be used to supplement draws from the other sources.

The nature of the yield benefits obtained from Raised Canning and Raised Mundaring would be intermediate between North Dandalup and South Canning. i.e. more than half their yield benefits would be obtained from increased draws on other sources.

The accuracy of the system yield benefit figures for each alternative is affected by the net evaporation estimate used in the calculation. A recent review of the reservoir evaporation figures suggests that they are likely to underestimate actual evaporation by several percent. The ratio of net evaporation to yield benefit provides an indication of the relative effect of this factor on the yield estimates of the alternatives. The effect is most pronounced for Raised Mundaring (64%) and South Canning (59%) and least for North Dandalup (17%) with Raised Canning (28%) intermediate between them.

Other effects could also be responsible for net evaporation at South Canning being higher than estimated in this investigation. Large portions of the reservoir would form broad shallow ponds with relatively high evaporation rates.

The Monadnocks range immediately west of the South Canning reservoir basin protrudes well above the surrounding country and is likely to cause some localised rainshadow effect on the basin itself. This was not accounted for in the current yield assessments due to lack of information to quantify the effect.

(v) RESERVOIR CHARACTERISTICS

The reservoir storage characteristics vary markedly from the relatively incised and deep valley forms at Canning and North Dandalup, to the relatively broad and shallow valley form at South Canning, with Mundaring intermediate between them. The surface area flooded per unit of additional storage is about twice as much at South Canning as the other three alternatives. Conversely, the 'average depth' (storage over surface area) at South Canning of 8.4 metres is a little over half that of the other alternatives.

An examination of reservoir water level fluctuation simulations revealed a distinct difference between the behaviour of South Canning and that of the other reservoirs. South Canning would have a much longer 'cycle' time than the other reservoirs, with long durations between fillings. The general operating level (median* water level) for South Canning would be flooded for a median duration of 14 years and exposed for a median duration of 17 years. In contrast, the other three reservoirs would be flooded for a median duration of three years and exposed for median durations of five years.

(vi) PROBABILITY OF RESTRICTIONS

The large size and long cycle time of the South Canning reservoir would have an effect on the actual probability of restrictions for the metropolitan water supply system. The reservoir would be less than a third full for a third of the time and the average duration of these periods of low water level would be about 10 years. During these periods of low reservoir storage, the actual probability of restrictions estimated for future years would be higher than the normal unconditional value of 10%. The long-term average could be maintained by periods of lower restriction probability when South Canning had substantial storage.

This effect would be much smaller with the other alternatives because of their smaller storages and shorter cycle times.

(vii) BASIN CLEARING

The South Canning reservoir poses particular difficulties in clearing and managing the basin. Analysis indicates that, upon completion, the median time for the reservoir to fill to the full supply level (FSL) of 267 metres AHD would be about 15 years. The shortest time to fill would be 4 years and the longest 67 years. Thus, clearing the whole 25 square kilometres of reservoir basin during construction of the dam could cause problems due to regrowth occurring during the long period before filling. The basin could be cleared in stages, but the clearing of subsequent stages ahead of reservoir filling could pose water quality difficulties in operating the reservoir.

Once the basin has been cleared and the reservoir filled for the first time, there would still be difficulties in managing the basin. Significant regrowth would occur in the upper 10 square kilometres because of the long durations (average of about 20 years) between inundations. Clearing the regrowth would be costly and may cause turbidity problems. Failing to clear it could lead to significant water quality problems when the regrowth is inundated and decomposes.

(viii) WATER QUALITY

North Dandalup water quality is among the best available in the hills near Perth. Canning Reservoir water quality is also very high, but the raising and associated increase in extent of shallow areas of impounded water may cause a slight increase in the small level of biological productivity evident in the existing reservoir. The water quality of the existing Mundaring reservoir is not as high as Canning or North Dandalup and may deteriorate further in the future as streamflow salinity due to clearing continues to rise. However, raising the dam is likely to increase the amount of high quality water available. South Canning was considered the least desirable alternative because of the risk of excessive biological growth. Based on the plant growth which occurs in the shallow region of the Canning reservoir along the Canning River, and the much greater areas of shallow water which would occur in the South Canning reservoir, the risk is considered to be significant.

The expected salinity levels in the four reservoirs vary significantly, with North Dandalup and Raised Canning averaging about 170 milligrams per litre Total Dissolved Solids (TDS) and South Canning and Raised Mundaring averaging about 500 milligrams per litre. South Canning would also have an effect on the salinity of the Canning reservoir downstream.

This is difficult to determine but is likely to lead to a general rise in salinity of the Canning reservoir to a level of about 210 milligrams per litre. All these levels of salinity are within the existing National Health and Medical Research Council water quality criteria and are not considered to pose any health problems.

The order of preference on water quality considerations was concluded to be: North Dandalup, Raised Canning, Raised Mundaring, South Canning.

*See Glossary

(ix) DOWNSTREAM FLOWS

The four alternative developments would cause quite different impacts on streamflows immediately below the dam wall. Raised Canning would cause the least reduction (24%) in mean streamflows, from 15.4 to 11.7 million cubic metres per year. Raised Mundaring would reduce the flows by 30% from 23.5 to 16.6 million cubic metres per year immediately downstream. South Canning would reduce flows immediately downstream by 33% (from 21.7 to 14.5 million cubic metres per year) and flows downstream of Canning Dam by 38% (from 15.4 to 9.6 million cubic metres per year). North Dandalup would cause the largest reduction (81%) in mean North Dandalup streamflows immediately downstream, from 18.8 to 3.6 million cubic metres per year. However, the catchment area downstream of the North Dandalup dam contributes substantial additional streamflow, and the reduction in mean North Dandalup streamflow at the confluence with the South Dandalup River would be less than 35%. Thus the reduction in total Murray River flow would be approximately 4%.

South Canning dam would reverse the seasonal pattern of streamflows immediately downstream. The winter and spring mean flows would be reduced to about one-third of their former values and there would be no flows at all in half the years. However, the summer mean flow would be increased dramatically from the present negligible level to a value of more than half the present winter mean streamflow. This is due to the manner of operation of South Canning Dam, in which releases would be made to maintain Canning reservoir at half full storage. Thus winter flows would be held back to prevent Canning reservoir overtopping, but if Canning storage fell below half full in summer, 'top up' water would be released from South Canning.

(x) WATER SUPPLY SYSTEM OPERATION

North Dandalup Dam would provide greater water supply system operational benefits than the other alternative developments. The dam would increase the average supply head of the source by 43 metres (compared with 11 metres for Raised Mundaring, 13 metres for Raised Canning and 7 metres at Canning for South Canning), improving supply pressures to Mandurah. In addition, the dam would provide a more flexible and secure system by easing the heavy reliance on Serpentine Dam and providing the potential for peak summer flow contribution.

5.2.5 Evaluation and ranking of alternatives

Of the characteristic and differential factors discussed in section 5.2.4, four are believed to best display the essential differences between the alternatives under consideration. The alternatives are compared on the basis of these four factors in Table 5.

An examination of the factors clearly identifies **North Dandalup** as the best source in terms of water supply considerations. It is the most reliable alternative, with its current yield estimate of 13.8 million cubic metres per year remaining steady under longer-term drier climatic conditions. It would be least affected by any underestimation of general reservoir net evaporation, and has the lowest risk of excessive biological growth.

Raised Canning is ranked second, ahead of **Raised Mundaring**, because analysis showed that its yield benefit performance would be better under drier climate conditions and it would be less affected by any underestimation of net evaporation. In addition, it would have higher general water quality than Raised Mundaring.

South Canning ranks lowest. Its yield reliability would be about the same as Raised Mundaring, but it would have a higher risk of excessive biological growth and would require a greater level of reservoir basin management.

Hence, from a water supply viewpoint, the ranking of the alternatives is North Dandalup, followed by Raised Canning, Raised Mundaring, and South Canning.

5.3 Economic considerations

5.3.1 Economic costs of water supply development

The Water Authority as a public utility has the responsibility for providing water services at the lowest possible long-term monetary cost to the overall community. Thus, for new water supply developments, the Authority takes into consideration the financial costs to its consumers as well as the broader economic costs to the general community.

Each alternative has a different associated Source Development Timetable. Therefore, the selection of any one of the four alternatives as the next major source will affect the sequence and timing of subsequent sources in the Source Development Timetable. In considering the financial costs of each alternative, these longer-term future cost implications need to be taken into account. This is done for each alternative timetable by bringing the capital and operating costs of all the source developments to a 'present value total' (PVT)*. Hence the most appropriate measure of the financial cost of each alternative is the PVT of its associated Source Development Timetable. The difference in PVT cost between two alternative timetables is the additional cost to the Authority (and hence its customers) of selecting the more expensive timetable.

Table 5: Water Supply Account for the Alternatives for the Next Major Source

COMPONENTS AND FACTORS	ALTERNATIVES			
	Raised Mundaring	Raised Canning	South Canning	North Dandalup
(1) Reliability				
Yield reduction for longer-term drier climate	24%	12%	22%	0%
Significance of net evaporation errors (net evaporation/yield)	64%	28%	59%	17%
(2) Water quality				
Risk of excessive biological growth (surface area less than 5 m deep)	320 ha	225 ha	735 ha	120 ha
Level of reservoir basin management required	low	low	high	low

The only other significant financial cost implication in selecting one alternative is the effect on possible remedial works required for the Canning Dam spillway (see section 5.3.4).

A consideration of the broader economic costs to the community identified only two important factors: timber production losses and salinity damage costs.

5.3.2 Objective for the economic account

The aim of this account was to compare and rank the four alternatives on the basis of best satisfying the economic objective which was to:

- provide the required additional water supply by such means as will minimise long-term monetary cost to the community.

5.3.3 Approach

The economic analysis involved both 'in-house' investigations by the Water Authority and enquiries to other government agencies with interests in or responsibility for the areas impacted by development of the four alternative sources.

Water Authority investigations centred on three economic aspects of the projects:

- establishing the economic optimum size for each alternative and refining the cost estimates for that optimum development of each source;
- determining estimates of present value total (PVT) costs for the respective source development sequences which would best complement the development of each of the alternatives as the next major source; and
- estimating the salinity damage costs which the community might carry in view of the fact that the sources would provide water of varying quality.

*See Glossary

Enquiries were also made to other State government departments and agencies requesting information on the absolute and relative economic impacts of development of the alternative sources. Most costs such as relocation of road and power services are included in the direct capital costs of each project. The Department of Conservation and Land Management (CALM) provided estimates of the value of future timber production foregone for each of the alternatives and these costs have been incorporated in the evaluation of the sources. An indication of the probability of sterilising significant mineral resources at each site was provided by the Geological Survey of Western Australia (See Appendix 2). After consideration of the relative economic significance of the potential impacts, sterilisation of minerals was ignored as a differential factor.

5.3.4 Characteristic and differential factors

The key factors which were considered to characterise and differentiate the four alternatives are:

- financial costs,
- salinity damage costs, and
- timber production losses.

These factors are discussed below in greater detail.

(i) FINANCIAL COSTS

Current capital cost estimates were produced for a range of sizes for each of the four alternative projects. The optimum size and associated capital and operating costs for each alternative are shown in Table 3 together with key engineering parameters. All the estimates were reviewed and confirmed by an estimating consultant.

Alternative source development sequences commencing with each of the projects as the next major source in 1993 were produced. Each timetable matched supply to projected 'most likely' demand over the next 25 years.

The present value totals (PVT) for each of the alternative timetables were calculated** (discount rate of 6%) with the following results:

North Dandalup timetable	- $363.8 million
South Canning timetable	- $392.6 million
Raised Mundaring timetable	- $397.6 million
Raised Canning timetable	- $412.3 million

(Note: Each timetable contains the other two 'alternative' projects. e.g. the North Dandalup timetable incorporates Raised Mundaring in 1997 and South Canning in the year 2002).

The North Dandalup timetable has the lowest PVT of the four alternatives and hence is the timetable used in the current Source Development Plan. The PVT of the South Canning timetable is larger than previous estimates due to the results of recent analyses which indicated a longer period for the dam to gain its full yield after completion (see section 5.2.4.iv). The South Canning and Raised Mundaring timetable PVTs are significantly more than the North Dandalup alternative, but less than the cost of the Raised Canning timetable.

An additional financial consideration was the possibility that remedial works may be required at Canning Dam in the medium term to improve its safety against extreme floods. The safety of all the Authority's existing dams against extreme floods and the level of remedial works required have been under active review. Should remedial works to enlarge the spillway capacity of Canning Dam be required, the timing would probably be after the year 2000, i.e. some ten years after development of the next major source. The estimated cost of the remedial work is $12.6 million, but if South Canning Dam were constructed first, its mitigating effect on floods would reduce the cost to $10.5 million (i.e. present value of $5.9 million if ten years hence). Since the Raised Mundaring, South Canning and North Dandalup timetables have South Canning constructed at or before the year 2005, a present value of $5.9 million would have to be added to their respective timetable PVTs. The cost estimate for Raised Canning incorporated a fully enlarged spillway so no additional figure needed to be added to the PVT of its timetable. Hence if remedial works are required for Canning Dam, the differences in PVT cost between Raised Canning and the other alternative timetables would be reduced by $5.9 million.

**All costs at December 1986 prices

(ii) SALINITY DAMAGE COSTS

Studies in the United States of America and Australia have indicated that increased water supply salinity causes additional costs to the community due to a range of factors such as damage to household fittings and appliances and increased use of soaps and detergents. A major study was carried out for Adelaide by the consulting firm AMDEL in 1983, and salinity damage cost estimates were used by the Water Authority in 1985 as part of the cost-benefit analysis for the Harris River project.

In the 'Water 2000: Consultants Report No. 8 - Salinity Issues' (Peck, Thomas & Williamson, 1983), the USA and Australian studies were reviewed and salinity damage costs estimated across Australia. Perth and Adelaide were identified as having the highest costs. The costs were based on a linear rate for each household of $0.20 per year for every milligram per litre TDS in excess of 200 milligram per litre. This was considered to be a minimal estimate of domestic salinity costs in Australia. The corresponding rate in December 1986 prices would be $0.26.

In the absence of a detailed study of salinity costs for the Perth metropolitan area, this linear rate was used as a conservative estimate of the relative salinity costs between the alternatives. Since the studies indicated that salinity costs dropped to zero for salinities somewhere between 100 and 200 milligram per litre, a value of 170 milligram per litre (corresponding to North Dandalup reservoir salinity) was chosen as a suitable and convenient level for zero salinity cost.

In the Perth metropolitan area, 70% of the public water supply is used by domestic consumers. The function used to estimate salinity costs to Perth householders was:

$$C = 0.26 \times H \times (S - 170)$$

where C = total household costs ($ December 1986) per year

S = salinity (mg/L TDS)

H = number of households served

Since the function is linear and 70% of the public water supply is used by domestic consumers, the number of households (H) can be calculated as the volume of water supplied multiplied by 0.7 and divided by the average household water use of 350 kilolitres per year.

Using current streamflow salinity values, the average reservoir salinity for each of the four alternative water supply sources was estimated by the concentrating effect of each reservoir.

i.e. Average reservoir salinity

$$= \text{average stream salinity} \times \frac{Q\ in}{Q\ out}$$

where

Q in = mean stream inflow

Q out = mean outflow through overflows and draws

North Dandalup salinity costs would be zero, since its salinity of 170 milligrams per litre was the base salinity level. The South Canning salinity costs of $13.5 million (present value total of annual costs at discount rate of 6%) would be significantly higher than the $3.0 million for Raised Canning due to its greater effect on Canning Dam salinities (210 milligrams per litre compared with 180 milligrams per litre for Raised Canning). Raised Mundaring would have the highest salinity cost of $31.4 million due to its effect of increasing reservoir salinity from 430 milligrams per litre to 495 milligrams per litre.

(iii) TIMBER PRODUCTION LOSSES

Clearing and inundation of a reservoir basin results in some loss to the community of the long-term benefit of future timber harvesting within the basin area. The Department of Conservation and Land Management (CALM) was requested to provide estimates of these losses for each of the alternatives. The present value figures for the value of future timber production foregone (not including the value of the current standing timber which would be harvested during basin clearing) are shown in Table 6.

CALM recommended that a real interest rate of 5% is more appropriate for discounting future forestry cost flows over relatively long periods, based on present and historical real interest rates.

These values include the value of timber production foregone in buffer zones adjoining the dams, where timber production will be restricted.

The values presented above do not include any conservation or recreation values foregone (which are difficult to estimate and are introduced in the environmental and social accounts), nor the commercial value of the land.

Table 6:
Value of Future Timber Production Foregone for Each of the Alternatives for the Next Major Source
(Figures supplied by CALM)

Alternative	Value foregone ($ Dec. 86)	
	Discount rate (over 30 years)	
	5%	6%
Raised Mundaring	306 000	220 000
Raised Canning	135 000	97 000
South Canning	103 000	50 000
North Dandalup	162 000	126 000

Forest road relocation costs were also provided by CALM, but they were comparatively small and were absorbed in the total capital cost estimates for each project.

5.3.5 Evaluation and ranking of alternatives

The key economic factors discussed in section 5.3.4 are summarised in Table 7.

The two dominant factors in the economic account are the Source Development Timetable PVT and the salinity damage costs. Timber losses are relatively minor and do not have a significant effect on the overall economic costs. The Canning Dam remedial works costs basically only help to make Raised Canning a little more competitive against the other alternatives.

The **North Dandalup** Source Development Timetable has consistently been shown to have the least financial cost. The project also has the lowest overall costs, particularly taking salinity costs into consideration.

The salinity damage costs must be used with caution since a detailed study of the actual local costs has not been carried out. Nevertheless, the values indicate that the costs are potentially quite large and work in favour of the fresher sources such as North Dandalup and Raised Canning and against the more saline water of the Raised Mundaring and to a lesser extent South Canning alternatives.

In terms of both the PVT of the Source

Table 7: Economic Account for the Alternatives for the Next Major Source

COMPONENTS AND FACTORS	ALTERNATIVES Raised Mundaring	Raised Canning	South Canning	North Dandalup
(1) Financial				
PVT of Source Development Timetable($ x 10⁶ Dec. '86)	397.6	412.3	392.6	363.8
PV of possible Canning Dam remedial works ($ x 10⁶)	6.2	0	6.2	6.2
(2) Timber losses				
PVT of foregone future value ($ x 10⁶)	0.31	0.13	0.1	0.16
(3) Salinity damage costs				
PVT of costs to community of increased salinity ($ x 10⁶)	31.4	3.0	13.5	0

PVT = Present Value Total
PV = Present Value

Development Timetable and overall costs, **South Canning Dam** ranks second to North Dandalup.

Comparing **Raised Mundaring** with **Raised Canning**, Mundaring's lower Source Development Timetable cost is outweighed by its higher salinity costs and the penalty attributable to the remedial work which might still be required at Canning Dam. Hence Raised Canning would rank ahead of Raised Mundaring.

Thus from an economic viewpoint the ranking of the alternatives is: North Dandalup, South Canning, Raised Canning and Raised Mundaring

5.4 Natural environment considerations

5.4.1 Regional setting

All four of the feasible alternatives are situated in the Northern Jarrah Forest east to southeast of Perth, in major valleys cut into the Darling Range plateau. The Northern Jarrah Forest is managed by the Department of Conservation and Land Management principally for timber production, water production, conservation, bauxite mining, recreation and tourism (Department of Conservation and Land Management, 1987).

The major features of the geology, landforms, soils, climate, vegetation and fauna of the region are described below to provide a background for the discussion of characteristic and differential factors which follows.

(i) GEOLOGY, LANDFORMS AND SOILS

The Darling Range plateau in the region of the four alternatives consists of a granite bedrock, much of which is overlain by a lateritic mantle. The laterite is present in aluminous and ferruginous forms, often as a cemented caprock and with an underlying pallid zone generally of kaolinitic clay. There is a belt of gneissic rocks on the western side of the plateau, and dolerite and epidiorite dyke intrusions through both the granite and the gneiss are common, especially in the escarpment area. Bedrock outcrops on the escarpment, on sides and floors of the more deeply incised valleys and on the higher peaks and ridges.

The heterogeneous nature of the soils of the Northern Jarrah Forest reflects the variation in local relief, geological nature of the substrate, movement and sorting of weathered and unweathered materials, and other factors. The dominant soils on the ridges are ironstone gravels in sandy matrices overlaying deep subsoils of kaolin and saprolite, while red and yellow earths are the dominant soils in major valleys.

The geomorphology, geology and soils of the Darling Range are described and mapped in greater detail in the Atlas of Natural Resources, Darling System, Western Australia (Department of Conservation and Environment, 1980).

(ii) CLIMATE

The region has a typical Mediterranean climate, with warm dry summers and mild wet winters. There is, however, a significant range in rainfall and evaporation potential among the four alternative areas, as indicated in Figure 3 by the location of each reservoir site in relation to the isohyets. In Dwellingup, in the Darling Range south of the four alternative sources, the temperature ranges from a mean daily minimum in August of 5.3°C to a mean daily maximum in January of 29.4°C, with lowest and highest recorded temperatures being -3.9°C and 42.9°C (Bureau of Meteorology, 1985).

There is a growing scientific basis for the concern that increasing levels of atmospheric carbon-dioxide and other greenhouse gases in the earth's atmosphere will cause global climatic change, including a gradual shift over the next 50 years to a drier climate in this region. Although ideally this possibility should be considered in this report's evaluations, the phenomenon is still too poorly understood and predictions too approximate for consideration of climate change to be built in as a clear decision factor at this stage. Effects of climatic change and variation on yield have been discussed in sections 3.3 and 5.2.4.

(iii) VEGETATION

Open forests of jarrah (*Eucalyptus marginata*) and marri (*E. calophylla*) are widespread on the lateritic and gravelly slopes of the four alternative areas, while varying amounts of wandoo (*E. wandoo*) and yarri (*E. patens*) open forests and semi-wetland or stream vegetation occur on lower slopes and in valleys. The types of vegetation richest in plant species in all four areas are the herbfields, heaths and woodlands on granite outcrops and associated shallow soil. The outcrops in the four areas do, however, differ significantly in the extent and types of vegetation and flora they support (Havel Land Consultants, 1987).

(iv) FAUNA

The four alternative development sites lie within the northwestern part of the Northern Jarrah Faunal Zone, Zone III of Christensen *et al.* (1985). The vertebrate fauna of this part of Zone III is, in general, widespread in the south-west and poor in bird, reptile and mammal species numbers relative to the bird and reptile faunas of the North Coastal Zone and the mammal fauna of eastern woodland parts of Zone III. Only one species of vertebrate animal restricted to the Northern Jarrah Forest might be expected to occur in the alternative areas: the skink *Ctenotus delli*. Bird species richness and densities in the alternative areas are generally highest in stream vegetation. Granite outcrops and their surrounds are particularly important habitats for reptiles.

Relatively little is known about the distribution, abundance and habitats of the Northern Jarrah Forest's invertebrate fauna. Two of the better-known groups are ants and aquatic invertebrates. Many local species of ants have wide distributions which include the Swan Coastal Plain as well as the Darling Range and Scarp, but, at least at the community level, there are consistent differences between the Darling Range and Coastal Plain ant faunas and among ant faunas in the Northern Jarrah Forest (Dunlop & Associates and Ninox Wildlife Consulting, 1987). Aquatic invertebrates of at least the escarpment area of the Darling Range are considered to be distinctive, and some species found in Darling Range streams are regarded as rare isolated survivors from the ancient past.

5.4.2 Objectives for the natural environment account

The principal objectives of the natural environment considerations were to:

- identify and compare significant (key) environmental factors which would be affected by development and which vary in the kind and degree of impact among the four alternative sources, and
- rank the four alternative source developments on the basis of the significance of their associated environmental impacts.

5.4.3 Approach

Independent specialist consultants were employed to undertake field work to collect the data upon which to base the comparison of alternatives and to report to the Water Authority their data, comparisons and conclusions regarding the best source development.

The teams of natural environment specialist consultants employed were:

- Havel Land Consultants - landforms, vegetation and flora, and
- J. N. Dunlop & Associates, with Ninox Wildlife Consulting - fauna.

Details of the objectives, methodology and results of the investigations and the consultants' interpretation, comparison and discussion of their results have been presented in two reports which are available as supporting documents to this Stage 1 ERMP (Havel Land Consultants, 1987; Dunlop & Associates and Ninox Wildlife Consulting, 1987).

The two sets of natural environment investigations were undertaken independently, but members of the two consulting teams co-operated and interacted throughout the investigations. For example, the fauna studies team used the vegetation categories developed by the vegetation studies team, the two teams carried out a broad-scale reconnaissance of the four alternative areas together as their first step in the field work, and they discussed the reconnaissance, their approaches to the detailed field work to follow and their respective projects throughout.

(i) VEGETATION AND FLORA

The primary consideration in planning the vegetation and flora investigations was the availability of existing information about the geomorphology, vegetation and flora of the four alternative development areas and the Northern Jarrah Forest region in which they occur. Prior to beginning detailed field work, a broad-scale field reconnaissance was undertaken and 1:20000 scale colour aerial photographs taken in February 1986 were interpreted. Ecological units and geomorphological categories of the four alternatives were delineated on the aerial photographs; mapping followed checking of types and boundaries in the field.

The principal techniques used in the field to sample the vegetation and flora of each area were to observe and record the abundance of each species present and the height, density and condition of trees at points along transects in the areas that would be subject to inundation. Landform features were also recorded at each location. Observations were recorded during November and early December 1986 at a total of 520 locations along 66 cross-slope transects. The locations of the transects are shown in Figures 4 to 7. The quantitative data collected along the transects were supplemented by a range of qualitative observations made across the four alternative areas regarding the effects of disturbances. Plant specimens collected during the field work were identified and lodged in the Western Australian Herbarium.

The data collected in the field were processed manually and by computer, together with previously existing information from the Atlas of Natural Resources, Darling System, Western Australia maps (Department of Conservation and Environment, 1980) and other sources. By grouping and cross-referencing the data in various ways, it was possible to describe and to estimate, in a regional context, the abundance, condition and conservation status of the vegetation complexes*, site-vegetation types* and rare and geographically restricted species of plants identified in the project areas. Impacts of different levels of inundation by each of the four alternatives on vegetation complexes, site types and plant species were also assessed, particularly in reference to the quantity affected by each alternative and the adequacy of representation of each within reserves established with conservation as a primary purpose. Consideration was also given to the impacts each alternative would have on any existing reserves that might be affected and on downstream vegetation and natural systems.

*See Glossary

(ii) FAUNA

The first stage in the fauna investigation was to obtain a regional overview and to plan field work with the aid of searches of relevant literature and of computer listings of mammal, frog, reptile and fish collections in the Western Australian Museum. The most useful and recent literature included bibliographies by the Forest Fauna Research Working Group (1984) and the Department of Conservation and Environment (1984a), surveys by Liehne and Company (1984) and Christensen *et al.* (1985) and other studies by Chapman and Dell (1985), Worsley Alumina Pty Ltd (1985) and Nichols *et al.* (1981).

Field teams conducted surveys of vertebrate fauna and ant fauna in the range of habitats to full supply level in each of the four alternative reservoir areas during November and early December 1986. Particular attention was given to birds and ants because they could be comprehensively sampled in a short survey and had considerable potential as ecological indicators.

Trapping, night searches, vehicle traverses and other standard techniques were used to determine the presence, distribution and abundance of species in all groups sampled. The circular plot procedure was used for censusing birds at ten observation stations along each of eighteen traverses, with observations being carried out at each station on five separate days. Small mammals, amphibians and reptiles were captured in 15 drift traplines of ten pitfall traps each operated over periods of between nine and eleven days. The drift traplines were augmented by lines of 20 Elliott box traps and one cage trap run more or less perpendicular to them and by intensive fauna searches in their vicinity and on granite outcrops. Mist nets and 'harp' traps were used for sampling bats, ants were sampled by pitfall-trapping and an 'electro-fishing' technique was used for sampling fishes, marron and related decapod crustaceans both in the reservoir sites and at other sites in the region. The locations of the fauna sampling transects and other sites are shown in Figures 4 to 7. The animals trapped were identified by the consultants in the field and at Murdoch University, Curtin University and the Western Australian Museum.

The data on species of vertebrate fauna and ants collected or observed at each sampling site, particularly their identities, numbers and density, were used to determine a number of parameters used for comparing the four alternative sources from a fauna point of view. These parameters included species inventory, relative abundance or density of a species, species richness*, diversity* and dominance* indices, importance values of individual species, rarity and conservation priority, habitat preference, similarity analysis and degree of affinity* between sites. Communities or assemblages of animal species were evaluated in terms of their representation in the broader region, and potential impacts on fauna, assemblages and habitats were described, evaluated and compared.

5.4.4 Characteristic and differential factors

(i) VEGETATION AND FLORA

Key vegetation and flora factors, and one landscape factor, which might be adversely and differentially affected on a regional scale by development of the four alternatives up to reservoir full supply levels were determined to be:

- vegetation complexes,
- site-vegetation types,
- flora diversity,
- rare and restricted plant species (flora),
- condition of vegetation,
- reserves for the conservation of flora (and fauna),
- off-site vegetation and flora (beyond immediate dam site and reservoir area), and
- geomorphological and geological rarity.

These eight key factors are discussed below.

Vegetation complexes

Vegetation complexes, as mapped in the Atlas of Natural Resources, Darling Range, Western Australia (Department of Conservation and Environment, 1980), which would be affected by inundation to full supply level at each alternative source are indicated in Figures 4 to 7 by number-symbols. The complexes signified by the number-symbols are described and defined in Appendix 3. Although the vegetation and flora team revised the mapping of complexes during their investigation (Havel Land Consultants, 1987), the mapping of vegetation complexes shown in Figures 4 to 7 provides approximations of the quantities and areal extents of vegetation complexes which would be affected by each alternative development.

*See Glossary

An approach used for calculating potential impacts on vegetation complexes at a regional level was to assess the extent of each vegetation complex which would be inundated by each alternative against an index of adequacy of its representation in conservation reserves. Although the vegetation-complex maps of the four alternative reservoir sites prepared by Havel Land Consultants were more precise than the comparable Darling Range atlas maps, the agreement between the two sets of maps was close enough for their use in this approach.

Site-vegetation types

Whereas vegetation complexes comprise groups of site-vegetation types, site-vegetation types are defined by groups of indicator plant species. The indicator species used to define standard forms of the ten lowland and rocky outcrop site-vegetation types identified in the four alternative reservoir areas during the investigation are tabulated in Appendix 3. When the site-vegetation types of each alternative were compared with the standard types, it was found that several differed significantly from the standards and that some of the variants and intermediate types may be rare, even at a regional level. The quantity of site-vegetation types which could become inundated was estimated for each alternative, with a subcategory of lowland types which could become completely inundated. Rarity and adequacy of representation in conservation reserves of the various types were also estimated.

Flora diversity

A total of 466 vascular* plant species was recorded from the four alternative areas. Eight are introduced species. It was estimated that at the maximum level of reservoir inundation which might be considered for each alternative, 306 species would be affected at South Canning, 261 at Raised Mundaring, 219 at Raised Canning and 201 at North Dandalup. Most of these species do, however, occur above the maximum level as well as below it.

Rare and restricted plant species

Twenty species of vascular plants found during the vegetation and flora investigation have been classified, at least tentatively, as rare or geographically restricted. Together with others recorded previously in the region, they are listed in Appendix 4. None of the twenty species is gazetted as rare under the Wildlife Conservation Act, 1950-1979 (Government Gazette, WA, 25 September 1987, pp. 3733-3734). The number of non-gazetted rare and restricted species affected by the alternatives would be seven by raising Mundaring, six by raising Canning and five by each of the other two developments.

Condition of vegetation

Each alternative site was assessed for current condition of vegetation, cause of disturbances and length of time since the most recent disturbance, on the assumption that the least disturbed and best recovered stands of vegetation have suffered the least impact. There was evidence in many areas of past severe disturbances, but recovery of the valley vegetation has been very good, particularly when compared with lateritic uplands. The impact of *Phytophthora cinnamomi* (P.c.) dieback disease has been relatively minor in comparison with its impact on vegetation in minor valleys and lateritic uplands. The North Dandalup area has been most severely affected by dieback, mostly above the full supply level, and part of the South Canning reservoir area was heavily logged in anticipation of construction of the South Canning Dam in the early 1980s.

Reserves for the conservation of flora (and fauna)

The raising of Canning Dam would significantly affect Monadnocks Reserve (Reserve No. 39826; formerly Forest Department Management Priority Areas 14 and 22, plus adjoining Corridor 67). South Canning Dam would also affect this reserve if access to the dam were via the track known as Scenic Drive, an option not favoured by the Water Authority. The construction of North Dandalup Dam would affect the northern end of existing 'unvested' Reserve C21038 (System 6 Recommendation C49), currently gazetted for Parklands and Recreation but recommended by the System 6 report to have the purpose amended to Conservation of Flora and Fauna, and Water (Department of Conservation and Environment, 1983).

Off-site vegetation and flora

Although off-site impacts (those outside the immediate vicinity of the dam and reservoir) were considered during the investigation, they were not used in ranking the alternatives.

The principal off-site impacts would result from relocating roads and powerlines from the valleys to be inundated to the adjacent uplands, with consequent clearing of vegetation and the risk of spreading P.c. dieback disease.

*See Glossary

It is believed that the steep valley topography and high rainfall immediately downstream of Mundaring, Canning and North Dandalup dams would generate sufficient runoff to support the narrow zone of phreatic* vegetation below the modified structures. As discussed in section 5.2.4, even in the case of North Dandalup, which would experience the greatest reduction in flow (81%) at the dam wall, the nature of the downstream catchment is such that the long-term average flow reduction would amount to only 34% at the confluence with the South Dandalup River and 25% at the confluence of the Dandalup Rivers with the Murray River. It is therefore predicted that impacts from altered stream flow patterns below the dams would be minimal. Below the South Canning dam, where the downstream valley is broader and in a drier zone and where flows would probably be radically altered due to the operating regime for the alternative described in section 5.2.4, the potential for impact is higher. In general, however, effects on downstream aquatic and phreatic vegetation are anticipated to be no more severe than those already occurring due to the erratic flows experienced during the past two decades.

There is known to be some concern amongst members of the public as to the potential effect of reduced streamflows due to further dam development on the algal problems being experienced in the Peel Inlet. Calculations by the Water Authority demonstrate that the reduction in average annual total streamflows into the Peel Inlet due to construction of North Dandalup Dam would be less than 4%. The additional draw on the North Dandalup River is therefore not considered significant. The technical advice of the Investigations Division of the Environmental Protection Authority was sought on this question, and the response was that the reduction of stream flow into the Peel Inlet caused by damming the North Dandalup River would not significantly reduce flushing of the Inlet, nor was it likely to have any detectable effect on the algal problem (see Appendix 5, Letter from Director Investigations Division, EPA.)

Geomorphological and geological rarity

Consideration of geomorphological and geological features has been incorporated in the vegetation section partly for convenience and because native vegetation in the western part of the Darling Plateau has been shown (Havel, 1975a,b) to be closely related to soils, topography and hydrology. Features used in ranking the alternatives include type and extent of outcropping rock, width of valleys, steepness of slopes, type of soil and the rarity of the features. Rarity was assessed by W.M. McArthur (Havel Land Consultants, 1987) on such features as water-worn boulders in the parent material and rate of change in valley forms.

(ii) FAUNA

The relative affects on fauna resources attributable to development of the four alternative projects were evaluated using seven ecological characteristics (factors):

- regional affinities of fauna,
- species richness and relative abundance (using birds and ants as indicators),
- species of high conservation priority,
- aquatic systems,
- extent (area) of habitat,
- habitat integrity, and
- environmental condition.

Regional affinities of fauna

The four alternative project areas lie broadly within the Northern Jarrah Forest ecosystem, their faunas being similar and generally representative of the associated lower slope and valley habitats. Some reptile and bird communities, particularly in wandoo woodland of the northern and eastern project areas, Mundaring and South Canning, are transitional, containing species of the adjacent sub-humid ecosystems of the coastal plain and eastern woodlands. The Northern Jarrah Forest is more limited in extent than the relatively vast, drier ecosystems. Thus, in considering the conservational importance of the various faunal communities present in the four areas, their "representativeness" of this ecosystem is given priority. In this respect, the faunas of the North Dandalup and Raised Canning areas have higher value. However, transitional environments usually support a greater number of species, including those which are locally uncommon or unique. Therefore, in assessing an areas ecological value, characteristics such as species richness and rarity may offset representativeness.

Species richness and relative abundance (birds and ants)

In general, bird species richness (i.e. number of species present) in comparable habitats did not differ greatly between the alternative sources, although one Mundaring stream zone traverse had an exceptionally large number of species. The total densities of birds (numbers of individuals present) did, however, show large variations between like habitats and alternative sites. In stream zone habitats, densities were highest at Mundaring, followed by Canning and South Canning, and were lowest at North Dandalup. In poorer jarrah forest habitats this trend in bird densities was generally reversed, being highest at North Dandalup. Ants showed similar, but less dramatic, trends to those of the birds sampled. The general north to south and east to west trends observed in bird distributions were less evident in ant distributions; ants appear to respond more to differences in local soil moisture and density of the understorey.

Species of high conservation priority

Five species of fauna gazetted as 'rare, or otherwise in need of special protection' (Government Gazette, WA, 22 November 1985, pp. 4408-4409) were recorded in the alternative reservoir areas: Red-eared Firetail (*Emblema oculatum*) at all four sites; Dell's Skink (*Ctenotus delli*) at South Canning, Canning and North Dandalup; Carpet Python (*Morelia spilota imbricata*) at Mundaring and North Dandalup; Crested Shrike-tit (*Falcunculus frontalis*) at Mundaring; and Western Quoll (*Dasyurus geoffroii*) at Canning.

Due to the Western Quoll's requirements for a large area of habitat and because the Northern Jarrah Forest is probably the most important remaining region in its restricted distribution, the species is particularly vulnerable to further loss of habitat. The Western Quoll is, therefore, considered to have a higher conservation priority than any other species found during the investigation.

Aquatic systems

The fish and macro-invertebrate aquatic faunas of the three northern alternatives are similar except that the Hardyhead (*Atherinosoma wallacei*) was not found in the Canning or South Canning locations and the marron (*Cherax tenuimanus*) was not found at Mundaring. The North Dandalup River above the Pipehead, with only two native fishes, is considered to be depauperate in native fishes.

Raising the Mundaring or Canning dam walls or replacing the North Dandalup pipehead dam with a larger dam would have minimal additional effects on downstream aquatic systems since the existing dams already limit fish migration and probably exclude fishes from suitable up-river spawning areas. The South Canning dam would limit fish migration in the part of Canning River above the existing Canning Reservoir and summer release of cold water from the dam could adversely affect remnant populations of fish and invertebrate fauna in pools between the dams.

Extent (area) of habitat

For the purpose of ranking the four alternatives according to the amount of fauna habitat which would be destroyed, it was assumed that the areal extent of habitat affected would be equal to the approximate surface areas of the reservoirs or reservoir extensions:

Raised Mundaring	- 6 square kilometres;
Raised Canning	- 3.5 square kilometres;
South Canning	- 25 square kilometres; and
North Dandalup	- 5 square kilometres.

Habitat integrity

One of the unique effects a South Canning dam would have is the reduction in size and continuity of downstream stream-zone habitats currently extending from the Canning Reservoir to the river's headwaters. The isolation of animals dependent upon these habitats and reduction of their population sizes could result in local losses of some species, e.g. Red-eared Firetails, White-breasted Robins and indigenous fishes.

Environmental condition

Analysis of ant sampling results indicated that stream-zone environments at Mundaring, Canning and South Canning were disturbed (highly disturbed at South Canning, where the disturbance is postulated to have been caused by the activity of feral pigs). One Mundaring wandoo woodland ant sampling site was slightly disturbed. There was no sign of disturbance in the ant assemblages at North Dandalup.

5.4.5 Evaluation and ranking of alternatives

The four alternatives are ranked in Tables 8 and 9 according to the significance of the anticipated impacts on each key landscape, vegetation, flora and fauna factor listed in the previous section. The judgement of significance and ranking of alternatives was presented by Havel Land Consultants and Dunlop & Associates and Ninox Wildlife Consulting in their respective reports, which are available as supporting documents to this ERMP. The lowest ranking, 1, indicates the alternative for which the impact on the key factor is considered to be least severe or significant. The alternative for which that factor is most severely affected or valuable is ranked 4. The alternative with the lowest combined severity of impacts on key factors is, on the basis of the information and rankings given in the tables, the best in terms of the natural environment. However, no numerical weighting of the relative significance of the various factors has been presented, and therefore the rankings in Tables 8 and 9 cannot be summed to give a number directly reflecting the relative ranking of the sources.

The factor rankings and comparisons for the four alternatives are discussed below and are amalgamated to provide account ranking of all the alternatives for the natural environment account.

Development of **North Dandalup** Dam is considered to entail by far the least significant impact on the natural environment. It does contain an unusual geological feature which would be affected by the saddle dams, but the dominant vegetation complexes and site-vegetation types are amply represented in reserves and the total area of vegetation lost is comparatively small. Only one restricted plant species would be strongly affected by inundation. Construction of the reservoir and associated loss of habitat is judged to have the lowest potential impact on fauna habitat both in area and abundance of animals supported by that resource. This location is considered to make the smallest contribution to conservation of both vegetation and fauna. The impact of a North Dandalup dam on Reserve C21038 downstream is not considered to compromise its viability for conservation (see section 6.2.4).

The ranking of **Raised Mundaring** and **South Canning** Dams is very much dependent on the significance attached to quality and quantity of biota impacted. Mundaring development would affect a number of unusual site-vegetation types inadequately represented elsewhere as well as several species of plants considered rare or restricted. Mundaring also contains, in the stream-zone habitat, the highest diversity and density of bird species. In addition, it ranks second to Raised Canning in terms of supporting fauna species of high conservation priority.

Whilst vegetation complexes and site-vegetation types of South Canning are generally better represented in regional reserves, the comparatively large area to be inundated by the reservoir would result in the loss of a far larger vegetation resource. It would also strongly affect two restricted plant species. Two gazetted rare fauna species were also recorded at South Canning, and the type and area of vegetation loss would be directly reflected in fauna habitat loss. The reservoir site's extensive stream-zone habitat supports a considerable diversity and abundance of fauna. The construction of a dam at South Canning would result in the further fragmentation of the South Canning River, with potential associated impact

Table 8: Ranking of Impact on Landscape and Vegetation for the Alternatives for the Next Major Source* (after Havel Land Consultants, April I987)

Components and Factors	Raised Mundaring	Raised Canning	South Canning	North Dandalup
Geomorphological and geological rarity	3	1	2	4
Vegetation complexes				
(a) Number of complexes affected	2	1	4	2
(b) Impact on qualitative basis (adequacy of representation in reserves)	4	1	3	2
(c) Impact on quantitative basis (area affected x adequacy of representation)	3	1	4	2
Site-vegetation types				
(a) Completeness of inundation of lowland types	4	1	3	2
(b) Number of site-vegetation types affected	3	1	4	2
(c) Rarity of site-vegetation types affected	4	1	3	2
Flora diversity-number of species affected at maximum level inundation	3	2	4	1
Rare and restricted flora				
(a) Impact on gazetted rare species	3	4	1	1
(b) Impact on restricted species	4	3	2	1
Condition of vegetation	2	4	1	2
Existing reserves for the conservation of flora and fauna	1	4	2	3

Table 9: Ranking of Impact on Fauna Resources of the Alternatives for the Next Major Source* (After J. N. Dunlop & Associates and Ninox Wildlife Consulting, I987)

Components and Factors	Raised Mundaring	Raised Canning	South Canning	North Dandalup
Regional affinities of fauna	1	4	3	4
Area of habitat	3	1	4	2
Species richness and relative abundance	4	3	2	1
Species of high conservation priority	3	4	2	1
Aquatic systems	2	3	4	1
Habitat integrity	1	1	4	1
Environmental condition	2	3	1	4

*Ranked on a scale of 1-4, from least to greatest significance of impact.
Note: these are rankings for significance of impact on each factor, and not comparable weighted scores to be summed between accounts to give a total impact.

on stream fauna through loss of habitat, isolation of populations and changes to the downstream environment.

Raised Canning is considered the least desirable of the four alternatives on the basis of the predicted impact on the natural environment. The environment of the Canning reservoir site is surprisingly undisturbed and representative of the biotic assemblage of the Murray landform of the Northern Jarrah Forest. Despite the relatively small area of proposed inundation involved, development of this project would have several severe impacts. A number of rare and restricted plant species and habitat occupied by a number of legally gazetted rare fauna species would be adversely affected. One of these, the Western Quoll, is now restricted to a few remaining pockets in the Northern Jarrah Forest. Also, the raising of Canning would extend the reservoir well into the Monadnocks Reserve.

Thus, the ranking of the alternatives from the viewpoint of natural environment is considered to be North Dandalup, followed by Raised Mundaring, South Canning and Raised Canning.

5.5 Social environment considerations

5.5.1 Objectives for the social environment account

The principal objectives of the social environment considerations were to:

- identify and compare significant (key) social environment factors which would be affected, both beneficially and adversely, by development of the four alternatives, particularly factors which vary in kind, degree and importance among the four alternative sites,
- ensure that in its assessment and implementation planning, the Water Authority recognises the views and concerns of Aboriginal people and complies with the conditions of the Aboriginal Heritage Act, and
- rank the four alternative sources on the basis of minimising social costs and maximising social opportunity without unduly adversely affecting any particular individual or sector of the community.

5.5.2 Approach

Independent specialist consultants were employed to review existing relevant information and undertake social, archaeological and ethnographic investigations to collect the data upon which the comparisons were based, and to report their data, comparisons and conclusions regarding the best alternative to the Water Authority.

The teams of social environment specialist consultants employed were:

- Feilman Planning Consultants - social and recreational setting,
- P. Veth - Aboriginal archaeological sites at the Raised Canning and Raised Mundaring alternatives, and an overview of all four alternatives (J. F. Anderson investigated and reported on North Dandalup and South Canning in 1981/82), and
- R. O'Connor and P. Bennell - Aboriginal ethnography.

Details of the objectives of the studies and the methodology used by the consultants, the results of their investigations and their interpretation, comparison and discussion of their results are presented in their reports, which are available as supporting documents to this Stage 1 ERMP (Veth, 1987; O'Connor and Bennell, 1987; Feilman Planning Consultants, 1987).

The approaches to each of these studies are described below.

(i) SOCIAL AND RECREATIONAL SETTING

The assessment of social costs and increased social opportunities of the four alternative projects was based primarily on a review of relevant literature and other data and on interviews with officers and representatives of the Water Authority, of other state and local government agencies and of various recreational organisations. The consultants also made site inspections and estimated the recreational potential of each alternative's development quantitatively, using a computer programme and data bank specifically designed for establishing the degree of recreational suitability of wetlands from the closeness of match of their characteristics with recreational activity requirements.

(ii) ABORIGINAL ARCHAEOLOGICAL SITES

Investigations commenced with a review of relevant literature and of existing records of sites held by the Aboriginal Sites Department of the Western Australian Museum. Then, comprehensive surveys for Aboriginal archaeological sites were undertaken in each of the four alternative reservoir areas using closely spaced walking traverses, generally 50 metres apart. At each site found, the dimensions of the site and the numbers, types and estimates of the densities of artefacts were recorded. Basic environmental data, including rock, soil and vegetation types, slope, distance to water and obvious economic resources were also recorded. The ease with which artefacts could be distinguished was assessed, and sources of artefact base material such as quartz and dolerite were noted.

The significance of the sites and the amount of detailed site recording and analysis and other work necessary before development of each alternative could proceed were estimated and compared.

(iii) ABORIGINAL ETHNOGRAPHY

Review of existing published and unpublished ethnographic information on the four alternative locations and discussions with officers of the Western Australian Museum's Department of Aboriginal Sites were conducted in preparation for the field survey. Appropriate Aboriginal and non-Aboriginal people were consulted, asked for advice and invited to provide input into the survey, and the alternative areas proposed for inundation were surveyed for Aboriginal cultural heritage sites. Specific sites found in the vicinity of the alternative developments were described in the context of anthropological theory and regional Aboriginal mythology, history and other concerns.

5.5.3 Characteristic and differential factors

(i) SOCIAL AND RECREATIONAL SETTING

The four alternative dam and reservoir sites are, with one small exception of private land, on State Forest or Crown Reserve land vested in CALM or other appropriate government agency. North Dandalup is the only alternative which would affect private land, a small parcel which the owner is willing to sell to the Water Authority.

Where riparian water users genuine requirements may be affected by a source development, the Water Authority will ensure that the users are not unfairly disadvantaged (see section 6.3.1).

Social benefits and problems associated with a dam construction workforce are considered to be similar for each location. Although the establishment of a construction workforce camp is slightly more likely for the North Dandalup alternative than for the three others, it is most likely that there will be no camp, whatever the alternative chosen.

The workforce for each alternative would probably be drawn from the same employment pool, in the Metropolitan Area. Consequently, the construction workforce is not considered a differential factor.

Key social and recreational setting factors which characterise the alternative sources or which might be differentially affected by development of the four sources up to reservoir full supply levels, were identified as:

- historical significance of existing structure and environs,
- disruption to public caused by construction,
- potential gain or loss in recreation opportunity, and
- distance from Perth.

These factors are discussed below.

Historical significance of existing structures and environs

Mundaring Weir and Canning Dam have historic significance, as does the C. Y. O'Connor Museum below Mundaring Weir. Raising the dam walls could adversely affect the historical significance of both of these dams and their environs. The other two alternatives have no existing structures of historical significance.

Disruption to public caused by construction

Temporary disruption of picnic sites and access to Mundaring Weir and C. Y. O'Connor Museum would occur during construction of a raised Mundaring Weir. Similarly, raising Canning Dam would cause temporary disruption of picnic sites and public access to the Dam. Public use of Lady McNess Drive at Canning Dam and of Scarp Road at North Dandalup Dam would be precluded during the period of construction, up to two years or longer. Construction of a South Canning dam would not cause significant disruption to access to picnic sites or use of public roads.

Some other disruptions caused by construction of the dams would be more long-lasting. For example, construction of a South Canning dam would lead to the inundation of an attractive, diverse area that is a favourite of bushwalkers, and it could reduce the wilderness quality of bushwalking in the nearby Monadnocks Reserve by replacing the view of native forest with one of the reservoir and, when reservoir water levels are low, extensive areas of bare bank. Another consequence of dam construction would be the need to relocate or redevelop roads.

Potential gain in recreation opportunity

The principal effects of construction of a new dam or the raising of an existing dam on recreational opportunities relate to the water impounded behind the dam and to water flowing over the dam spillways. For instance, Canning Dam is described as 'a spectacular sight when over-flowing' (Western Australian Water Resources Council, 1984). Raised Mundaring, Raised Canning and North Dandalup dams would have reduced frequencies of overflows, although North Dandalup overflows would be more spectacular than those over the pipehead dam it would replace and the public would have the opportunity to view these, which is not the case at present. Water releases from a South Canning dam would be a new public attraction, as would a completely new reservoir behind that dam and the considerably enlarged reservoir replacing the North Dandalup Pipehead Dam reservoir. However, as a terminal water storage reservoir, North Dandalup, like Mundaring and Canning, would have strict controls on public access to the immediate vicinity of the water body to protect water quality. Even pedestrian access would be strictly controlled, being restricted to designated public locations and access paths. The public exclusion belt around a Raised Canning reservoir would extend a considerable distance into Monadnocks Reserve, further restricting public use of that area.

Recreational use of Mundaring Weir and its facilities, by far the most popular and well-known of the four alternatives, is close to saturation and has little potential for gain in recreational opportunity. The potential for gain in recreational opportunity at a Raised Canning Dam exists even if the dam is not raised, through the improvement of existing facilities and the creation of additional facilities. The change of catchment management classification from Class I* to Class II* and easing of water quality management restrictions which would accompany the replacement of the North Dandalup Pipehead dam with a storage dam would permit greater public use of the catchment, in addition to the construction of public facilities at the dam wall. As a South Canning reservoir would be used for non-terminal* water storage, both the reservoir and its catchment would have significant potential for more intense public use, at least during the probably infrequent periods when the reservoir is close to full (see discussion in Section 5.1).

Distance from Perth

The closer a recreation location is to Perth, the more convenient and economical a destination it is for the large metropolitan population. Mundaring Weir, 30 kilometres travel from Perth's centre, is slightly closer than Canning Dam, at 35 kilometres. The South Canning alternative, at 60 kilometres, and North Dandalup, at 75 kilometres, are about twice as far.

*See Glossary

(ii) ABORIGINAL ARCHAEOLOGICAL SITES

Forty-five Aboriginal archaeological sites were found during the investigations: 10 surface scatters of stone artefacts at North Dandalup, 19 surface scatters and 1 possible stone arrangement at South Canning, 5 surface scatters and 1 possible stone arrangement with several associated artefacts at Mundaring, and 9 surface scatters at Canning. Three of the Canning sites are particularly significant for being the first major (containing more than 500 artefacts) sites ever found in near-scarp jarrah-forest and for having implements manufactured from dolerite, mylonite and fossiliferous chert, as well as from the more commonly used quartz. One of the Mundaring surface scatter sites, on a Little Darkin River bank, was the only site found during the surveys with significant stratification potential. The consultants strongly recommended that this site and the three major sites at Canning be recorded and analysed in detail if development were to proceed.

(iii) ABORIGINAL ETHNOGRAPHY

The region in which the alternative sources are set is a focus of Aboriginal interest; therefore, any large development in the Darling Range is of potential concern. The concern is based upon long-term Aboriginal association with the area and mythology relating to the environment, especially river environments and flowing water.

No sites of exceptional Aboriginal cultural significance were identified at North Dandalup or South Canning. The registration of the Helena River (Raised Mundaring) as an Aboriginal site reflects its cultural, traditional and mythological importance. The area of springs, pools and swamps between the present Canning reservoir and Turtle Pool is an important Waugal (mythological 'water serpent') place. The Helena River and Canning River were both used as traditional tracks beween the coastal plain and the hinterland and have both historical and religious importance for Aboriginal people.

5.5.4 Evaluation and ranking of alternatives

The four alternatives are ranked in Table 10 on a scale of 1 to 4 for each of the key factors listed and discussed in the previous section. A value of 1 is most beneficial or least disruptive while a value of 4 is least beneficial or most disruptive. As in the case of the natural environment account, no numerical weighting of these values has been presented, and therefore it is not valid to sum the factor values for each alternative as a method of comparison. The significance weighting attributed to the various factors is stated or implied in the discussion and comparison which follow. The alternative with the lowest total combined adverse impact and greatest potential benefit is, based on the information and rankings presented in Table 10, assessed as being best in terms of social, archaeological and ethnographic benefits and impacts.

North Dandalup presents the opportunity to increase the range of recreational opportunities available to the public at that location both through the creation of new facilities and the downgrading of catchment restrictions on other activities. Recreational use of North Dandalup should reduce pressure on heavily utilised areas closer to Perth. The temporary disruption caused to use of public roads during construction is considered minor compared to the benefits which would result from their subsequent upgrading and the increased recreational opportunity at the site.

South Canning would provide the same range of recreational opportunities as North Dandalup and in addition has potential for some water-based activities which cannot be pursued on other, terminal* water supply reservoirs close to Perth. However, the Water Authority believes that the reservoir would have less recreational value than North Dandalup because of the extended periods during which the reservoir basin would be only partly full of water, with extensive bare banks exposed around the reservoir. Water-based activities would be likely to be limited by water quality considerations. There has also been a view expressed to the Authority that development of this area would dramatically reduce the regional availability of semi-remote settings and also detract from the satisfaction of 'wilderness' recreation in the adjacent Monadnocks Reserve overlooking the reservoir basin.

Canning Dam has some historical importance but not so much as Mundaring. Severe disruption to public access would result during the construction period. Other land-uses within the catchment would remain unchanged. Some of the Aboriginal archaeological sites would require considerable scientific work prior to disturbance. The impact on ethnographic sites would require resolution prior to any development.

Raised Mundaring is considered to have the greatest potential for adverse impact on the social environment and the least benefit. The present dam has recognised public appeal due to the perceived historical nature and character of the structure. Little opportunity exists to improve public use of the area as a result of the raising of the Dam, and disruption to public use of the site's recreation facilities would result during the construction. The area is believed to be of considerable significance to Aboriginal people and proposals for redevelopment could create concern and distress. The area also contains a significant Aboriginal archaeological site which would probably require full scientific appraisal prior to development.

The ranking of alternatives from the viewpoint of the social environment is therefore considered to be North Dandalup, followed by South Canning, Raised Canning and Raised Mundaring.

Table 10: Ranking of Social Impacts of the Alternatives for the Next Major Source

Components and Factors	Raised Mundaring	Raised Canning	South Canning	North Dandalup
Historical significance of existing structure and environs	4	3	1	1
Disruption to public caused by construction	3	4	1	2
Potential gain or loss in recreation opportunity	4	3	2	1
Distance from Perth	1	2	3	4
Archaeological significance	3	4	2	1
Ethnographic significance	4	3	1	1

*See Glossary

5.6 Evaluation and ranking of alternatives

The rankings of the alternatives for each of the accounts presented in sections 5.2 to 5.5 are summarised in Table 11.

In the **water supply account**, North Dandalup was clearly ahead of the other alternatives and South Canning was decidedly the worst alternative, with Raised Canning and Raised Mundaring evenly spaced between them. Investigations undertaken during the assessment planning have raised new concerns about the hydrological acceptability of South Canning Dam because of its slow development of yield.

In the **economic account**, it is clear that North Dandalup has the lowest and Raised Mundaring the highest overall costs. Raised Canning and South Canning are grouped between the other two, with South Canning having slightly higher ranking.

The **natural environment account** identified North Dandalup as consistently having the lowest overall level of impact. Raised Canning was identified as being the least desirable. South Canning and Raised Mundaring fall between the two extremes, with the ranking determined to some extent by the consideration of quality and quantity of the biotic environment lost. The conclusion of this evaluation is that the absolute quantity of natural resource lost at South Canning makes it less desirable as a development option.

In the **social environment account**, North Dandalup ranked as the most desirable option, slightly ahead of South Canning. The two raised dam alternatives and South Canning each have distinct adverse social impacts. South Canning, however, also has considerable additional recreation potential which does not exist for the two raised dams. This is considered to make it more desirable than Raised Canning or Mundaring on the balance of factors. North Dandalup involves few adverse impacts and has the potential for significantly increased recreational use following development. South Canning is considered slightly less desirable than North Dandalup because of its greater impact on a semi-remote recreational setting.

An overall comparison of the account rankings shows North Dandalup ranking highest in all four accounts.

Hence it is clear that, overall, North Dandalup is the best of the four alternatives and provides the most benefits at the least cost.

Table 11: Ranking of Water Supply, Economic, Natural Environment and Social Environment Accounts for the Alternatives for the Next Major Source

Account	Alternative			
	Raised Mundaring	Raised Canning	South Canning	North Dandalup
(1) Water supply	3	2	4	1
(2) Economic	4	3	2	1
(3) Natural environment	2	4	3	1
(4) Social environment	4	3	2	1

6. *The Best Alternative—North Dandalup Dam: Its Impacts and their Management*

Evaluation of the feasible alternatives (Section 5) identified North Dandalup Dam as the best source for development in terms of meeting the nominated objectives for all four accounts: water supply, economics, natural and social environment.

This section reviews the North Dandalup project and environment in greater detail and discusses impacts which might result from construction and operation of the project. Strategies for management of some adverse impacts are also put forward.

After assessment of the environmental acceptability of North Dandalup on the basis of this Stage 1 ERMP, the implementation planning process will define the project more precisely. Design of the project will incorporate environmental enhancement and impact mitigation and the associated development of a full management and monitoring programme. Further details of the project and of the management and monitoring programme will be set out in the Stage 2 ERMP.

6.1 The North Dandalup Dam Project

6.1.1 Location and proposed works

The proposed project is located some 65 kilometres south south-east of Perth. The project consists of the construction of an embankment dam, of maximum height about 54 metres and crest length about 660 metres, across the North Dandalup River upstream from the existing small pipehead dam. A reservoir of about 75 million cubic metres storage capacity and 505 hectares in area at full supply level would be formed by the dam. Ancillary works would include an intake tower, outlet works and a spillway. Two saddle dams of homogeneous earth construction would be required just north of the main embankment. Figure 8 shows the proposed works. Some consideration is being given to staged construction of the works. In this event, the dam could possibly be built to a lower crest and subsequently raised to the full size.

The estimated capital cost of the proposed works is $34.8 million (December 1986). Preliminary investigations into the geology of the damsite and sources of suitable embankment materials have been undertaken, although further work will be required to carry out the detailed design.

6.1.2 Damsite

SITE DESCRIPTION

The centre-line of the proposed damsite is located some 200 metres upstream of the existing pipehead structure. Streambed elevation is about 170 metres AHD. A local narrowing of the valley minimises embankment volume while the bed grade gives good storage versus height characteristics, being flatter upstream and steeper downstream. There is a marked bend in the river at the damsite.

GEOLOGY

The bedrock is mainly granitic, with a few intrusive dolerite dykes. Overburden is generally not deep in the central portion of the valley. There are deeply weathered zones upstream from the spillway crest (caused by a shear zone) and on the right abutment.

EXISTING WORKS

The existing pipehead dam is a 6 metre high concrete gravity structure which impounds a basin of capacity 20 000 cubic metres. The dam diverts water through a screening chamber and along a 915 millimetre diameter pipeline down the valley to connect with the 1065 millimetre diameter pipeline from South Dandalup Dam. A ranger's house and a treatment house for chlorination and fluoridation of the water are located on the valley slope above the pipehead dam.

The pipehead structure would be taken out of service when embankment construction commences, with the wall and adjacent screening chamber probably being removed. The existing disinfection and treatment facilities and the ranger's house would have to be replaced. The existing pipeline from the pipehead dam to the South Dandalup trunk main would continue to be used to deliver water into the metropolitan water supply system, and no additional trunk main would be required.

ROAD SYSTEM

The existing access road to the pipehead dam and proposed damsite is from South Western

Highway along Hines Road, Scarp Road and a track to the left of the pipehead and damsite. The reservoir of the proposed dam would cut Scarp Road, Sharp Road and some lesser forest roads (as shown in Figure 8). Scarp Road is a major north-south link road used by CALM and by local and tourist traffic. The section of road flooded would be relocated over the main embankment wall. The sections of Scarp Road (above Full Supply Level) abandoned due to the relocation would be ripped and rehabilitated. Similarly, any other tracks to be abandoned would be ripped between the nearest through-road to the reservoir full supply level and rehabilitated.

Sharp and Reynolds Roads would be closed to the public as they would be too close to the water body. Alternative east-west routes exist north and south of the area. Agreement has been reached with CALM on this issue.

Current road access to the damsite would need upgrading before construction activities commenced. A road of high standard, being two bitumen-surfaced lanes with a design speed of 70 kilometres per hour, is proposed to cater for main construction traffic from Perth and for subsequent tourist and local traffic, water supply operations and maintenance and forestry activity.

6.1.3 Major components

The following description of the project is based on preliminary design undertaken as part of the feasibility studies. Detailed design may modify these details during the implementation planning phase of the project.

EMBANKMENT

The current proposal is for a main dam embankment approximately 54 metres high and 660 metres long. Several embankment types, ranging from homogenous earthfill to rockfill, are currently being examined to determine the most economical structure. The elevation of the top of the bank would be approximately 224 metres AHD, some 5 metres above the full supply level.

SADDLE DAMS

Two saddles located some 650 metres and 900 metres north of the main embankment on the right bank would have minimum elevations of 204 metres and 216 metres AHD respectively. An embankment with a top at elevation 224 metres AHD would therefore require saddle dams at these locations of height 20 metres and 8 metres respectively. Homogeneous earth embankments with conventional sand filters are proposed, with cut-off trenches to a depth of about 5 metres.

*See Glossary

SPILLWAY

A spillway crest and chute on the left bank are currently proposed to take advantage of the bend in the river (as shown in Figure 8). The crest would be ungated, and water would discharge through a transition section into a chute with an energy dissipating structure where the flow enters the river.

The final spillway capacity will be designed on the basis of flood studies to be undertaken as part of the detailed design. The spillway will be designed to cope with the maximum probable flood* conditions.

OUTLET AND DIVERSION WORKS

The intake tower would allow water to be drawn from a number of screened intakes at varying levels and conveyed by pipe down the tower and through the outlet culvert. A bridge would provide access to the intake tower. An open channel would be required to divert water from the river bed to the tower during construction, and for scour purposes. The outlet culvert would be constructed to divert streamflows during the construction period and water supply flows subsequently. The culvert would be located either along the existing streambed or through the left (facing downstream) abutment, depending on the final location of the intake tower.

6.1.4 Construction

MATERIALS SOURCES

Sources of earth and rockfill materials for use in construction have been identified within the area to be covered by the storage basin. Concrete aggregates and filter materials will probably be obtained from established commercial sources.

TEMPORARY SITE WORKS

A number of possible sites for the construction office and contractor's camp have been tentatively identified. Final siting will depend on consideration of environmental effects and the possible future use of the sites (for example, as parking or picnic areas for sightseers) and will be addressed in greater detail in the Stage 2 ERMP.

CONSTRUCTION PROGRAMME

Foundation work is tentatively scheduled to commence in late 1990, with construction of the embankment and associated works due to begin in late 1991, for completion in time to store water in the winter of 1993.

6.2 The North Dandalup Dam natural environment

The regional setting of the proposed North Dandalup Dam's natural environment is described briefly in Section 5.4.1, while more specific environmental factors comparing and contrasting it with other alternatives are dealt with in Section 5.4.4. This section describes components of the environment which could potentially be impacted by the the project and outlines ways in which the impacts will be mitigated or managed. It also assesses what additional information is needed about the natural environment in order to permit further refinement of impact prediction and development of management proposals in the Stage 2 ERMP.

The great majority of environmental impacts will be in three areas: the damsite and part of the associated construction area, the downstream area and the reservoir basin area. Other areas will also be affected by access road construction and the rerouting of existing roads.

The activities causing major impacts, either directly or indirectly, will be the clearing of vegetation on the dam site and the reservoir basin, construction of the main dam, associated saddle dams (Figure 8) and sections of re-routed access roads, and inundation of the reservoir basin. The impacts of these activities on soils, vegetation, flora and fauna, and proposed management measures are outlined below.

6.2.1 Soils

IMPACTS

Dust production may be a problem during the construction period, while clearing and construction activities will predispose the soil to accelerated erosion and consequently increase sediment loads and turbidity in the North Dandalup River immediately downstream, at least during the period of construction.

MANAGEMENT OF IMPACTS

To minimise dust production and erosion of soil by water:

- clearing will be restricted to the minimum required for safe access and construction,
- wherever possible, existing roads will be used for clearing and construction activities,
- earthworks and other soil-disturbing activities will be carried out only during the dry summer months,
- working areas prone to dust production or other erosion will, where necessary, be surfaced or watered,
- the area upstream from the dam wall and below full supply level will be utilised, where feasible, for lay-down and other construction-related purposes and as the source of most of the sand, gravel and other available material required for construction, and
- disturbed areas not intended for long-term use will be revegetated as soon as possible. Long-term use areas include the reservoir site and passive recreation sites such as picnic areas. Topsoil from the reservoir site will be stockpiled for use in rehabilitation of other disturbed areas.

6.2.2 Vegetation and flora

IMPACTS

The principal impact of the project on vegetation and flora will be the permanent clearing and disposal of trees and other vegetation in the reservoir site, possibly to full supply level (505 hectares). In both local and regional senses, vegetation types and species that are low in the profile will be more adversely affected than ones on the higher slopes and plateau.

The largest area of vegetation that will be affected by the project is classified as Murray (M/H) Complex. Significant and adequate representation of the Medium/High Rainfall Murray Complex vegetation remains nearby on the Canning River in the Monadnock Forest Reserve, on the Serpentine River in the Serpentine and Karnet Reserves and on the Murray River and its tributaries in the Lane-Poole Forest Reserve. However, a large proportion of the highest rainfall examples of Murray (M/H) Complex vegetation of the stream-lines and valleys within 50 kilometres of the project area has already been replaced by reservoirs or cleared for rural and urban use.

Relatively small areas of vegetation will also be cleared on the damsite and along the routes proposed for access to the damsite and for diversion of Scarp Road. Suitable trees in the areas to be cleared will be salvaged for various purposes; the remaining cleared vegetation will be piled and burnt.

Other potential impacts include the introduction and spread of noxious weeds and P.c. dieback disease, the creation of habitats for water plant communities and communities that colonise and vegetate shores along fluctuating lake margins, and the alteration of water regimes for downstream vegetation.

AFFECTED VEGETATION

Vegetation complexes and site-vegetation types of the dam site, the reservoir site and the streamline below the dam were surveyed by Liehne & Company (1984) and Havel Land Consultants (1987). In their detailed report, Havel Land Consultants predicted that areas of four high-rainfall zone vegetation complexes will be affected by the North Dandalup Dam project and calculated that of the vegetation cleared, 73% will be in the Murray (M/H) Vegetation Complex, 7% in the Yarragil (Minimum Swamp) Complex, 19% in the Dwellingup-Hester (H) Complex and 1% in the Helena (M/H) Complex. These complexes comprise Site-vegetation Types C, D, G, O, P, Q, R, S, T, U and W (vegetation complexes and site-vegetation types are explained in Appendix 3).

Site-vegetation types C, R, G, W, Q, U, T and S are represented at the damsite and below it: Type C along stream-lines, Types R and G on steep, rocky slopes, Type W on a mildly sloping terrace, Types Q and U on a dolerite outcrop and Types T and S on upper slopes and the laterite plateau. There are also variations of these types and intermediates between them.

In the upstream portion of the main river valley, the southern half of the reservoir site, the proportions of Types Q, S, and T relative to Types R and G increase as the slopes become milder, shorter and less rocky.

In the northern half of the reservoir site, where the more abundant mild, laterised slopes are drained by Cronin Brook, Types S and T are also abundant, but Types D and W flank some of the Type C, stream-line vegetation, and Types O and P flank some Type W vegetation.

Some of the North Dandalup forest has been severely infected by P.c. dieback disease, mostly above the full supply level.

Surveys of the vegetation that will be cleared for road construction have yet to be done, and the importance and commonness of the flora affected by the North Dandalup Dam project have yet to be addressed fully in a regional context. Havel Land Consultants (1987) recommend additional vegetation transects be included in future studies in order to reduce the gaps in the original survey pattern, in order to confirm the conclusions arrived at by interpolation.

It will also be necessary to establish a basis for predicting what types of vegetation and species of plants are likely to colonise the reservoir margins and the reservoir itself. Surveys of the vegetation and flora of margins of other reservoirs in the area, such as South Dandalup and North Dandalup pipehead, can assist in that prediction.

AFFECTED FLORA

Havel Land Consultants assessed that 201 species of plants will be affected by inundation to full supply level behind North Dandalup dam. For most of the species, the impact will be only partial since they occur above full supply level as well as below it. As the consultants' survey was done late in the flowering season, there were probably many early-flowering species and annual plants not recorded. Consequently, the number 201 may be an underestimate.

The consultants found five sensitive species of flora during their November-December 1986 survey of the North Dandalup Dam project area (sensitive flora are species of plants which are gazetted, rare, geographically restricted, vulnerable, threatened, at risk, poorly collected or poorly known). *Acacia barbinervis* was found only above the full supply level, in the widespread, lateritic uplands intermediate Site-vegetation Type SP. *Boronia crenulata* var. *gracilipes* was found twice below full supply level, in Type WP, a type characteristic of valley floors and lower slopes. *Dryandra praemorsa* was recorded once at North Dandalup, in Type RG in the vicinity of the spillway site, but it was also recorded at the other three alternative water supply sites investigated. Two of the three locations where *Eucalyptus laeliae* (buttergum) was recorded will be submerged, and the third might be affected by the spillway. However, the species is common in Reserve C21038, immediately downstream from the dam, and occurs extensively in the Helena (M/H), Scarp and Cooke Vegetation Complexes. Two locations where *Senecio leucoglossus* was found are below full supply level while two are above.

Additional searches for sensitive species in the areas to be affected by the project, including road construction, will be needed in order to better assess their abundance and distribution. These searches will be undertaken in late winter or early spring, when species flowering earlier than the ones located during the November-December 1986 survey may also be found. Very recently the rare, winter-flowering *Boronia tenuis* was located near the proposed spillway in Reserve C21038 (CALM, personal communication).

Because the sensitivity status of species changes as collections increase and improve and more is learned about them, the list of sensitive species which might occur in the project area will be updated. Sensitive species found during the searches will also be sought in the same types of habitats outside the immediate impact area in order to place the potential effect in a broader context.

MANAGEMENT OF IMPACTS

To minimise impacts on existing native vegetation and flora, the relevant measures outlined in Section 6.2.1 will be followed and:

- additional flora and vegetation surveys will be undertaken to confirm or refine descriptions contained in this report and facilitate detailed project design causing minimum adverse impact,
- areas to be cleared will be carefully delineated,
- the construction workforce will be given specific directives to clear only within the delineated areas and to avoid unnecessary damage to vegetation,
- vehicular movement will be confined to specified roads and tracks,
- all construction operations will be subject to CALM forest hygiene requirements, and
- liaison will be maintained with CALM in accordance with these requirements.

Rehabilitation of disturbed areas will aim to create self-sustaining systems of native species.

6.2.3 Fauna

IMPACTS

The principal impacts of the project on native fauna will be the destruction of animals and their habitats in the reservoir basin area. The most severe impacts in the reservoir area will be on species with habitats and resources on the valley floor and in the dense stream-line vegetation. Altered stream flows below the dam could affect aquatic fauna by regularly reducing winter flood levels necessary for reproduction and summer flows necessary for maintaining and mixing water in pools (Pen, 1987). The dam wall will act as a barrier preventing fish that spawn in the river's headwater, such as *Galaxias occidentalis*, from migrating upstream during the winter; however, because the existing pipehead dam already presents such a barrier, there will be no change in the situation. The reservoir will develop an aquatic fauna including both indigenous and exotic species.

AFFECTED FAUNA

Liehne & Company (1984) and Dunlop and Ninox (1987) undertook fauna surveys in the North Dandalup Dam project area in December 1983-January 1984 and November-December 1986, respectively. Late spring and summer are acceptable seasons for undertaking terrestrial fauna surveys; winter is better for aquatic fauna, especially invertebrate aquatic fauna. The first team recorded 6 species of frogs, 17 of reptiles, 3 of small terrestrial mammals, 2 of larger mammals, 5 of bats, 47 of birds and at least 66 of vertebrate and invertebrate aquatic fauna. The second team recorded 6 species of frogs, 25 of reptiles, 6 of terrestrial mammals, 4 of bats, 50 of birds, 42 species of ants, 7 of fish and two of *Cherax* (fresh-water crustaceans). In general, the species recorded are common and widespread.

Both teams recorded two species officially gazetted as 'rare or otherwise in need of special protection' (Government Gazette, WA, 22 November 1985, pp. 4408, 4409): Red-eared Firetail (*Emblema oculatum*) and Dell's Skink (*Ctenotus delli*). Red-eared Firetails were common in the stream-line vegetation of all four alternative water supply sites investigated and have been found to be common in this type of relatively undisturbed vegetation throughout most of the Northern Jarrah Forest (Nichols, Watkins and Kabay, 1982). Dell's Skink was also common in all four alternative sites, in a wide range of habitats. At North Dandalup River it is near the southern end of its limited geographical range.

Dunlop and Ninox also recorded a third gazetted species, Carpet Python (*Morelia spilota imbricata*), and Liehne & Company noted that two species of aquatic fauna with very restricted known distributions have been collected from restricted sites above the flood area of the proposed dam. These are a snail, *Glacidorbis occidentalis*, and a stone-fly, *Reikoperla occidentalis*.

Two skinks that are infrequently recorded in the Northern Jarrah Forest, *Egernia kingii* and

E. luctuosa, were found by both teams during their surveys. The first skink is associated with rocky talus, the second is found mainly in streamline habitats.

A bird species of particular interest recorded during the surveys is the White-breasted Robin (*Eopsaltria georgiana*). This species, whilst not gazetted rare, has been declining markedly in abundance within the Northern Jarrah Forest but was found to be common in stream-line vegetation in the North Dandalup Dam project area. White-breasted Robins were found in particularly high densities at South Canning by Dunlop and Ninox (1987).

The North Dandalup project area also contains habitats similar to those recorded elsewhere during the investigations of the four water supply alternatives in which two other gazetted species might occur, the Crested Shrike-tit and the Western Quoll.

Crested Shrike-tits (*Falcunculus frontalis*) are most common in wandoo woodland and other lightly timbered country but have also been found in jarrah and karri forest. The species was recorded during investigations of the four alternatives along Raised Mundaring Stream Transect 2; suitable habitat may also occur in the North Dandalup project area.

Suitable habitat may also occur in the North Dandalup area for the Western Quoll (*Dasyurus geoffroii*), recorded only at Raised Canning during the 1986 investigations. It is a species particularly difficult to observe or trap and, as discussed in Section 5.4.4, has high conservation value.

The University of Western Australia's Aquatic Research Laboratory, based in the Department of Zoology, is currently undertaking investigations for the Water Authority of the macroinvertebrate and fish fauna of the Canning and North Dandalup river systems. The investigations are intended to provide an inventory of the macroinvertebrate and fish fauna of the two rivers, provide an explanation of the distribution of species and populations, predict the likely impact on these fauna of various changes in catchment and stream characteristics and, finally, to provide the basis for recommending key indicator species of aquatic fauna most suitable for monitoring the condition of the streams, both above and below Water Authority impoundments.

By September 1987, the study had progressed to the point where preliminary analysis of the results could provide qualified but meaningful description of the aquatic fauna of the North Dandalup River, comparison of the North Dandalup River fauna with the Canning River fauna, an indication of environmental conditions responsible for species distribution and maintenance of populations. The study results also provide the basis for tentative prediction of the impact the fauna would experience if environmental conditions were to change as a result of the project's construction or operational impacts.

In view of the value of the information to the Stage 1 environmental review process, the Water Authority requested, in September 1987, that the Aquatic Research Laboratory undertake a preliminary assessment of the results available, looking specifically at comparisons between catchment streams of the North Dandalup and Canning Rivers. Despite the extremely short time available for this exercise, the Aquatic Research Laboratory undertook the analysis and produced a brief report of its findings in late September 1987 (Aquatic Research Laboratory, 1987). Detailed analysis will be undertaken in 1988 as originally programmed and will be addressed in the Stage 2 ERMP report.

The study has recorded a total of 202 taxa of aquatic macroinvertebrates from the North Dandalup pipehead and Canning Dam catchment streams, and 9 species of fish from the North Dandalup and Canning Rivers. Of the 144 taxa of aquatic macroinvertebrates recorded for North Dandalup and 164 for Canning, 106 were common to both rivers. Of the fish, 7 species were common. In addition, trout were found in the North Dandalup River but not in the Canning.

Statistical analysis of the population similarity (based on species presence/absence) among all sample sites on the two rivers indicated a greater similarity of macroinvertebrate species in the upland (Darling Range) sites of the two rivers than in the respective lowland (coastal plain) sites of each river. The next level of division in this analysis separated North Dandalup upland sites from all except two of the Canning upland sites. The explanation for the similarity in fauna of the two Canning exceptions and the North Dandalup sites is the frequency and duration of desiccation they experience; they all have more consistent water flows and shorter periods without flow. The conclusion of this preliminary analysis is that North Dandalup does have a distinctive macroinvertebrate fauna, largely as a result of its location and flow characteristics.

The fish fauna of North Dandalup contains two introduced species. Only two native species, *Galaxias occidentalis* and *Bostockia porosa*, were found at sites above the existing pipehead dam. Both of these species were also found in the Canning River. The preliminary report concludes that the fish fauna of the North Dandalup River above the pipehead dam is depauperate compared to the known fish fauna of the Darling Range.

Research is continuing, in order to establish the long-term viability of the native fish populations upstream of the pipehead dam and to predict downstream impacts and provide input to impact mitigation and management proposals.

MANAGEMENT OF IMPACTS

To minimise impacts on native fauna, the relevant measures outlined in Sections 6.2.1 and 6.2.2 will be followed and:

- an ecological study and monitoring programme will be designed and undertaken to assess streamflow-related requirements of local fish and other aquatic fauna, including exotic species, and to detect changes in their populations which might be related to operation of the dam. The information will be used for planning future water supply projects and in managing North Dandalup River flows in ways most beneficial to aquatic fauna. The aquatic investigations presently being conducted for the Water Authority by the University of Western Australia will provide a sound contribution to designing these studies and the management framework.

6.2.4 Nature reserve

IMPACTS

The existing pipehead dam and the first 7 kilometres of the existing pipeline are located in the unvested Reserve C21038, which was gazetted as a Public Reserve for Parklands and Recreation in 1933.

In the 1983 'System 6 Redbook' (Department of Conservation and Environment, 1983), the EPA recommendend (C49.2) that:

> 'The purpose of Reserve C21038 be amended to Conservation of Flora and Fauna, and Water and that the reserve be vested in the Western Australian Wildlife Authority for a limited term of 10 years to be managed in consultation with the Metropolitan Water Authority under a published management plan.'

However, the Water Authority believes that if North Dandalup Dam is selected as the next major source, proceeding with the recommendation for a dual purpose, temporary 10 year vesting would not be appropriate. Consequently the Water Authority proposes that the north-east arm of the reserve (approximately 10 hectares) be excised and vested in the Authority for the purpose of water supply and that the remaining area be reclassified as Class 'A',to be permanently vested in the National Parks and Wildlife Conservation Authority for the purpose of conservation of flora and fauna. Some form of easement on the existing pipeline and access track in the reserve would be required. It is the view of the Water Authority's consultants (Havel Land Consultants, 1987) that the impact of excising this land from the Reserve C21038 would not critically compromise its viability for conservation.

The agreement in principle of CALM to this proposal was sought and has been obtained. CALM inspected the area proposed for excision for presence of rare flora before agreeing to the proposal.

MANAGEMENT OF IMPACTS

The project will be carefully designed and managed, in consultation with CALM, to preserve the conservation value of the remaining reserve as well as to minimise environmental impacts on the excised portion. The management measures to achieve this during the construction and operation phases of the project will be reviewed in the Stage 2 ERMP.

6.3 The North Dandalup Dam Social Environment

Regional and specific aspects of North Dandalup Dam's social environment are dealt with in Section 5.5.3 in relation to the selection of the best of four alternative water supply sources. This section describes aspects of North Dandalup's social environment likely to be affected by the project, predicts what the impacts of the project on them will be, and outlines ways in which the impacts will be managed and mitigated. It also assesses what additional information is needed about the social environment in order to permit more confident predictions about impacts and their management.

6.3.1 Social and recreational setting

IMPACTS

No significant long-term adverse social and recreational impacts are anticipated. On the contrary, replacement of the existing pipehead dam with the larger dam will be accommpanied by a change in catchment classification from Class I to Class II. Class II classification permits increased public use of the catchment and the opportunity for establishment of public facilities near the dam wall. Increased recreational use of the North Dandalup area should reduce pressure on Mundaring Weir and other similar popular areas nearer Perth.

Scarp Road, which currently crosses the North Dandalup River valley immediately upstream of the pipehead dam reservoir, will be re-routed westwards to cross over the dam wall. The current inherent and substantial aesthetic appeal of the valley to travellers along Scarp Road will be replaced by the view of a large reservoir fringed by forest above the full supply level.

The Bibbulmun Bushwalking Track, which previously followed Scarp Road across the valley, was moved further east in 1987 and will therefore be unaffected.

During construction there will be some disruption of local traffic and inconvenience to farm residents along Hines Road.

A reduction in scenic and aesthetic river flows will be experienced downstream.

The existing pipehead dam is taken out of operation towards the end of November each year when the streamflow falls below about 30 000 cubic metres per day. It recommences again in late May or June, when the first winter rains re-establish steady streamflow. Thus, during summer the natural streamflow is allowed to flow downstream.

Streamflows measured upstream of the existing pipehead dam indicate that the last 10 years of streamflows have been the lowest on record. Low rainfalls in the region since the mid 1970s have resulted in streamflows into the pipehead ceasing in 9 of the last 10 summers.

There appears to be little dependance on North Dandalup River flows by riparian landowners, most of whom have alternative water sources such as groundwater and farm dams available, probably because summer riverflows over the past decade have been unreliable. The main use of the river is for stock-watering and any natural streamflows during spring, summer and autumn may be particularly helpful in this regard.

Replacing the existing pipehead dam with a major storage reservoir would reduce downstream streamflows, which may, unless water is released, at times reduce the availability of water below the dam for use by riparian landowners, particularly in early and late summer.

MANAGEMENT OF IMPACTS

To minimise inconvenience to residents nearest the dam site and along access roads:

- noisy, heavy equipment will operate along Hines Road only during daylight hours,
- unsealed portions of roads near residences will be sealed or watered to prevent dust production, and
- residents will be fully informed of any blasting operations. Furthermore, everyone will be excluded from the danger area during shot-firing.

To minimise inconvenience to and adverse effects on the construction workforce:

- working areas will be sheeted with gravel or, where acceptable or preferable, watered by a water tanker fitted with sprays, and
- where appropriate, employees will be issued with equipment to protect them from unacceptable levels of dust and noise.

To maintain and increase the aesthetic and recreational potential of the project area:

- all oils, fuels and other chemical products will be stored and used according to the requirements of the appropriate regulations,
- special care will be exercised in the storage and handling of petroleum-based products to prevent contamination of surface soils, rock surfaces and water by oil and fuel spills,
- all wastes will be collected in a sump and trucked to an approved waste disposal site, and
- sites for picnics, barbeques, information and ablution facilities and bushwalking trails will be selected, developed and landscaped to blend in with the surrounding natural environment.

The Water Authority is not required by law to release any water stored behind the proposed dam. However, in view of the possible adverse impact on riparian users, the Authority will review present use of the river flow and will determine, in consultation with existing riparian landowners, a satisfactory arrangement for meeting the genuine and reasonable domestic, stock and garden watering requirements of the landowners. If the arrangement arrived at is to release prescribed flows, the amount released would not exceed the natural streamflow into the reservoir at the time and no water would be released in periods when the natural streamflow ceased altogether.

6.3.2 Aboriginal archaeological sites and ethnography

IMPACTS

The ten surface scatter sites found by Anderson will all be inundated by the reservoir (Veth, 1987). None of them are major sites; eight had fewer than 50 artefacts and two had between 50 and 500. Two sites, S1660 and S1662, were considered to have excavation potential and have been recorded in detail and archaeological material collected.

Little Dandalup Hill, to the south of the North Dandalup Dam project area, is a specific site of Aboriginal significance, but the informants consulted during these investigations were not aware of specific sites, permanent springs or areas of Waugal association within the area of proposed inundation (O'Connor and Bennell, 1987). Relevant Aboriginal groups will be further consulted as part of the public review process for the project.

MANAGEMENT OF IMPACTS

The Water Authority acknowledges its obligations to site protection as outlined in the Western Australian Aboriginal Heritage Act, 1972-80, and has accordingly sought and obtained approval from the Minister for Aboriginal Affairs to use the area at North Dandalup for development of a dam.

Any new sites discovered during the course of dam construction and associated work will be reported to the Registrar of Aboriginal Sites.

6.4 Environmental acceptability

Growing demand for water from the Metropolitan Water Supply due to population growth will ultimately have to be met by development of additional sources. Changes towards a drier climate could hasten the requirement for development of new sources by reducing the yield from existing sources (see section 3.3).

The rate of increase of demand on the public water supply system might be curbed by restraining growth in, or reducing, per capita consumption. The Water Authority has responded to this challenge to defer the need for new sources by implementing an active water conservation programme to encourage less water use and introducing a new tariff structure with progressively more expensive unit costs as water consumption increases (see section 3.2). The Authority is also reviewing the current levels of standards of service. For instance, allowing the probability of restrictions to increase would reduce the need for new sources, if this approach were acceptable to the community (see section 3.4).

Such measures should result in reducing the need for new sources of water to a minimum. However, this minimum need for new water supplies would represent a basic community requirement and the additional water required would have to be considered to have a high value placed on it by the community.

Examination of the water supply options and broad-based evaluation of the source development alternatives clearly indicates that North Dandalup Dam is the best alternative to meet additional demand on the Metropolitan Water Supply system.

The Water Authority acknowledges that the development of North Dandalup dam will affect the local natural and social environment, both adversely and beneficially. The largest adverse impacts are related to the permanent loss of approximately 500 hectares of vegetation ranging from dense streamline fringe to open jarrah forest of the slopes. The area supports a rich fauna, which will suffer further decline in the Northern Jarrah Forest as a result of the loss of restricted habitat.

Socially, the new water supply will contribute to the maintenance of a lifestyle similar to that which the people of Perth now enjoy. Reclassification of the North Dandalup catchment from Class I to Class II will permit greater recreational opportunity in a desirable environment.

As noted in section 5.4.4, the Water Authority is aware of some concern in the community regarding potential impacts on the Peel Inlet as a result of further regulation of the North Dandalup River flow. Water Authority calculations show that the reduction of flow to the estuary as a result of this project would be minimal and, as the nature of the nutrient problem in the estuary is insensitive to such small changes in flushing effect, the impact is considered insignificant. Technical advice provided by the Investigations Branch of the EPA confirms this conclusion; it describes the flushing effect as insignificant and predicts there will be no detectable effect on the algal problem. Impacts on important components of the fishery are 'likely to be minor, or non-existent' (see Appendix 5). The

Water Authority recognises the incremental nature of water supply development and potential for cumulative impacts. The above predictions included the reduction in flow associated with development of the proposed Conjurunup Creek Pipehead.

The majority of potential impacts associated with development of a new dam are well known, and minimisation of adverse impact will be a fundamental consideration in the detailed design, construction and operation of the North Dandalup dam. A range of standard management measures adopted to mitigate adverse impacts are outlined in this report. Some potential effects are less well understood and will be the subject of further investigation during the implementation planning phase of the project.

The nature and magnitude of these impacts are not considered critical to the decision on environmental acceptability of the North Dandalup site. It is the Water Authority's opinion that, where necessary, acceptable measures can be incorporated into the project design and operating regime to satisfactorily mitigate negative impacts. The Stage 2 ERMP will provide more detailed project specifications as implementation planning advances, and present refined impact predictions and strategies to manage project construction and operation with minimal adverse impact.

6.5 Conclusions

The Water Authority believes that there is a demonstrated need for a new water supply source, possibly as early as 1993, and after a broad-based evaluation of the options and feasible alternatives believes North Dandalup to be the best source for development to meet that need.

The Water Authority's assessment planning investigation, reported in this Stage 1 ERMP, has established that there are no adverse impacts, either locally or for the region, the significance of which would make the development of a new storage dam at North Dandalup environmentally unacceptable.

Accordingly, the Water Authority seeks agreement in principle from the EPA and Minister for Environment that the development of a new storage dam on the North Dandalup River is environmentally acceptable.

Following such agreement in principle being given, the Water Authority will proceed with implementation planning and the preparation of a Stage 2 ERMP that:

1. **elaborates on planning and details of the proposed project;**
2. **refines predictions of impacts made in Stage 1, reviews measures for mitigation of adverse environmental effects and outlines means for realising the environmental benefits of the project;**
3. **includes the framework for and approach to be adopted in an active monitoring and management programme for the project, identifying systems and components of the environment which require ongoing attention.**

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8. *Glossary and List of Abbreviations*

Glossary

Affinity (fauna)	An expression of the similarity and relationship between faunal assemblages of the surveyed sites.
Artesian	Artesian water is confined under pressure in an aquifer between impermeable layers, usually at a considerable depth, and flows to the surface when intersected by a well.
Catchment	The surface area from which runoff flows to a river or any other collecting reservoir, e.g. swamp, groundwater.
Class I, II, catchment	A system of classification for water supply catchments reflecting different management practices appropriate to maintaining water quality in the associated reservoir.
Class 1	Developed catchment – small domestic diversion dam: Water from this class of catchment is fed directly into the domestic supply system. The catchment and water area are small and susceptible to pollution. Public access to the catchment is limited to open roads, marked walk trails and designated areas. Access to the water area is not permitted.
Class II	Developed catchment – large domestic dam: Water is supplied to the domestic supply system either directly or via a downstream dam. The size of the reservoir ensures detention of inflow for a significant period. Therefore low intensity recreation is normally permitted within the catchment except for specified exclusion zones. Public access within two kilometres of the water area is limited to open roads, marked walk trails and designated areas. Access to the dam wall is permitted but not to the water area.
Demand	The amount of water required from the water supply system.
Demand projections	Short-term projections of demand are basically an extrapolation for the next five years of recent trends in water use. Projections are based on assumptions which can lead to higher demands ('maximum' projection) and to lower demands ('minimum' projection), (Mauger, 1987).
Desalination	The process of removing salts from water to produce fresh water.
Diversity index	A measure of the ratio between the number of species and importance values of individual species.
Dominance index	A measure of the apportionment of individuals amongst taxa.
Groundwater	Water which occupies the pores and crevices of rock or soil.
Maximum probable flood	The flood resulting from a combination of the greatest rainfall physically possible over a particular catchment and the worst flood producing catchment conditions that could be realistically expected in the prevailing meteorological conditions.
Median value	The middle value in a given sequence of values.
Phreatic vegetation	Vegetation located along streamlines and dependent on the shallow groundwater associated with the streambed.

Pipehead	A small dam allowing the water flowing in a river to be diverted into a pipe (see Chapter 5: Water Supply Schemes).
Present Value Total (PVT)	The sum of all the expected future costs, discounted to their current values, for a project or sequence of projects.
Pumpback	A pipehead dam diverting streamflow by pumping through a pipeline into a storage dam.
Runoff	The discharge of water through surface streams into larger water courses.
Salinity	The measure of the total soluble (or dissolved) salt, i.e. mineral constituents in water. Water resources are classified on the basis of that salinity in terms of milligrams per litre Total Soluble Salts (mg/L TSS).
Site-vegetation type	A vegetation unit defined by a characteristic group of overstorey and understorey plant species (see Havel 1975a and 1975b).
Species richness	The number of different species found in a defined area.
Stand (of vegetation)	A cluster of plants of uniform species or structure composition.
System yield	The maximum unrestricted annual demand that the water supply system can sustain under specified expectation of restrictions (currently restrictions are expected in 10% of years).
System yield benefit	The increase in system yield which occurs when a new source is added to the system.
Talus	A mass of broken rocks of all sizes at the bottom of a slope.
Terminal supply reservoir	A reservoir supplying domestic water direct to a distribution system.
Vascular plants	The higher plants, with true leaves, stems and roots through the tissue of which liquids are conducted.
Vegetation complex	Mappable groups of site-vegetation types, or other vegetation units, characteristic of various combinations of landforms, soils and rainfall.
Yield benefit	See System yield benefit.

Abbreviations

AHD	Australian Height Datum.
CALM	Department of Conservation and Land Management.
EPA	Environmental Protection Authority.
ERMP	Environmental Review and Management Programme.
FSL	Full Supply Level.
G & AWS	Goldfields and Agricultural Water Supply Scheme.
MWS	Metropolitan Water Supply System.
PVT	Present Value Total.
SDP	Source Development Plan.
WAWRC	Western Australian Water Resources Council.
TDS	Total Dissolved Solids

9. *Study Team*

Proponent

Water Authority of Western Australia

B. SADLER	Steering Committee Chairman
R. STONE	Project Engineer, Evaluation of Source Alternatives
G. MAUGER P. WHITE P. VANDERWAAL S. DALLAS	Source Behaviour Modelling
R. WARK G. MEINCK	Dam Design
P. MOORE	Catchment and Reservoir Management
R. STOKES	Hydrology
R. ROSICH	Water Quality
B. CARULLI	Word Processing
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Consultants

Ian Pound & Associates Pty Ltd

I. POUND	Principal Consultant, Environmental Studies Co-ordination, ERMP Preparation
A. Weston	ERMP Preparation
K. Majer	Editorial review

Havel Land Consultants

J. HAVEL	Leader - Vegetation Studies
E. MATTISKE	Botanical Investigations
W. McARTHUR	Geomorphology
B. KOCH K. KEATING	Botanical Investigations
D. DEVEREUX	Computer System Analysis
P. HAVEL J. DROGE	Vegetation Data Analysis

J. N. Dunlop & Associates and Ninox Wildlife Consulting	
J. N. DUNLOP	Leader Fauna Studies
K. YOUNGSON	Co-leader Fauna Studies
J. HENRY	Fauna Investigations
D. WATKINS	Avifauna
M. BAMFORD	Fauna Investigations
J. MAJER	Ant Fauna Identification
P. CRYSTAL	Aquatic Fauna Sampling
L. PEN	Fish Fauna Impact Prediction
Feilman Planning Consultants	
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M. DAY	Recreation and Social
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S. O'CONNOR B. O'BRIEN F. WALSH	Archaeological Assistants
Rory O'Connor & Associates	
R. O'CONNOR	Leader – Ethnography
P. BENNELL	Ethnography
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PETER LIEHNE & COMPANY	Preliminary Review - Biotic Environment
J. ANDERSON	Archaeology

10. Authorities Consulted and Acknowledgements

Environmental Protection Authority, W.A.

Department of Conservation and Land Management, W.A.

Western Australian Museum

Western Australian Herbarium

Aquatic Research Laboratory, University of Western Australia

Department of Agriculture, W.A.

Geological Survey of Western Australia

State Planning Commission, W.A.

CSIRO

Department of Sport and Recreation, W.A.

Western Australian Tourism Commission

State Energy Commission, W.A.

National Trust of Australia (W.A.)

Western Australian Heritage Committee

Alcoa of Australia Ltd

Shire of Mundaring

Shire of Kalamunda

Shire of Wandering

Shire of Murray

City of Armadale

Conservation Council of Western Australia

The Water Authority wishes to thank the numerous individuals who attended and contributed to the Perth Water Supply Planning and Environmental Assessment Seminar/Workshop in November 1986.

Figures 3 – 8

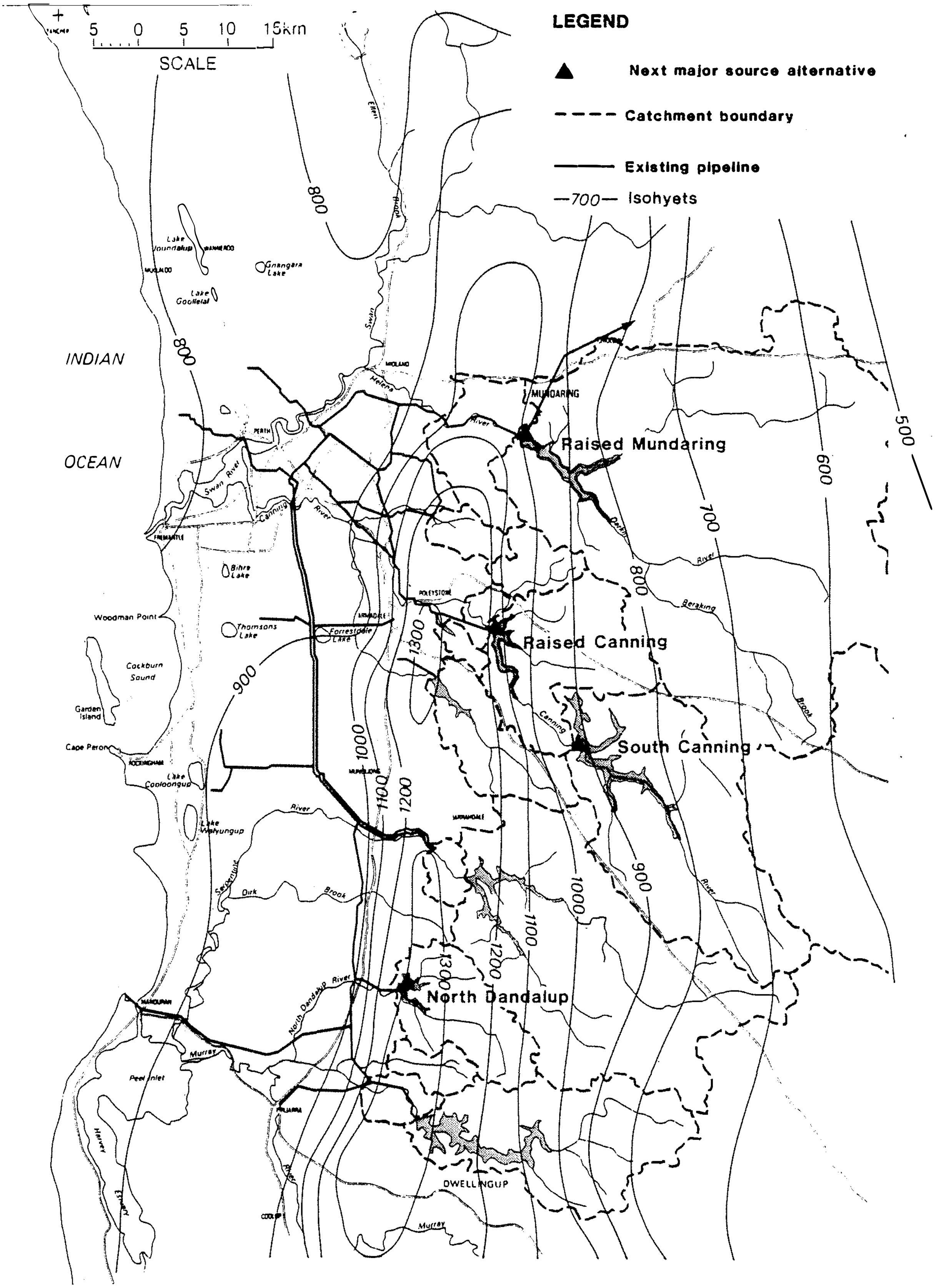

Figure 3: Alternatives for the Next Major Water Supply Source for Perth

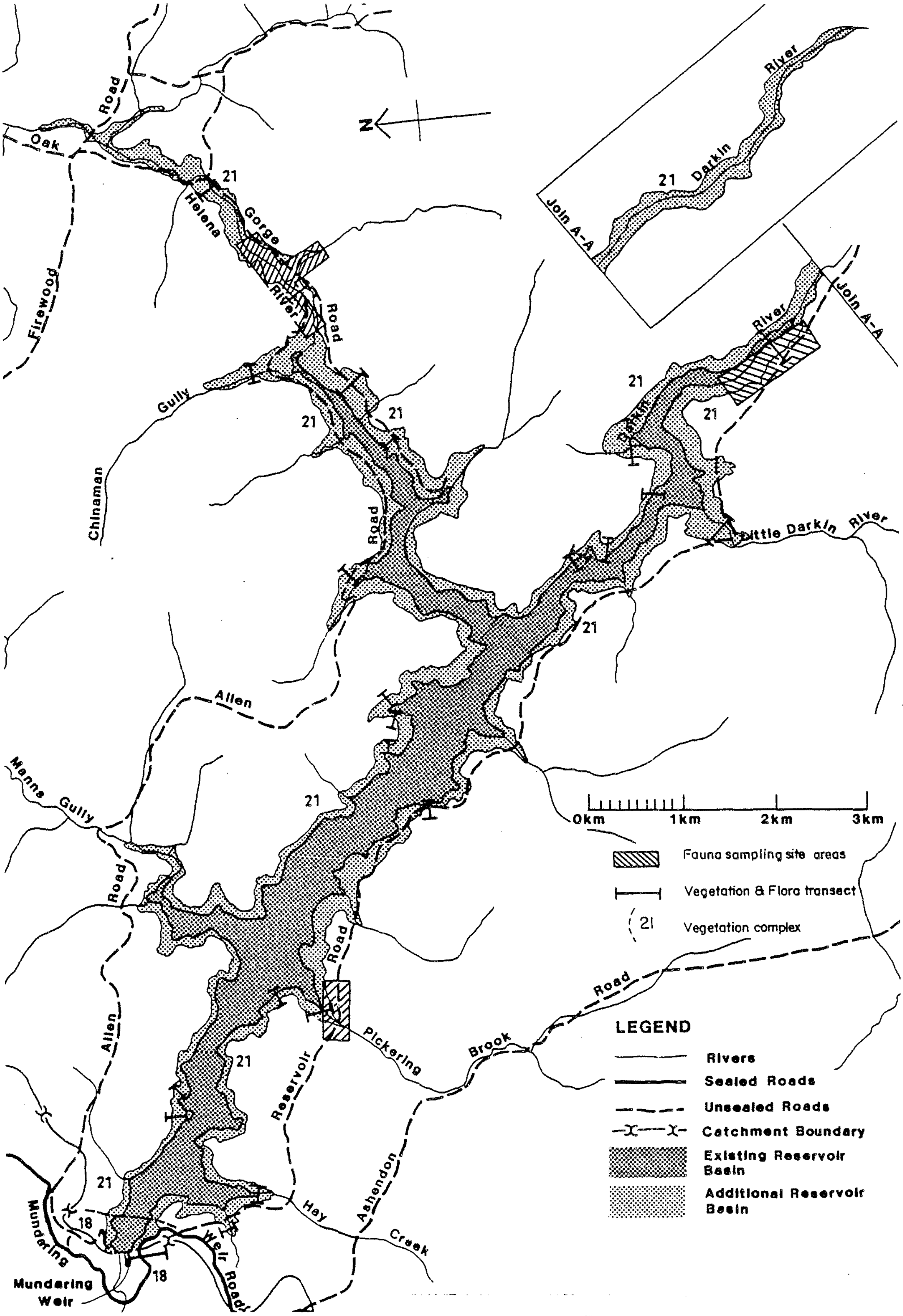

Figure 4: Raised Mundaring

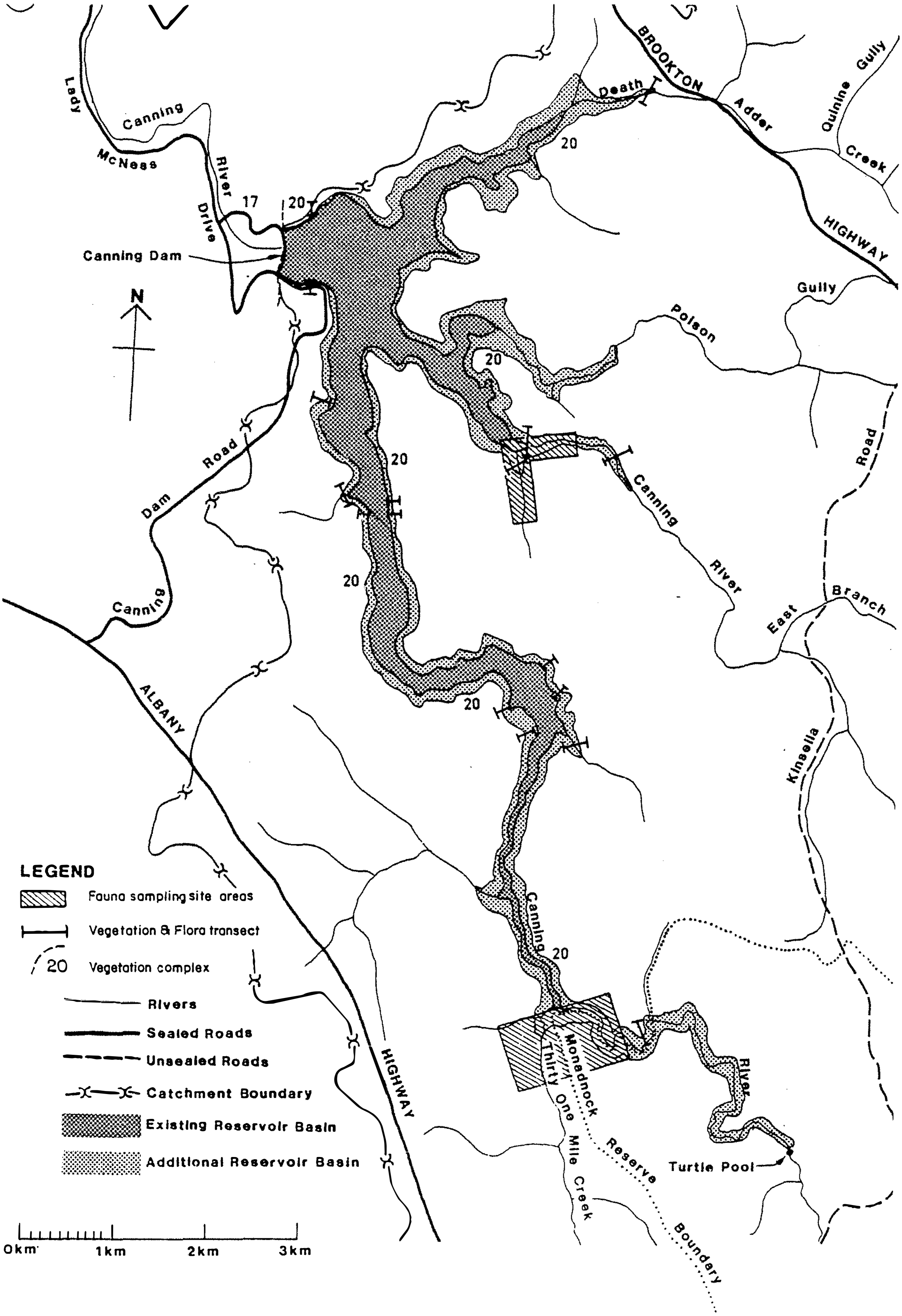

Figure 5: Raised Canning

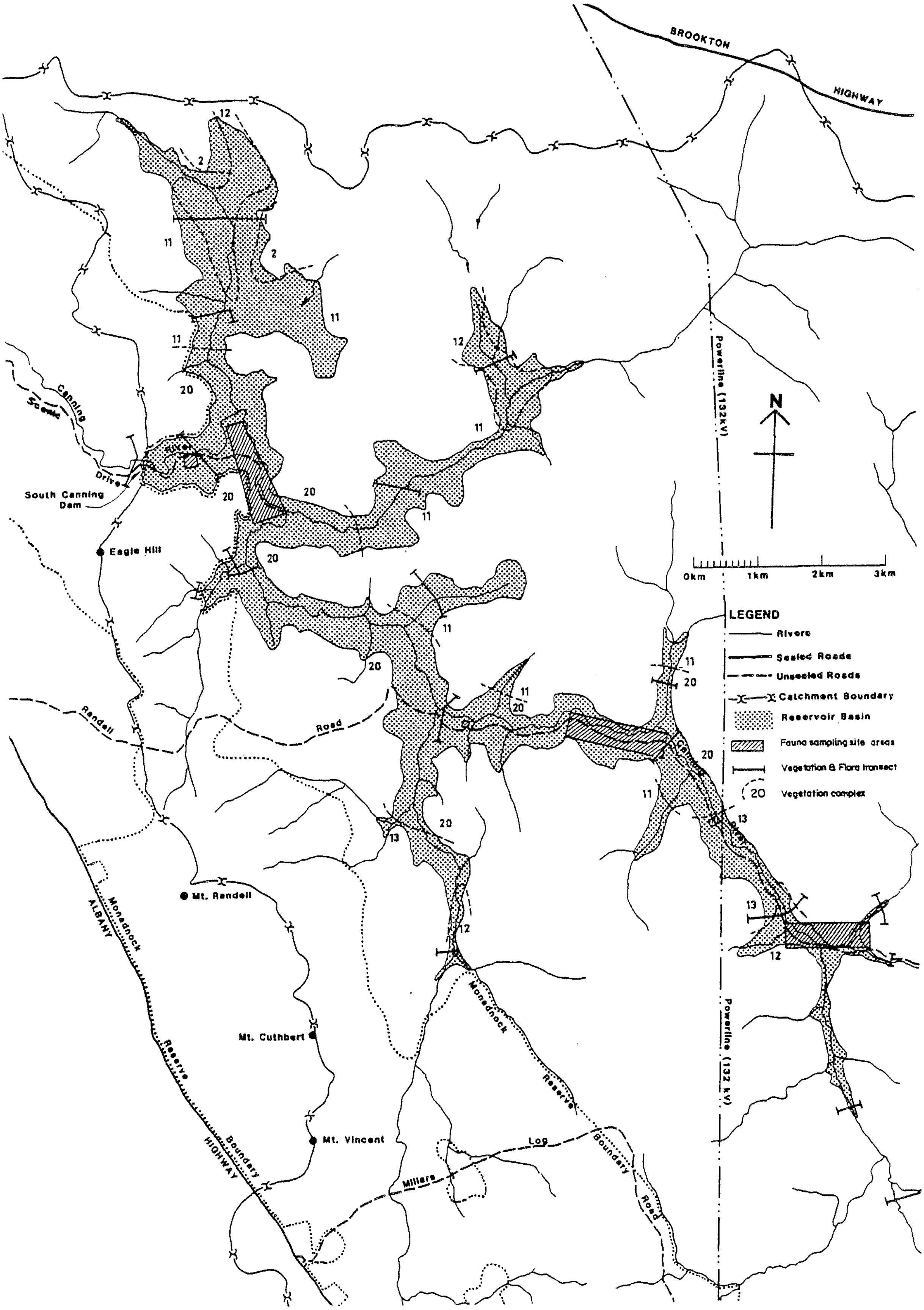

Figure 6: South Canning

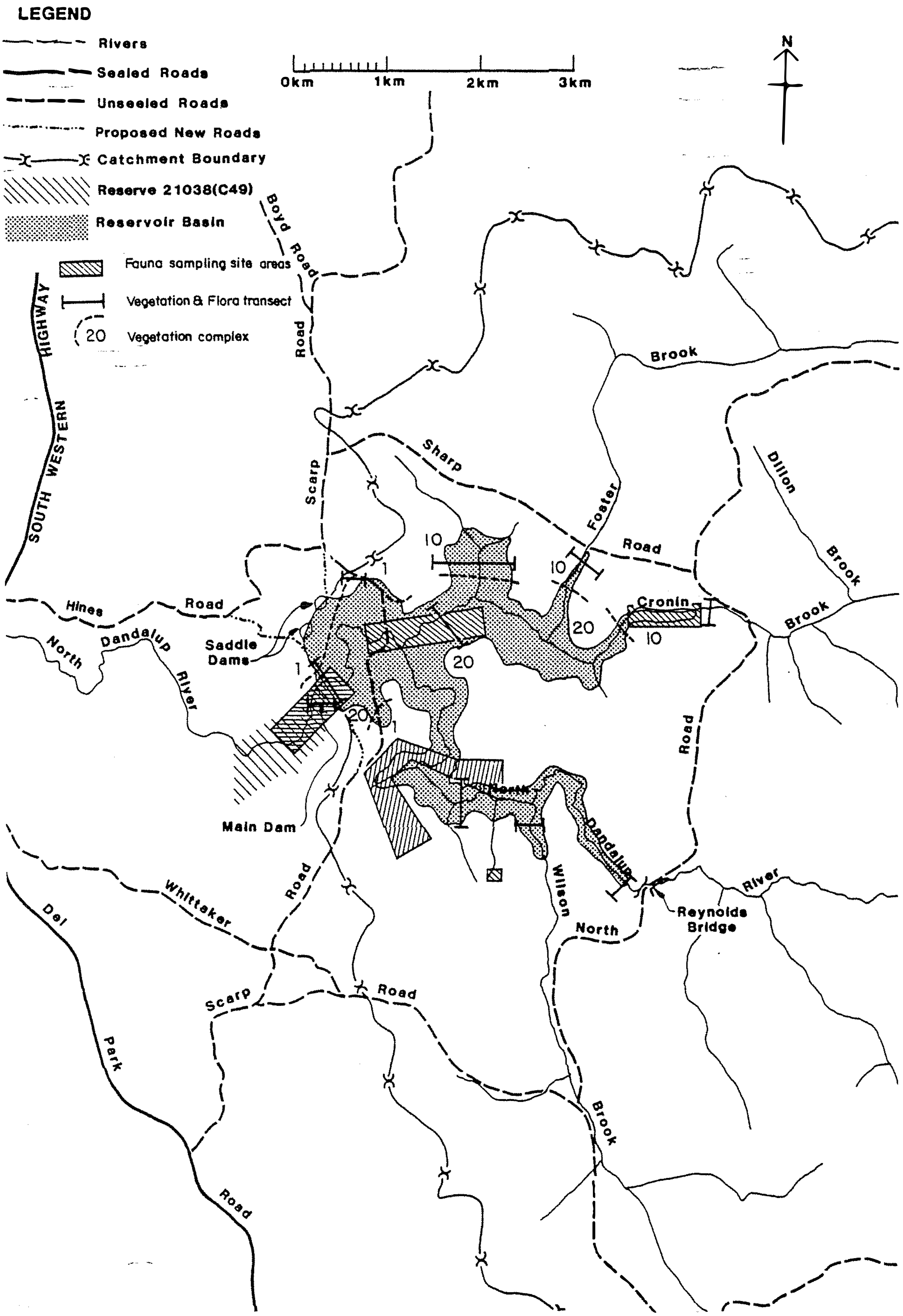

Figure 7: North Dandalup

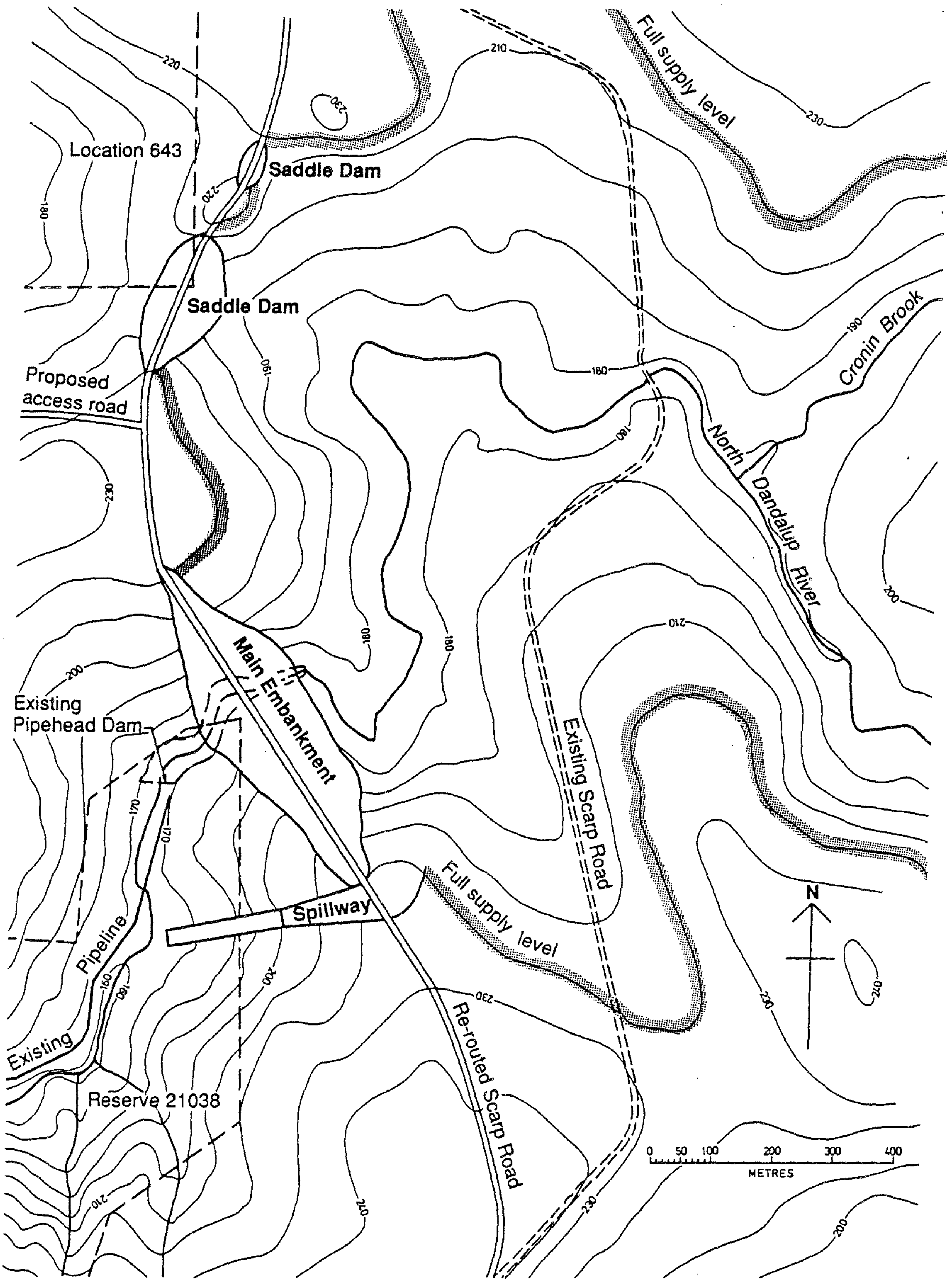

Figure 8: North Dandalup Dam; Plan of Works

Appendix 1

Environmental Protection Authority
ERMP Guidelines

SELECTION OF THE PROPOSED NEXT MAJOR PUBLIC WATER SUPPLY SOURCE IN THE DARLING RANGE

GUIDELINES FOR THE ENVIRONMENTAL REVIEW AND MANAGEMENT PROGRAMME

PREAMBLE TO GUIDELINES

The following guidelines have been prepared for an Environmental Review and Management Programme on the proposed development of a major water supply source in the Darling Range.

For such major projects, the EPA considers that a staged assessment, with each ERMP involving public input, may be more appropriate than a single assessment. Typically, the Authority could require an ERMP to be staged for a number of reasons, two of which are:

- the environmental implications of a proposed development or course of action are too complex for adequate public review based on a single document; and/or

- the environmental impact assessment process for a particular development requires an analysis of a number of alternatives (eg alternative sites, technologies or strategies) followed by the detailed consideration of a smaller number of options or specific alternative.

The Next Major Public Water Supply Source proposal clearly falls into the latter category and the Authority has determined that a two-stage ERMP is appropriate.

The objective of the Authority's assessment of the Stage 1 ERMP is to provide environmental advice for the "approval in principle" stage to a preferred strategy (or strategies), to identify those matters that require consideration in the Stage 2 ERMP and to formulate a framework for the Stage 2 ERMP that would ensure that the context for that assessment is appropriate.

Emphasis in the Stage 1 ERMP should be placed on outlining the rationale behind the selection of the preferred option(s) or strategy(ies) (including alternatives), a description of the proposal(s) and its (their) environmental impacts. Sufficient detail should be presented for the public and the EPA to understand the implications of the proposal(s).

The Stage 2 ERMP and its associated EPA assessment report will be the documents upon which final decisions on the ultimate management strategy to be implemented will be based.

These guidelines are issued as a checklist of matters which the Environmental Protection Authority considers should be addressed in the Stage 1 and 2 ERMP. They are not exhaustive and other relevant issues may arise during the preparation of the document: these should also include in the Stage 1 and 2 ERMP.

It should also be noted that the guidelines are not intended to convey the Authority's wishes with respect to the format of the document. The format is a matter for the proponent and its consultant.

A copy of these guidelines should appear in the ERMP.

1. SUMMARY

The Stage 1 ERMP should contain a brief summary of:

- salient features of the proposal;
- alternatives considered;
- description of receiving environment and analysis of potential impacts and their significance;
- environmental monitoring and management programmes, safeguards and commitments;
- proposed Staged ERMP strategy; and
- conclusions.

2. INTRODUCTION

The Stage 1 ERMP should include an explanation of the following:

- identification of proponent and responsible authorities;
- background and objectives of the proposal;
- brief details and timing of the proposal;
- relevant statutory requirements and approvals; and
- scope, purpose and structure of the ERMP.

3. NEED FOR THE DEVELOPMENT

The Stage 1 ERMP should examine the justification for the project and projected costs and benefits (in the broad sense) at local and regional levels. The justification should include consideration of various demand options.

4. EVALUATION OF ALTERNATIVES

The evaluation of alternatives is an important part of an ERMP. A discussion of alternatives to the proposal, including demand management and alternative sites as well as the "do nothing" option, should be given. A comparison of these in the context of the stated objectives should be included as well as costs and benefits at both construction and operational stages. This discussion should also consider various scales (sizes) of the project and their implications. In this way the rationale for not choosing certain alternatives should be clear as would the basis for choosing the preferred option.

5. DESCRIPTION OF PREFERRED PROPOSAL

The Stage 1 ERMP should include brief details of:

- overall concept;
- location and layout;

- proposed land uses, land tenures and a clear indication of boundaries of private and public land;

- construction schedule and methods of construction including source of materials and disposal of wastes;

- infrastructure, including pipeline construction;

- access;

- auxiliary services (eg power);

- control and staging of project;

- operation during and after construction;

- public recreation facilities; and

- projected lifetime.

6. EXISTING ENVIRONMENT

The Stage 1 ERMP should provide an overall description of the environment and an appraisal of physical and ecological systems likely to be affected by the alternatives, at local and regional level.

It should concentrate on the significant aspects of the environment likely to be impacted by the development. Only the processes, habitats, resources and potential resources which could be influenced should be defined. Detailed inventories should be placed in appendices to the ERMP.

Wherever possible in the discussion of physical and biological processes that are essential determinants in the maintenance of habitats and resources, conceptual models or diagrams should be used to illustrate and synthesize the interactions between the processes.

It would be expected that the Stage 2 ERMP would particularly address the processes sustaining the ecological systems for the preferred alternative.

The following matters should be addressed:

6.1 PHYSICAL
- meteorology;
- geology and geomorphology;
- soils;
- hydrology and hydrogeology;
- water quality.

6.2 BIOLOGICAL
- vegetation communities in the project catchment;
- riverine vegetation communities downstream of the project;
- terrestrial and aquatic fauna in the project catchment and downstream;
- definition of habitats and ecological relationships;
- identification of areas subject to or susceptible to forest disease;
- vegetation and fauna in pipeline construction and other infrastructure areas.

6.3 HUMAN

- land use, including past land uses, land tenure, zoning and reservation;
- conservation and recreational aspects in project catchment;
- road systems and traffic;
- landscape;
- public access;
- sites affected by System 6 "Red Book" recommendations;
- historical, archaeological and ethnographic sites;
- use of waters downstream of proposal, including groundwater.

These issues need to be discussed in both a local and regional context. In addition, the Stage 1 ERMP should, where appropriate, take cognisance of any other known developments proposed for the general area.

7. ENVIRONMENTAL IMPACTS

This is the most important part of the ERMP and the result should show the overall effect on the total ecosystem and social surrounding of the location during and after construction.

The objective is to take an overview of the elements of the systems involved and the external factors with which they interact and to present them as a synthesis or conceptual model which can be used to predict system behaviour under the stresses likely to be encountered. This should include as assessment of the resilience of the systems identified in Existing Environment to natural and man-induced pressure. Impacts should be quantified where possible. Criteria for making assessments of their significance should be outlined. Compliance with relevant standards should be demonstrated.

There may be advantage in discussing construction and operation impacts separately. These would be expected to be discussed in more detail in the Stage 2 ERMP.

It will be necessary to determine impacts on individual components of the environment before a final overall synthesis of potential impacts is made.

Use of experience from similar projects in comparable sites, landscapes or ecosystems should be made to illustrate or demonstrate changes or expectations outlined in this analysis.

The following potential environmental impacts should be included in the ERMP:

- resource utilisation in the catchment and reservoir;
- catchment management;
- restriction of movement of aquatic and terrestrial fauna;
- loss of particular, representative or significant habitats;
- establishment of new ecosystems;

- forest disease management;
- effect of altered flows on downstream flora and fauna;
- water quality and quantity within the proposed reservoir and downstream, and groundwater;
- land stability (with particular reference to areas disturbed during construction);
- landscape;
- local and regional significance of forest;
- any historical, archaeological and ethnographic sites;
- any System 6 areas;
- emissions (air, water, waste disposal, noise);
- land use including conservation and recreation aspects;
- access road systems and transport;
- effect on existing community and facilities;
- services (power, water, sewerage);
- effect on the Peel-Harvey estuary (if relevant);
- construction and operational workforce.

The final synthesis should include an assessment of the significance and timing of the various potential impacts identified.

8. ENVIRONMENTAL MANAGEMENT

In the Stage 1 ERMP, a management approach should be identified. A major part of the Stage 2 ERMP would relate to management of identified impacts.

An environmental management programme should be described on the basis of (and cross-referenced to) the synthesis of potential environmental impacts.

The purpose of the management programme is to demonstrate the manner in which potential environmental impacts can be ameliorated.

Authorities responsible for management should be clearly identified as should management administration, costs and funding including long-term financial contingency.

Elements of monitoring and the environmental management programme should include the impacts identified in Environmental Impacts.

Emphasis should be placed on the manner in which monitoring results will lead, where appropriate, to amendments to the management programme.

Environmental safeguards should be described.

Procedures for reporting the results of monitoring and management to appropriate authorities should be given.

It is important that specific commitments are given to all components and procedures of the management programme and that these are clearly listed in the ERMP.

9. CONCLUSION

An assessment of the environmental acceptability of the project in terms of its overall environmental impact and in the context of the proposed management programme should be given.

10. REFERENCES

A list of references should be included in the ERMP.

11. OTHER

If necessary, a glossary providing definitions of technical terms or abbreviations should be included.

A copy of these guidelines should appear in the ERMP.

Appendix 2

Mineral Resource Potential of the Four Reservoir Sites
(Letter from Geological Survey of Western Australia)

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

MINERAL HOUSE · 66 ADELAIDE TERRACE · PERTH · WESTERN AUSTRALIA · 6000

TELEPHONE (09) 222 3333
TELEGRAMS "WAMINES" PERTH
TELEX AA 95791 MINEWA
FACSIMILE (09) 325 1920

Please address all letters to : DIRECTOR

Manager
Water Resources Planning
Water Authority of W.A.
629 Newcastle Street
LEEDERVILLE WA 6007

Your Ref :
Our Ref : GS 195/86
Enquiries to: AJS:RM
Telephone:

Attention: Mr R Stone

MINERAL RESOURCE POTENTIAL OF AREAS
INVOLVED IN THE FOUR RESERVOIR IMPLEMENTATION SITES

As requested by your principal consultant, Mr I Pound, the mineral resource potential of the four sites under investigation has been assessed. An examination of data held by the Geological Survey of W.A. reveals that there would be minimal sterilization of significant mineral resources.

The following table summarizes the mineral resource potential within, and immediately adjacent to, the proposed dam sites and reservoirs.

PROBABILITY OF STERILIZATION OF SIGNIFICANT MINERAL RESOURCE

	MINERAL RESOURCES			
DAM/RESERVOIR	PRECIOUS	BASE	BAUXITE	INDUSTRIAL
Mundaring (Raised)	L	L-M	L	L
Canning (Raised)	L	L	L	L
South Canning (New)	L	L	M-H	L
North Dandalup (New)	L-M	L	L-M	L

KEY: L: Low M: Medium H: High

.../2

DEPARTMENT OF MINES WESTERN AUSTRALIA

Gold has been reported from workings adjacent to the Scarp. The old workings are down stream from the proposed North Dandalup damsite. An inspection of the area in 1913 cast doubt on the bona fides of the discovery. However, it is possible that gold could be found associated with small quartz veins or as alluvial concentrations in valley-fill material. Alluvial tin may occur, but not in sizable amounts. Alcoa of Australia Limited has applied for an exploration licence (E70/262) at North Dandalup and two licences at Canning (E70/257 and E70/258). It is suggested that you contact Alcoa to determine the extent of its exploration program.

Bauxite occurs in the mid-slopes of laterite ridges. Under established water and stream vegetation practices, no mining would be allowed by the W. Authority (and the Mining and Management Planning Liaison Group) within 100 metres of the full-water mark. It is estimated that some 0.5 million tonnes of bauxite would be sterilized or abandoned in the case of the North Dandalup proposal; and approximately 4 million tonnes would be similarly affected if the more extensive South Canning reservoir proposal went ahead. Mining of bauxite would not take place in either area until early or mid-21st century.

Hardrock for rock aggregate is the principal industrial mineral affected by the four proposals. There are ample supplies of this resource readily available in more accessible and less environmentally susceptible sites.

I trust that this information is sufficient for the preliminary phase of your assessment of the four reservoir sites.

P E Playford
DIRECTOR

GE801UDA063,13/14
2 February 1987

Appendix 3

Vegetation Complexes and Site-vegetation Types

Appendix 3

Vegetation complexes and site-vegetation types

The 'vegetation complex' is the basic mapping unit introduced by Heddle, Loneragan and Havel (1980) to map the vegetation of the Darling System at a scale of 1 : 250 000. While incorporating features of various pre-existing systems of vegetation classification and mapping, it is particularly similar to a CSIRO 'land system' in relating vegetation components to landform, soil and climatic components. The names and boundaries of most of the Darling System vegetation complexes are the same as the corresponding landform-soil complexes or combinations of them, except that a three-zone rainfall classification is superimposed (Department of Conservation and Environment 1980). Two examples are the two major valley vegetation complexes, of which one includes the largest proportions of vegetation that will be affected by the next major water supply project, Murray Complex in Medium to High Rainfall (Murray (M/H)) and Murray and Bindoon Complex in Low to Medium Rainfall (Murray-Bindoon (L/M)).

'Site-vegetation types' are segments of a continuum of Northern Jarrah Forest vegetation each of which is defined by the presence or absence of particular indicator species and underlying environmental conditions (Havel 1975a &, 1975b). The species that define the site-vegetation types are listed alphabetically in Table 3.2, which is taken from Department of Conservation and Environment (1980). Some of the names of plant species used in the table are no longer used for those species, due in most cases to recent taxonomic revisions. For example, *Casuarina fraserana* and *Casuarina humilis* are now species of *Allocasuarina*, and the *Borya* is not *Borya nitida*. There are also intermediate types and derivatives, such as CR, TR, GT, WG, RG, at North Dandalup.

Northern Jarrah Forest vegetation complexes bear a somewhat similar, though not definitive, relationship to site-vegetation types as site-vegetation types do to indicator species. This relationship is shown in Table 3.4, also taken from Department of Conservation and Environment (1980). The relationship of vegetation complexes to structural formations and their associations is shown in Table 3.3, from Heddle, Loneragan and Havel (1980).

A new, additional landform unit (Myara) is described by McArthur in the Havel Land Consultant (1987) report. It describes the very steeply profiled valley systems characteristic of minor streams which descent rapidly from the plateau to the coastal plain. A corresponding vegetation complex has not been described, chiefly because its component site-vegetation types are not sufficiently different from the ones in Murray (M/H) and Yarragil (Min. Swamp) complexes. They are, however, telescoped into a much shorter valley-segment. Furthermore, as the Myara unit was not mapped in the Atlas of Natural Resources, regional-scale comparison would be difficult.

TABLE 3.2: DEFINITION OF SITE-VEGETATION TYPES IN THE NORTHERN JARRAH FORREST OF THE DARLING PLATEAU (HAVEL 1975A AND B)

	SITE-VEGETATION TYPES																			
PLANT SPECIES	A	B	C	D	E	F	H	J	L	M	O	P	Q	R	S	T	U	W	Y	Z
Acacia alata	–	–	●	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Acacia extensa	–	–	–	–	–	–	–	–	–	–	○	–	–	–	–	–	–	○	–	–
Acacia browniana	–	–	–	–	–	–	○	–	–	–	–	●	–	–	●	–	–	–	–	○
Acacia urophylla	–	–	–	–	–	–	–	–	–	–	○	–	○	–	○	○	–	–	–	–
Adenanthos barbigerus	–	–	–	–	–	–	–	○	–	–	–	●	–	○	●	–	–	–	–	–
Adenanthos obovatus	○	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Agonis linearifolia	–	–	●	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Astartea fascicularis	●	–	●	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Baeckea camphorosmae	–	–	–	○	●	–	○	○	–	○	–	–	–	–	–	–	–	–	●	–
Banksia attenuata	–	–	–	–	–	–	–	○	–	–	–	–	–	–	–	–	–	–	–	–
Banksia grandis	–	–	–	–	–	–	–	–	–	–	●	●	–	–	○	○	–	–	–	–
Banksia littoralis	●	–	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Bossiaea aquifolium	–	–	–	–	–	–	–	–	–	–	○	–	○	–	○	○	–	–	–	–
Casuarina fraserana *	–	–	–	–	–	–	–	○	–	–	○	●	–	–	○	–	–	–	–	–
Casuarina humilis *	–	–	–	–	–	–	–	–	–	–	–	–	–	○	–	–	–	–	–	–
Caustis dioica	–	○	–	–	○	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Chorizema ilicifolium	–	–	–	–	–	–	–	–	–	–	–	–	○	–	–	○	○	–	–	–
Clematis pubescens	–	–	–	–	–	–	–	–	–	–	–	–	●	–	–	●	○	–	–	–
Conospermum stoechadis	–	●	–	–	–	–	–	●	–	–	–	–	–	–	–	–	–	–	–	–
Dampiera alata	–	–	○	●	●	–	–	–	–	○	–	–	–	–	–	–	–	○	●	–
Dasypogon bromeliaefolius	○	●	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Daviesia pectinata *	–	○	–	–	○	–	●	●	–	–	–	○	–	–	○	–	–	–	–	–
Diplolaena drummondii	–	–	–	–	–	–	–	–	●	–	–	–	–	–	–	–	–	–	–	–
Dillwynia cinerascens	–	–	–	–	○	–	–	–	–	○	–	–	○	–	–	–	–	–	–	–
Eucalyptus calophylla	○	●	–	●	○	–	–	○	–	○	●	○	●	●	○	●	●	●	–	○
Eucalyptus marginata	–	●	–	○	●	●	●	●	–	○	●	●	○	●	●	●	–	○	–	●
Eucalyptus megacarpa	–	–	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Eucalyptus patens	●	–	○	○	–	–	–	–	○	○	–	–	●	–	–	○	●	●	–	–
Eucalyptus wandoo	–	–	–	–	–	–	–	–	●	●	–	–	–	–	–	–	–	–	●	–
Gastrolobium calycinum	–	–	–	–	–	–	–	–	–	○	–	–	–	–	–	–	–	–	○	○
Grevillea diversifolia	–	–	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Grevillea wilsonii	–	–	–	–	○	–	–	●	–	–	–	●	–	–	–	–	–	–	–	–
Hakea cyclocarpa	–	–	–	–	–	–	○	○	–	–	–	–	–	–	○	–	–	–	–	–
Hakea ceratophylla	●	–	–	–	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Hakea lissocarpha	–	–	–	○	○	–	–	–	●	●	–	–	●	●	○	○	○	●	●	●
Hakea ruscifolia	–	–	–	–	○	–	○	●	–	–	–	○	–	–	–	–	–	–	–	–
Hakea varia	●	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Hibbertia lineata *	–	–	–	–	–	–	–	–	●	–	–	–	○	–	–	–	–	–	●	–
Hibbertia polystachya	–	●	–	–	–	○	–	●	–	–	–	–	–	–	–	–	–	–	○	–
Hovea chorizemifolia	–	–	–	–	–	–	–	–	–	–	○	●	○	–	●	●	–	–	–	–
Hypocalymma angustifolium	●	○	○	●	●	–	○	–	●	○	–	–	●	○	–	–	–	●	●	–
Isopogon dubius	–	–	–	–	–	–	○	○	–	–	–	–	–	–	–	–	–	–	–	–
Kennedia coccinea	–	–	–	–	–	–	–	–	–	–	○	–	○	–	–	○	–	–	–	–
Kingia australis	–	–	–	○	●	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lasiopetalum floribundum	–	–	–	–	–	–	○	–	–	–	–	○	–	–	●	●	–	–	–	○
Lepidosperma angustatum	○	●	●	●	●	–	●	○	–	–	●	●	○	○	○	–	–	●	○	○
Lepidosperma tetraquetrum	–	–	●	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Leptocarpus scariosus	●	●	●	●	●	○	–	○	–	–	–	–	–	–	–	–	–	○	○	–
Leptomeria cunninghamii	–	–	–	–	–	–	–	–	–	○	–	○	–	○	●	○	–	–	–	○
Leptospermum ellipticum *	●	–	–	●	○	–	–	–	–	–	–	–	–	–	–	–	–	○	–	–
Leucopogon capitellatus *	–	–	–	–	–	–	–	–	–	–	–	–	○	●	●	○	–	–	–	●
Leucopogon oxycedrus	–	–	–	–	–	–	–	–	–	–	–	○	–	–	–	–	–	–	–	–
Leucopogon cordatus	–	●	–	–	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Leucopogon propinquus	–	–	–	–	–	–	–	–	–	–	○	–	○	●	○	○	–	–	–	●
Leucopogon verticillatus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	●	–	–	–	–
Lyginia tenax	–	●	–	–	–	–	–	●	–	–	–	–	–	–	–	–	–	–	–	–
Macrozamia riedlei	–	–	–	–	–	–	–	–	○	●	–	–	●	●	●	●	●	–	–	●
Melaleuca preissiana	●	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mesomelaena tetragona	●	●	●	●	●	○	●	●	–	–	–	–	–	–	–	–	–	●	○	–
Nuytsia floribunda	–	–	–	–	–	○	–	○	–	–	–	–	–	–	–	–	–	–	–	–
Patersonia occidentalis	–	●	–	–	○	○	–	–	–	–	–	–	–	–	–	–	–	–	○	–
Patersonia rudis	–	–	–	–	○	–	●	○	–	○	–	●	–	○	○	–	–	–	–	●
Persoonia longifolia	–	–	–	–	–	–	–	–	–	–	–	●	–	–	○	–	–	–	–	–
Phyllanthus calycinus	–	–	–	–	–	–	–	–	–	○	–	–	●	●	●	○	–	–	–	○
Pteridium esculentum	–	–	–	–	–	–	–	–	–	–	–	–	○	–	–	●	●	–	–	–
Sphaerolobium medium	–	○	–	–	○	–	○	○	–	–	–	–	–	–	–	–	–	–	–	–
Stirlingia latifolia	–	–	–	–	–	●	○	○	–	–	–	–	–	–	–	–	–	–	–	–
Styphelia tenuiflora	–	–	–	–	–	–	●	○	–	–	–	●	–	○	○	–	–	–	–	●
Synaphea petiolaris	○	○	–	○	●	–	○	–	–	–	–	–	–	–	–	–	–	●	–	–
Trymalium ledifolium	–	–	–	–	–	–	○	–	–	–	–	○	–	●	–	–	–	–	–	○
Trymalium spathulatum	–	–	–	–	–	–	–	–	–	–	–	–	●	–	–	–	–	–	–	–

● Species should be present
○ Species should be present, but absence not critical
– Species generally absent.

TYPE G was defined subsequently. It has a variable and unique set of indicator species which are characteristic of granite outcrops and their surroundings in low to medium rainfall zone, such as lichens, *Borya nitida*, *Grevillea bipinnatifida*, *Hakea elliptica*, *Hakea undulata*, *Eucalyptus laeliae*, *E. wandoo* and *Casuarina huegeliana*.

Table reproduced from *Atlas of Natural Resources, Darling System, Western Australia*, Department of Conservation and Land Management, Perth, 1980.

*Species now known by a different name.

TABLE 3.3: SUMMARY OF VEGETATION COMPLEXES OF THE DARLING PLATEAU IN RELATION TO THE STRUCTURAL FORMATIONS

		STRUCTURAL FORMATIONS																						
		TALL OPEN-FOREST		OPEN-FOREST		WOODLAND					OPEN-WOODLAND	LOW OPEN-FOREST					LOW OPEN-WOODLAND			OPEN-SCRUB	HEATH		HERBLANDS	SEDGELANDS
Mapping Unit No.	Vegetation Complexes	*E. diversicolor*	*E. marginata-E. calophylla*	*E. marginata-E. calophylla*	*E. marginata-E. calophylla-E. patens*	*E. wandoo-E. calophylla*	*E. wandoo*	*E. wandoo-E. accedens*	*E. loxophleba*	*E. rudis-M. rhaphiophylla*	*E. wandoo*	*C. huegeliana*	*M. preissiana*	*C. obesa*	*Agonis flexuosa*	*E. rudis-M. rhaphiophylla*	*E. wandoo-E. calophylla*	*B. attenuata-B. menziesii*	*M. preissiana-B. littoralis*	*C. obesa-Acacia* spp.*-Melaleuca* spp.	Closed	Open		
1	Dwellingup-Hester	–	●	●	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	Dwellingup	–	○	●	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3	Dwellingup-Yalanbee	–	–	●	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4	Dwellingup-Yalanbee-Hester	–	–	●	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5	Yalanbee-Dwellingup	–	–	●	–	●	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6	Yalanbee	–	–	○	–	○	–	●	–	–	–	○	–	–	–	–	–	–	–	–	–	–	–	–
7	Cooke **	–	–	○	–	○	–	–	–	–	–	○	–	–	–	–	–	–	–	–	●	●	●	–
8	Goonaping	–	–	○	–	–	–	–	–	–	–	–	○	–	–	–	–	●	○	–	–	–	–	–
9	Wilga	–	–	●	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
10	Yarragil (Min. Swamps)	–	○	●[a]	●[a]	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
11	Yarragil (Max Swamps)	–	○	●	○	–	–	–	–	–	–	–	–	–	–	–	–	–	○	–	–	–	–	–
12	Swamp	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	●	–	–	–	–	○
13	Pindalup-Yarragil	–	–	●	–	○·	–	–	–	–	●	–	–	–	–	–	–	–	–	–	–	–	–	–
14	Coolakin	–	–	–	–	○·	●	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
15	Catterick	–	○	●	●	–	–	–	–	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–
16a	Yarragil-Catterick	●	●	●	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
16b	Balingup	●	●	●	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
17	Helena **	–	–	○	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○	○	○	–
18	Helena **	–	–	○	○	–	–	–	–	–	●	–	–	–	–	–	–	–	–	–	○	○	○	–
19	Bridgetown **	–	○	●	○	–	–	–	–	–	–	–	–	–	–	○	–	–	–	–	○	○	○	–
20	Murray	–	○	●	●	–	–	–	–	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–
21	Murray-Bindoon	–	–	●	○	–	●	–	–	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–
22	Balingup	–	○	●	○	–	–	–	–	○	–	–	–	–	–	–	–	–	–	–	–	–	–	–
23	Williams-Avon-Brockman-Mumballup	–	–	–	–	–	–	–	–	●	–	–	–	–	–	–	–	–	–	–	–	–	–	–
24	Nooning	–	–	–	–	–	–	–	–	○	–	–	–	●	–	–	–	–	–	○	–	–	–	–
25	Lowdon	–	–	●	–	–	–	–	–	●	–	–	–	–	○	–	–	–	–	–	–	–	–	–
26	Bindoon	–	–	–	–	–	○	–	●	–	–	○	–	–	–	–	–	–	–	–	–	–	–	–
27	Michibin	–	–	–	–	–	●	–	○	–	–	○	–	–	–	–	–	–	–	–	–	–	–	–
28	Darling Scarp * **	–	–	–	–	–	–	–	–	–	–	○	–	–	–	–	●	–	–	–	○	○	○	–

[a] Local admixtures of *E. megacarpa*
** Lithic complex associated with granitic rocks
· Local admixtures of *E. patens*
* Local admixtures of *E. laeliae* and *E. haematoxylon*
● Structural Formation should be present
○ Structural Formation should be present, but absence not critical
– Structural Formation generally absent.

Table reproduced from *Atlas of Natural Resources, Darling System, Western Australia*, Department of Conservation and Land Management, Perth, 1980.

TABLE 3.4: SUMMARY OF VEGETATION COMPLEXES OF THE DARLING PLATEAU IN RELATION TO THE SITE-VEGETATION TYPES AS DEFINED BY HAVEL (1975A AND B)

		SITE-VEGETATION TYPES (*)																				
Mapping Unit No.	Vegetation Complexes	A	B	C	D	E	F	G	H	J	L	M	O	P	Q	R	S	T	U	W	Y	Z
1	Dwellingup-Hester	–	–	–	–	–	–	–	–	–	–	–	○	○	–	○	●	●	–	–	–	–
2	Dwellingup	–	–	–	–	–	–	–	○	–	–	–	○	●	–	○	●	–	–	–	–	○
3	Dwellingup-Yalanbee	–	–	–	–	–	–	○	●	–	–	–	–	●	–	○	–	–	–	–	–	●
4	Dwellingup-Yalanbee-Hester	–	–	–	–	–	–	–	●	–	–	–	–	○	–	–	–	–	–	–	–	●
5	Yalanbee-Dwellingup	–	–	–	–	–	–	○	●	–	–	●	–	–	–	–	–	–	–	–	–	●
6	Yalanbee	–	–	–	–	–	–	○	○	–	–	●	–	–	–	–	–	–	–	–	–	○
7	Cooke	–	–	–	–	–	–	●	–	–	–	○	–	○	–	●	○	–	–	–	–	○
8	Goonaping	○	○	–	–	–	●	–	–	●	–	–	–	–	–	–	–	–	–	–	–	–
9	Wilga	–	–	–	–	○	–	–	●	–	–	–	–	–	–	●	–	–	–	●	–	–
10	Yarragil (Min. Swamps)	–	–	●	●	–	–	–	–	–	–	–	–	–	○	–	–	○	○	●	–	–
11	Yarragil (Max. Swamps)	○	○	–	●	●	○	–	–	○	–	–	–	○	–	–	–	–	–	●	–	–
12	Swamp	●	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
13	Pindalup-Yarragil	○	–	–	–	○	–	–	●	–	○	●	–	–	–	–	–	–	–	–	●	○
14	Coolakin	–	–	–	–	–	–	○	○	–	○	●	–	–	–	–	–	–	–	–	●	○
15	Catterick	–	–	●	●	–	–	–	–	–	–	–	–	–	●	–	–	–	–	●	–	–
17	Helena	–	–	○	–	–	–	●	–	–	–	–	–	–	○	●	–	○	–	–	–	–
18	Helena	–	–	○	–	–	–	●	–	–	–	–	–	–	○	●	–	–	–	–	○	–
19	Bridgetown	–	–	●	–	–	–	○	–	–	–	–	–	–	●	○	–	●	○	–	–	–
20	Murray	–	–	●	○	–	–	–	–	–	–	–	○	–	●	○	–	●	●	○	–	–
21	Murray-Bindoon	○	–	○	–	–	–	●	○	–	○	○	–	–	○	●	–	–	–	○	●	–
22	Balingup	–	–	●	●	–	–	–	–	–	–	–	–	–	–	–	○	○	–	●	–	–
28	Darling Scarp	–	–	–	–	–	–	●	–	–	–	–	–	–	–	●	–	–	–	–	–	–

● Site-vegetation type should be present
○ Site-vegetation type should be present, but absence not critical
– Site-vegetation type generally absent
* Site-vegetation types as defined by Havel (1975a and b)

Table reproduced from *Atlas of Natural Resources, Darling System, Western Australia*, Department of Conservation and Land Management, Perth, 1980.

Appendix 4

Rare and Restricted Flora and Fauna

Appendix 4

Rare and restricted flora and fauna

This appendix presents a discussion of rare and restricted species, peripheral information not covered in the main ERMP and a table of rare and restricted plant species looked for during the botanical surveys of the four major water supply alternatives.

The completeness and accuracy of most lists of rare and restricted flora and fauna are limited by the fact that the intensity, uniformity and seasonal coverage of collecting and systematic surveying have been insufficient to distinguish between genuinely rare (and restricted) species and species which only appear to be rare (or restricted) because, for various reasons, they have been poorly collected. In some cases, rare species occur in areas where they were not previously known to occur. In others, rare species once known to occur in an area are no longer there. Furthermore, most lists are incomplete in that they do not contain undescribed species, some of which are also rare. Other sources of ambiguity are insufficient locality information given with specimens, inaccurate identification of specimens and treatment of groups of species as single species. So little is known about the abundance, distribution and taxonomy of invertebrate animals and nonvascular plants that few, if any, species in these groups are included in lists of rare biota, although many of them may also be rare or geographically restricted.

Lists of particular flora and fauna which are gazetted as rare or otherwise in need of special protection and are protected by law are printed in the Western Australian Government Gazette from time-to-time, when species are either added to a list or deleted from it, or both. The most recent such list of fauna was printed in the gazette in November 1985. The list of rare flora printed in the Gazette in March 1982, was used as a basis for the Havel Land Consultants (1987) investigation, and the September 1987 revised list was used for this report.

Flora

Table 1 lists the 66 rare and geographically restricted species which J. Havel, E. Mattiske, B. Koch and C. Keating expected could be in the region of the four alternatives (Havel Land Consultants, 1987). The Table 1 list of species replaced a longer, preliminary list which was compiled from six reports produced between 1981 and 1985. The revision of the preliminary list to Table 1 was the result of more recent information about the listed species being acquired during checks of Western Australian Herbarium collections and of information from consultations with herbarium staff, S. Hopper and other Department of Conservation and Land Management staff. The new information relates to species name changes, reclassifications, more accurate identifications, extended geographical ranges, abundances greater than previously indicated, and restriction to habitats which do not occur in the four alternative catchments. Two of the species listed by Liehne & Company (1984) and an internal, unpublished 1984 Water Authority report, *Pultenaea skinneri* and *Hibbertia silvestris*, were deleted for some of these reasons. Table 2 lists another ten plant species which were deleted from the preliminary list because the new information indicates that they are neither restricted geographically nor poorly collected.

Five geographically restricted or rare species had their known geographical ranges extended by the Havel Land Consultants November-December 1986 botanical survey: *Conostylis setosa, Gastrolobium epacridoides, Hibbertia pilosa, Lasiopetalum bracteatum* and *Microcorys longifolia*.

Fauna

The same internal, unpublished 1984 Water Authority report lists four species of gazetted rare fauna as having geographical ranges which might include the North Dandalup alternative's catchment: the Shrike-tit (*Falcunculus frontatus*), the Red-eared Firetail (*Emblema oculatum*), the Woylie (*Bettongia penicillata*) and the Numbat (*Myrmecobius fasciatus*). Although both Woylies and Numbats have been recorded in drier parts of the jarrah forest, neither is likely to occur in the high rainfall, North Dandalup catchment. Red-eared Firetails were observed at North Dandalup and the other alternative sources by the Dunlop and Ninox survey in 1986.

Table 1: Rare and Restricted Plant Species

	Species	Geographical Range	Geographical range <100km	Geographical range 100-160km	Conservation status	Representation in catchments M	C	SC	ND
	Acacia anomala	Chittering Valley - Bickley			G-				
	Acacia aphylla	Helena Valley - Spencers Brook			G-				
+	*Acacia barbinervis*	Bullsbrook - Coolup		120	C	-	1	6	1
	Acacia horridula	Helena Valley - Serpentine	60		-				
	Acacia subflexuosa	Jarrahdale - W of Cuballing		105	-				
	Anthocercis gracilis	Mundaring	x		-				
+	*Aotus cordifolia*	Gidgegannup - Dwellingup		105	-	-	1	-	-
	Astroloma foliosum	Carmel	x		-				
	Baumea arthrophylla	Chidlow - Bayswater	45		-				
	Beaufortia purpurea	Kalamunda - Toodyay	30		C				
+	*Billardiera drummondiana* var. *collina*	Kalamunda - Mundaring	10		C	2	-	-	-
	Billardiera parviflora var. *guttata*	Serpentine	x		C				
+	*Boronia crenulata* var. *gracilis*	Mundaring - Banksiadale	85		C	-	-	-	2
	Boronia tenuis	Helena Valley - Oakley Dam above Pinjarra	20		(G)-				
+	*Calothamnus rupestris*	Red Hill - Boyagin Rock		105	C	-	9	-	-
	Centrolepis inconspicua	Armadale - SE of Pingelly		140	C				
+	*Conospermum heugelii*	Mogumber - Serpentine Falls		155	-	2	-	-	-
+	*Conostylis setosa*	Bindoon - Jarrahdale		105	C	3	-	20	21
	Craspedia pleiocephala	Wooroloo - Guildford	35		-				
	Darwinia pimelioides	Red Hill	10		C				
	Diplolaena andrewsii	Helena Valley	x		C				
	Drakaea elastica	Lesmurdie - Mahogany Creek	20		-				
+	*Dryandra praemorsa*	Clackline - Dwellingup		120	-	3	1	5	1
+	*Eucalyptus laeliae*	Helena Valley - Harvey		135	-	-	1	-	10
	Gastrolobium acutum	Helena Valley - Armadale	30		-				
+	*Gastrolobium epacridoides*	Moore River - Helena Valley		105	-	1	-	-	-
	Gastrolobium tricuspidatum	Boddington - Cannington		145	C				
+	*Grevillea drummondii* var. *pimelioides*	Bolgart - Shannon River		>160	(G)-	13	-	-	-
	Hakea crassinervia	Bickley - York	65		-				
	Hakea cristata	Helena Valley - Wooroloo	30		-				
	Hakea myrtoides	Helena Valley	5		-				
	Halgania corymbosa	Gidgegannup - Gosnells	35		-				
	Haloragis tenuifolia	Midland - Wooroloo	35		-				
	Hibbertia lasiopus	New Norcia - Kalamunda		115	-				
+	*Hibbertia nymphaea*	Helena River - Serpentine River	50		-	-	-	8	-
+	*Hibbertia pilosa*	Dwellingup; Margaret River		155	-	17	3	54	13
	Jacksonia gracilis	Perth - E of Mandurah	70		-				

Table 1: Rare and Restricted Plant Species (continued)

	Species	Geographical Range	Geographical range <100km	100-160km	Conserv -ation status	Representation in catchments M	C	SC	ND
+	*Lasiopetalum bracteatum*	Helena Valley	10		(G)-	-	4	-	-
	Lasiopetalum cardiophyllum	Boddington	40		-				
+	*Lasiopetalum glabratum*	Mt Cooke - York	80		-	-	-	11	-
	Lasiopetalum membranaceum	Dwellingup - Capel		115	C				
	Lepyrodia heleocharoides	Helena Valley	x		-				
+	*Lepyrodia* sp. *A.*	W of Beverley - Harvey area		120	-	-	1	-	-
	Lhotskya acutifolia	Helena Valley - Popanyinning		125	-				
	Lomandra spartea	Armadale	x		C				
+	*Microcorys longifolia*	Mogumber - Helena Valley		105	-	1	-	-	-
	Parsonsia diaphanophleba	Coolup	x		-				
	Patersonia babianoides	Carmel	x		-				
+	*Petrophile biloba*	Red Hill - Gosnells	30		-	1	-	-	-
	Pithocarpa achilleoides	E of Wannamal - Wooroloo	75		-				
	Restio stenostachyus	Gingin - Canning River	80		-				
	Senecio gilbertii	Bindoon - York	90		-				
+	*Senecio leucoglossus*	Perth - Harvey		130	-	-	-	-	4
	Stylidium rigidifolium	Helena Valley - Lesmurdie	10		-				
	Synaphea acutiloba	Helena Valley - Cannington	25		-				
	Synaphea pinnata	Millendon - Gosnells	35		(G)C				
	Templetonia drummondii	Bindoon - Kalamunda	60		-				
+	*Tetratheca nuda*	Wooroloo - Canning River	45		C	1	-	3	-
	Tetratheca pilifera	Helena Valley - York	70		C				
	Tetratheca similis	E of Binoon - W of Brookton		105	-				
	Thomasia glutinosa	Clackline - Gosnells	70		C				
	Thysanotus fastigiatus	Kalamunda	x		C				
	Trymalium angustifolium	Muchea - Helena Valley	45		-				
	Verticordia fimbrilepis	E of Canning River	x	-	(G)				
	Wahlenbergia stricta	Mt Cooke area	x		-				
	Xanthosia sp. (aff. *fruticulosa*)	Chittering - Serpentine		105	C				

KEY

Geographical range

The named places indicate the approximate end points of the longest distance across the species' known range.The figures in the next two columns give this distancein kilometres.

\+ species recorded during this study.

x known only from one locality.

Conservation status

G gazetted as rare. (Note: a revised list was gazetted in September 1987.)

(G) deleted from list of gazetted species, September 1987.

C species occurs on a conservation reserve.

\- species does not occur on a conservation reserve.

Representation within catchments

'4' number of site occurrences

\- not recorded.

Table 2: Summary of Species Deleted from Rare and Restricted List

Species	Comments
Adenanthos cygnorum ssp. *chamaephyton* (syn *A. teges*)	Not poorly collected
Boronia defoliata	Not restricted
Comesperma virgatum	Not restricted
Danthonia pilosa	Not poorly collected
Dodonaea ericoides (syn. *D. cryptandroides*)	Not restricted because of reclassification
Hibbertia rhadinopoda	Not restricted
Lomandra hermaphrodita	Not restricted
Pericalymma ellipticum (syn. *Leptospermum ellipticum*)	Not restricted because of reclassification
Pimelea sylvestris (syn. *P. graciliflora*)	Not restricted because of reclassification
Wahlenbergia multicaulis (syn. *W. simplicicaulis*)	Not poorly collected because of reclassification

Appendix 5

Impact of North Dandalup Dam on the Peel Inlet.

(Advice from Investigations Division, Environmental Protection Authority)

ENVIRONMENTAL PROTECTION AUTHORITY
1 MOUNT STREET, PERTH, WESTERN AUSTRALIA 6000
Telephone (09) 222 7000

Manager
Water Resources Planning
Water Authority of Western Australia

Your Ref:
Our Ref: 23/82 011378
Enquiries:

ATTENTION: MR ROY STONE

PEEL INLET AND ADDITIONAL WATER SUPPLY DEVELOPMENT OF THE NORTH DANDALUP RIVER SYSTEM - TECHNICAL ASSESSMENT

In response to your request for a technical assessment of the likely effects of impoundment and diversion of North Dandalup River flows from Peel Inlet, the following comments can be made. Please note that our earlier response of 19 June 1987 contained some computational errors, and that this letter supercedes it.

(i) The reduction in North Dandalup system flows to the eastern part of Peel Inlet is unlikely to have an detectable effect on the algal problem in the estuary, either positive or negative. This is because the load of phosphorus to the estuary will not change detectably, therefore the amount of algae produced will not change, and the slight increase in phosphorus concentration of waters entering the estuary will not increase algal growth rates, because algal growth is not limited by phosphorus concentration in winter.

(ii) The estimated current contribution of river inflows to the flushing of Peel Inlet is about 61%, or about 7.1 estuary volumes/year of a total of about 10.3 volumes/year.

The estimated increase in total flushing of Peel Inlet from the dredging of the Mandurah Channel is about 24%, which would increase the annual volumetric exchange with the ocean to about 13 volumes/year. (See Mandurah Channel Dredging PER pp 7-8)

The reduction in total flushing from the full development of the Dandalup system would therefore be 21 x 10^6 m^3/yr divided by 986 x 10^6 m^3/yr, or about 2.1%. This effect would not be measurable in an average year. In dry years, the reduction in river flushing would be slightly greater, but still not significant. The reduction of river-induced flushing would be about 21/546 x 10^6 m^3/yr, or about 3.9%.

(iii) Biological effect of these small reductions in flushing on organisms other than algae are less clear, but, as Professor Potter has stated, deleterious impacts on important components of the fishery are likely to be minor, or non-existant.

As this letter is a technical assessment, we have no objection to the letter being published for the purpose of indicating advice.

C C Sanders
DIRECTOR
INVESTIGATIONS DIVISION

15 October 1987

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