Water Authority
of Western Australia

WATER RESOURCES DIRECTORATE
Water Resources Planning Branch

Denmark Water Supply Salinity Improvement

Quickup Dam Proposal

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DENMARK WATER SUPPLY SALINITY IMPROVEMENT

QUICKUP DAM PROPOSAL

1. SUMMARY

The Denmark town water supply was commissioned in 1960/61, with supply from a concrete weir on the Denmark River about 5 kilometres north of the town. Since that time, agricultural development on the catchment area in the 1950s and 1960s has caused a significant rise in the salinity of the Denmark River. The salinity of water in the Denmark River is now unacceptably high, particularly in years of below average rainfall. Legislative controls limiting further clearing on the catchment area were implemented in 1979 to protect the water resource from further deterioration in water quality. However, because of the delay between clearing and the development of the full hydrological effects, stream salinities will continue to increase until early next century.

Studies have shown that the development of a major regional water supply scheme, supplying Denmark in conjunction with Albany is not a viable solution to the Denmark town water supply salinity problem. The demand at Albany can be supplied more economically by the development of local resources until well into the next century. A local scheme will therefore be required to be developed to improve the quality of water supplied to Denmark. As an interim measure, a scheme has been in operation since July 1985 to utilise stream flows in Scotsdale Brook. There are abundant flows in Scotsdale Brook to ensure a satisfactory supply during winter but the stream ceases to flow for a period during most summers, when Denmark River water must be supplied to the town.

To ensure a reliable good quality supply to Denmark, a range of options has been investigated. This report outlines the various proposals and shows that for the most probable future growth rates of around 3% per annum, development of the Quickup River is the preferred option. The Quickup River proposal is the least cost (expressed in terms of present value) option and provides the greatest consumer benefit from reduced salinities. Further, the Quickup River proposal is preferred ahead of the next cheapest option (the Scotsdale off-stream storage proposal) because the catchment area is almost fully forested, whereas the Scotsdale Brook catchment area is almost completely alienated and developed for farming. Other water quality factors (pesticides, herbicides, nutrients) and catchment management considerations strongly favour the Quickup River proposal.

2. WATER QUALITY CRITERIA

Water quality standards are set primarily to achieve satisfactory health, taste and aesthetic levels. In 1980 the Australian Department of Health (through the NH & MRC and AWRC) set out two criteria for water quality. These are the "desirable current criteria", which are the maximum levels appropriate to present Australian conditions to give drinking water of satisfactory quality and the "long-term objective", as a more stringent level which could be aspired to, and which, if achieved, result in drinking water of excellent quality. For total solids (salinity) these levels are 1500 mg/L and 500 mg/L respectively.

The more critical water quality parameter in most Western Australian waters, however, is chloride. The Australian Department of Health's desirable current criteria and long-term objectives for chloride are 600 mg/L and 200 mg/L respectively. Based on the proportion of chloride to total salinity occurring in the Denmark River, these chloride levels correspond to total salinities of about 1200 mg/L and 400 mg/L.

The 1980 criteria are presently under review. The draft of the new Guidelines for Drinking Water Quality recognises that the provision of good quality water is dependent on the availability of suitable supplies as well as the cost of developing the supply and the public desire for improved quality water. With respect to total dissolved solids (salinity), the draft of the new guidelines suggests that levels up to 1000 mg/L are generally acceptable on the basis of taste considerations.

With respect to chloride, the draft of the new Guidelines for Drinking Water Quality indicates that a guideline value of up to 400 mg/L is considered appropriate. This level corresponds with a salinity of 800 mg/L in the Denmark River.

3. PROJECT NEED

Clearing for agricultural development in the Denmark River catchment area in the 1950s and 1960s has caused a significant rise in the salinity of the Denmark River. To provide some relief from these high salinities being supplied to the town, the original supply from the Denmark River was augmented in July 1985 from the Scotsdale Brook which, although extensively cleared, is in a high rainfall zone and supplies low salinity water. However, the Scotsdale Brook ceases to flow during summer and then higher salinity Denmark River water must be supplied to the town.

The maximum salinities of water supplied to Denmark in recent years is shown in Table 1. This sequence of high salinities is due in part to the successive years of below average rainfall. Nevertheless, because of the delay between clearing and the full development of hydrological effects, stream salinities are expected to continue to increase until early next century. At that time, it is estimated that the salinity of water in the Denmark River Dam during summer will exceed 950 mg/L 50% of the time and will exceed 1500 mg/L for 10% of the time. At the same time, further agricultural development on the Scotsdale catchment area will cause increased competition and reduced availability of water, particularly in late spring, summer and early winter. This reduced availability of water from Scotsdale Brook will be more pronounced in years of low rainfall, when higher salinities prevail in the Denmark River.

By any water quality criteria guidelines, the supply of water from the Denmark River Dam during summer is undesirable. There has been strong public agitation by the local community to have the situation improved and the Water Authority has undertaken to commission a scheme to ensure the supply of good quality water by the summer of 1988/89.

TABLE 1

Year (End June 30)	Maximum Salinity (mg/L)	Annual Rainfall For Previous Calendar Year (mm)	Remarks
1978	680	1036	
1979	776	1121	
1980	885	1049	
1981	945	917	
1982	1014	1089	
1983	1434	909	
1984	1111	796	
1985	824	1033	
1986	989	877	Scotsdale Brook augmentation commenced July 1985. No flow Jan 22-Feb 7.
1987	1280	825	Scotsdale Brook no flow Jan 17-Mar 17.
1988[1]	1600	820	Scotsdale Brook no flow at least 2 months.

Notes: 1. Salinity, rainfall and Scotsdale no flow period for year ending June 30, 1988 are estimates based on currently available data.

2. Mean annual rainfall 1113 mm (Denmark P.O.)

4. DEMAND

The history of service connections and consumption at Denmark is shown on Figure 1. Since 1970, the growth in the number of services at Denmark has averaged 3.3% per annum. Despite continuing growth in the number of services, consumption in recent years has stabilised at about 230 000 m^3 per annum. This levelling off in the growth of demand is considered to be at least partly due to the community perception of the water quality problems that have evolved since 1980.

In the future, growth in the number of services at Denmark is anticipated to be at least 2% per annum, and more probably about 3% per annum. The demand for water is expected to grow at least at these rates when good quality water is supplied.

5. DEVELOPMENT PROPOSALS

To allow a comparison of some of the alternative development proposals, it is necessary to fix target salinity levels which will be acceptable to the community. These levels are selected as a median salinity of 500 mg/L and an upper value of 750 mg/L which is not exceeded for more than 10% of the time. The following sections describe the alternative proposals for improving the salinity of water supplied to Denmark.

5.1 Clearing controls and reforestation

In 1979 the Country Areas Water Supply Act was amended to prohibit unlicensed clearing within the Denmark River Catchment Area. With clearing restrictions as the only control measure, the salinity of streamflows in the Denmark River are predicted to rise by approximately 20% over current salinities when the full effects of clearing develop early next century. At that time, the 10%, 50% and 90% exceedance probabilities of the monthly stream salinities are estimated to be 1430, 900 and 460 mg/L.

The capacity of the Denmark River Dam (420 000 m^3) is small in comparison with the streamflow (average annual flow approximately 45 000 000 m^3). Except in years of high stream flow during spring, water supplied from the Denmark River Dam during summer will be high salinity late season flows. The frequency of supply of high salinity water from the existing dam will therefore exceed the monthly stream salinities quoted above. This situation has not been analysed in detail, but the 10%, 50% and 90% exceedance probabilities of the monthly salinities of supply from the existing Denmark River Dam are conservatively estimated to be 1500, 950 and 500 mg/L.

A reforestation programme has not yet commenced on the Denmark River catchment area, but investigations are in hand to assess the feasibility of the development of agroforestry to reverse the rising salinity trends. Even assuming the most optimistic outlook for these investigations, it will be at least 20 years before water of suitable quality can be supplied from the existing Denmark River Dam.

Clearing controls and reforestation measures will not therefore be effective in improving the quality of water supplied to Denmark in the short term. They are, however, very important initiatives in the rehabilitation of the Denmark River catchment to preserve this valuable water resource for use in the future.

5.2 Denmark Dam reservoir management

In some cases, scouring from a stratified reservoir can be used to improve the salinity of water supplied from the reservoir. Implementation of this strategy on the Denmark River Dam would require the construction of an enlarged scour, with provision of an inlet to scour water from the lowest point in the reservoir. Construction of this enlarged scour is estimated to cost $50 000.

The benefits of installing a larger scour lie principally in reducing salinities during the winter months when salinity stratification exists in the reservoir and saline inflows exceed the present scour capacity. This benefit is only marginal because ample flows are available in the Scotsdale Brook to ensure the supply of good quality water to Denmark at these times.

Summer salinities would only occasionally be improved by the construction of a larger scour. This would occur when the scour is successful in controlling late spring and early summer inflows. The effectiveness of this operation cannot be assured.

5.3. Scotsdale off-stream storage

The existing scheme supplying low salinity water from Scotsdale Brook for mixing with water from the Denmark River Dam, was commissioned at low cost in July 1985. Although ample water is available from the Scotsdale Brook to supply the total demand over the winter months, mixing with water from the Denmark River is practised to achieve a target salinity of 500 mg/L. This procedure keeps the Scotsdale Brook pumping costs down and also minimises the range of salinity supplied to Denmark, in anticipation of limiting consumer complaints when the full supply must be drawn from the Denmark Dam when the Scotsdale Brook ceases to flow during summer.

To overcome this deficiency a storage is required to store excess winter flow from the Scotsdale, for use during summer. A dam on Scotsdale Brook is not feasible because the entire watercourse runs through alienated land developed for agriculture. An off-stream storage of 80 000 m^3 storage capacity, filled by pumping from Scotsdale Brook has therefore been considered.

The preferred site for the off-stream storage is within State Forest, adjacent to the Scotsdale pumpback pipeline as shown on Figure 2. Several alternative sites, on flatter ground were also investigated, but development of these sites is not feasible because of a high water-table.

There is no reliable long-term stream flow data for Scotsdale Brook. Over the summer of 1986/87, the Scotsdale Brook stopped flowing for two months, from January 17 to March 17. The Denmark rainfall records suggest that a similar period of two months of no flow could have happened 11 times in the 87 complete years of summer record since 1897 (six of these events occurred since 1972/73). On two of these eleven occasions, the no flow period could have been three months. Allowing for further agricultural development on the catchment area of Scotsdale Brook, it is apparent that 2 month periods of no flow will be quite frequent, with 3 month periods of no flow occurring occasionally. For the extended period of no flow, the 80 000 m^3 storage would have a reduced life for meeting the target salinities.

Project estimates have been prepared for 2 monthly, or alternatively 3 monthly, periods when Denmark must be supplied by mixing water from Denmark Dam with Scotsdale water from an 80 000 m^3 off-stream storage. The estimates allow for further upgrading of the headworks supplying Denmark until well into the next century, when some improvement in the Denmark River salinity through reforestation and agroforestry initiatives should be achieved. The present value of the capital expenditure of these proposals, calculated for alternative demand growth rates of 2% and 3% per annum and using a discount rate of 6% per annum, are summarised in Table 2.

TABLE 2

SCOTSDALE OFF-STREAM STORAGE

PERIOD OF SUPPLY FROM OFF-STREAM STORAGE	ESTIMATED COSTS ($ x 1000)			
	INITIAL CAPITAL	FUTURE CAPITAL (1)	PRESENT VALUE (AT 6% P.A. DISCOUNT RATE)	
			2% p.a.Growth	3% p.a.Growth
2 months	590	1 130	894	1 000
3 months	590	1 070	1 105	1 195

Notes: 1. Timing of future capital expenditure is dependent on the rate of growth of demand.

From Table 2, it is apparent that the comparative cost (i.e. present value) of the off-stream storage proposal is relatively sensitive to future demand growth rates and also to the period of no flow (or low flow) in Scotsdale Brook, when the demand is supplied by mixing water from Denmark Dam with water held in the off-stream storage.

5.4 New surface sources

There are two rivers in relatively close proximity to Denmark which could be used to augment the supply. These are the Mitchell and Quickup Rivers.

5.4.1 Quickup River

The Quickup River is located about 3 kilometres east of the Denmark River and discharges into the Denmark River about 2 kilometres downstream of the existing Denmark Dam (Figure 2). Earlier considerations for developing this resource (December 1986) were based on the construction of a dam on private property in the vicinity of the existing gauging station on location 2029. At this site, it is apparent that there could be problems with saline run-off from cleared catchment, particularly in years of low rainfall.

Further investigations (Appendix 4) have now shown that it is feasible to develop the Quickup River at a site further upstream, where the catchment area is almost completely forested (Site 3.5). Due to the reduced catchment area at this site, a slightly larger storage is required to provide carryover to secure the quantity and quality of water in years of low rainfall. The natural streamflow salinities expected at Site 3.5 and is summarised in the following table:

YEAR WITH PROBABILITY OF NON-EXCEEDANCE	SALINITY (mg/L) AT SITE 3.5
5%	948
10%	665
50%	345
90%	217

The estimated cost of developing the Quickup River, at this site, to supply Denmark is $920 000. The present value of the initial development and subsequent upgrading required is estimated to be $927 000 or $951 000 for demand growth rates of 2% p.a. or 3% p.a. respectively.

5.4.2 Mitchell River

The Mitchell River is located some 12-15 kilometres west of the Denmark River and is a tributary of the Hay River. A gauging station was recently commissioned but as yet only limited data is available. Nevertheless, there is ample forested catchment to ensure that a small storage on the river would be capable of supplying good quality water to Denmark in the longer term. The cost of implementing this option is of the order of $1 700 000.

5.5 Groundwater

Several prospective areas for groundwater resources have been identified within a reasonable distance of Denmark. If it exists, groundwater in any of these areas could be developed to supply Denmark either in full, or, if the groundwater resource is limited, supply could be restricted to the summer period when Scotsdale Brook stops flowing. Details of the prospective areas are set out in the following sections. The comparative costs (present value) of these proposals are shown in Appendix 1.

5.5.1 Ocean Beach

Six exploratory bores were drilled in the area shown in Figure 2 in late 1986. The results were disappointing with bedrock occurring in most holes at 15 to 30 metres. Consequentially, where water-bearing strata were intercepted, only low yields (less than 50 m^3 per day) would be available.

It is possible that an area closer to the coast within A Class Reserve 24913 (Parklands and Recreation) may be more promising. Assuming that water is available and that no treatment is required, the development of groundwater in this area to supply peak summer demands at Denmark is estimated to cost about $1 200 000 initially.

5.5.2 Madfish Bay

A reportedly perennial stream, which is fed by springs, flows into the Southern Ocean at Madfish Bay, about 6 kilometres west of Ocean Beach. This area includes part of the William Bay National Park. Assuming that the groundwater in this area can be developed to supply the peak demands at Denmark, and that treatment would not be required, an initial expenditure of about $1 500 000 would be required for this option.

5.3 Nullaki Peninsula

There are good prospects of obtaining groundwater on the Nullaki Peninsula, but its development for Denmark water supply would require a submarine pipeline across the mouth of Wilson Inlet. Assuming that treatment is not required, the initial expenditure required to develop this source to supply Denmark is estimated to be of the order of $2 000 000.

5.6 Desalination

A desalting plant could be installed to secure the supply of good quality water to Denmark. Because of the high operating costs associated with desalination, operation of the plant could be restricted to the summer months when insufficient supply is available from Scotsdale Brook.

The most economic method of desalination of the Denmark River water is expected to be reverse osmosis or electrodialysis. Budget costs for desalination plants capable of supplying the existing demand suggest that an initial capital expenditure of the order of $500 000 would be required. After allowing for plant enlargement costs, plant replacement costs at the end of its economic life, the required earlier enlargement of colour removal treatment facilities and desalting plant operating costs, the total comparative present value of this option for alternative demand growth rates of 2% and 3% per annum is as set out in Appendix 1.

6. COMPARISON OF ALTERNATIVES

6.1 Evaluation Criteria

The evaluation of alternative proposals must take account of economic, health, social, environmental and engineering factors. The standard criteria adopted by the Water Authority for the economic comparison of alternative proposals is the net present value, using discounted cash flow analysis. When the projects' benefits (economic, social, health, etc.), revenue and operating costs are the same, this practice is reduced to a comparison of the present value of the capital costs associated with the different projects.

Appendix 1 sets out the present value of the capital costs of the various proposals (the desalination option includes the high operating costs associated with it). The Scotsdale off-stream storage and Quickup River proposals are the lowest cost options. The other proposals are significantly more expensive or, in the case of the groundwater schemes (particularly the Ocean Beach proposal) based on the assumed availability of water with no treatment requirement. The Scotsdale off-stream storage and Quickup River proposals have therefore been examined in more detail to identify any differences between the schemes.

6.2 Salinity Benefit

In addition to improved palatablity, the supply of lower salinity water to Denmark provides an additional benefit by reducing household costs. This benefit is due to reduced consumption of soaps and detergents and reduced damage to domestic plumbing fittings, hot water systems and appliances. The Australian Department of Resources and Energy report on Salinity Issues for the Water 2000 study estimated this benefit to be $0.20 per mg/L per household per annum in 1982. This cost is currently estimated to be $0.29 per mg/L per household per annum.

Median salinities in Scotsdale Brook and the Quickup River are approximately the same at 300-350 mg/L. However, as the demand grows the Scotsdale off-stream storage proposal will involve an increasing use of the more saline Denmark River water to supply summer demands. The supply of this slightly more saline water implies that there is a salinity benefit (to the consumer) associated with the Quickup River proposal. The total present value of this benefit is independent of demand growth rates and has been calculated to be about $80 000 for a 2 month period of no flow in Scotsdale Brook, or about $90 000 for a 3 month period of no flow.

6.3 Operating Costs

In general terms, the operation of the Quickup River proposal and the Scotsdale off-stream storage proposal would be very similar. The water from both sources is coloured and would be pumped to the existing colour removal treatment plant adjacent to the Denmark River for treatment prior to delivery to Denmark. The manpower requirements of the two proposals will therefore be the same.

Water from the Quickup River will be more highly coloured (300-400 Hazen units) than water from the Scotsdale (150-200 Hazen units). This will not affect the capacity of the existing colour removal treatment plant, but there will be some additional use of chemicals in the treatment process. Extensive testing would be required to quantify the required chemical dosages. It is conservatively estimated that the cost of additional chemicals will be in the range 1-2 cents per m^3.

Due to the higher static lift involved, the pump-back from Scotsdale Brook to the Denmark River treatment plant is more costly than from the Quickup River. The incremental (i.e. power) cost is estimated to be 2.7 cents per m^3. After allowing for the slightly greater quantities to be pumped from the Quickup River in future years, compared with the Scotsdale (i.e. because the Scotsdale proposal involves some continued use of the Denmark River), this cost advantage of the Quickup scheme over the Scotsdale will offset the additional treatment costs referred to above.

In summary, the total operating costs for the Quickup and Scotsdale schemes would be roughly equivalent.

6.3 Catchment Management

The catchment area of Scotsdale Brook at the diversion site is 98% alienated land, with about 70% to 80% cleared for agricultural purposes. Regular sampling is carried out to ensure that the water presently used from this stream is not contaminated from the use of pesticides and herbicides. To date all samples have been well within acceptable limits. This sampling programme would be continued if the Scotsdale off-stream storage proposal is implemented.

Although the quality of the Scotsdale water is assured at the present time, there is a risk of pollution in the future. This would most probably occur through accidental spillage rather than normal use of the chemicals involved. Some control of activities on the catchment area would be required to minimise the risk of pollution.

As further and more intensive agricultural development takes place on the Scotsdale catchment, there will be greater competition for the water resource, particularly in the periods of low flow. To ensure the availability of good quality water for Denmark, there will be pressure to initiate controls on the diversion of water from the stream. This would create a significant work-load for the Water Authority and would restrict or otherwise inhibit productive agricultural development in an area already zoned for agriculture.

The catchment area of the proposed dam on the Quickup River is about 98% forested and is State Forest under the control of the Department of Conservation and Land Management (CALM). This status of the catchment area offers ideal protection of the water resource. Catchment management considerations strongly favour the Quickup River scheme over the Scotsdale off-stream storage proposal.

6.5 Environmental Impacts

The Scotsdale off-stream storage proposal would involve the construction of an 80 000 m^3 excavated storage on the site shown on Figure 2. This proposal would involve clearing of about 6 hectares of State Forest. Pipelines and pumping facilities required by this proposal are already operating as part of the existing supply to Denmark.

The Quickup River development proposal involves the construction of an earth embankment of about 9 metres height on the Quickup River to create a reservoir of about 900 000 m^3. This proposal would required clearing of about 50 hectares of State Forest covering the reservoir basin and embankment. The proposal also involves the construction of an above ground power main to supply power to the proposed transfer pumping station at the Quickup Dam and the construction of about 3.8 kilometres of 250 mm pipeline from the Quickup Dam to the existing colour removal treatment plant on the Denmark River. The pipeline will be laid below ground following already developed access corridors as much as possible to avoid any further unnecessary clearing.

Preliminary discussions have been held at officer level with CALM on the impact of the Scotsdale and Quickup Dam proposals and measures to mitigate their impacts. A field survey of the occurrence of rare flora and fauna at the latter site (Appendix 2) found no evidence of rare species likely to be affected. Advice from the Western Australian Museum (Appendix 3) is that there are no known Aboriginal sites likely to be impacted.

The disjunction of the flow regime and its effect on other water users has to be considered. During winter, run-off from the cleared farm areas will be more than adequate to meet the needs of local users. Stream gauging carried out to date indicates that very little summer flow is generated from the forested catchment upstream of the dam site and most of the summer flow which persists in the lower reaches of the river is generated by groundwater flow from the cleared areas. The construction of the Quickup Dam would therefore be expected to have a fairly small impact on the availability of water to downstream users.

The Water Authority has discussed the proposals with the Water Supply Committee of the Shire of Denmark in mid September. The background to the problem was raised and the relative merits of the alternative solutions aired. The selection of the 3.5 km site on the Quickup River would involve the resumption of a small area of private farmland, partly for the construction of the works and partly for the reforestation of some cleared farmland to control salinity. Discussions on the implications of this proposal have been held with the owner.

6.6 Timing

The Water Authority is committed to upgrade the supply to Denmark to ensure that good quality water can be supplied to the town in the summer of 1988/89. To achieve this commitment, either the 80 000 m^3 off-stream storage (for the Scotsdale proposal) or the Quickup Dam must be constructed during the 1987/88 summer, for filling with good quality water in the 1988 winter.

6.7 Selected Option

The Quickup River development proposal is selected as the preferred option. As set out in Appendix 1, it is the lowest cost (present value) proposal for all cases except the shortest period of supply from the Scotsdale Brook off-stream storage and at the lowest demand growth rate. Further, the Quickup proposal will provide a salinity benefit to consumers which is estimated to have a present value of $80 000 or $90 000. When this benefit is taken into account, the Quickup River proposal is the best economic solution for all development scenarios.

Catchment management for pollution control and securing the availability of water strongly favours the Quickup River proposal as the better long term option. Environmental approval is therefore sought for this proposal, however because of the commitment to improve the Denmark town water supply by the summer of 1988/89, it will be required to proceed with the Scotsdale off-stream storage proposal if environmental considerations preclude development of the Quickup River.

7. PROPOSED PROJECT

7.1 Description

The proposed Quickup River project is shown in outline in Figures 3 and 4 and includes the following components:

- A homogeneous earthfill embankment of about 9 metres height and 235 metres crest length. The embankment would create a reservoir of about 900 000 m^3 with a full supply level below R.L. 45 m A.H.D.

  A positive cutoff would be required to limit under-seepage through the foundation soils. Embankment fill materials would be obtained from within the storage basin and from established sources in the region.

- A concrete lined bywash channel to divert flood discharges around the dam.

- A concrete encased offtake pipe in the embankment and associated floating offtake in the reservoir.

- A transfer pumping station located immediately downstream of the dam. An above ground power main will supply power for the pumps.

- A 3.8 kilometre, below ground 250 millimetre pipeline to deliver water to the existing colour removal treatment plant on the Denmark River. The approximate route of the pipeline, subject to site investigation is shown in Figures 2 and 3.

7.2 Investigation and Construction Programme

Key dates for the implementation of the project to secure the supply of good quality water to Denmark in the summer of 1988/89 are as follows:

.	November 14, 1987	Complete design, tender documentation
.	December 1, 1988	Advertise tenders
.	February 15, 1988	Award contract for construction of dam
.	April 29, 1988	Complete dam
.	September 30, 1988	Complete transfer pumping station and pipeline.

7.3 Management Commitments

7.3.1 In conjunction with CALM the Water Authority will prepare a management progamme for the catchment area above the water storage. The catchment would be treated as a Class 1 catchment within the meaning of the Western Australian Water Resources Council publication "Recreation on Reservoirs and Catchments".

7.3.2 The Water Authority will negotiate with the land owner affected by the development of Site 3.5.

7.3.3 The Water Authority will minimise the disruption to State Forest outside the area of the works. Any areas which are disturbed and are not required for the permanent works will be rehabilitated.

7.3.4 The project will involve the clearing of almost 50 ha of State Forest. Arrangements will be made with CALM to maximise the utilization of forest products from within the project area.

7.3.5 The Water Authority will negotiate with CALM for the transfer of an alternative piece of land to CALM to compensate for the loss of State Forest on the Quickup River.

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7.3.6 The Rights in Water and Irrigation Act gives the Water Authority power to allocate water to competing water users on the river downstream of the dam. If necessary, the provisions of this Act will be used to resolve any problems that may occur.

7.3.7 The Water Authority will implement CALM forest hygiene and fire control provisions during the construction of the project.

7.3.8 The Water Authority will implement the recommendations of the Registrar of Aboriginal Sites (Appendix 3).

7.3.9 The Water Authority will continue to discuss the implications of the project with local people directly affected by the proposal and with others who may have an interest in the scheme.

APPENDIX 1

SUMMARY OF ESTIMATED COSTS AND PRESENT VALUES OF ALTERNATIVE PROPOSALS

APPENDIX 1

DENMARK WATER SUPPLY
AUGMENTATION FOR SALINITY IMPROVEMENT
SUMMARY OF DEVELOPMENT PROPOSALS

SCHEME	COSTS ($x 1000		
	INITIAL CAPITAL	PRESENT VALUE (AT 6% DISCOUNT RATE)	
		2% p.a. Growth	3% p.a. Growth
Scotsdale off-stream storage			
2 month supply period	590	894	1 000
3 month supply period	590	1 105	1 195
Quickup River	920	927	951
Mitchell River	1 700	1 632	1 632
Groundwater			
Ocean Beach	1 200	1 265	1 287
Madfish Bay	1 500	1 565	1 587
Nullaki	2 000	2 098	2 130
Desalination	500	1 412	1 473

APPENDIX 2

RARE FLORA AND FAUNA OF THE QUICKUP DAMSITE AREA

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RARE FLORA AND FAUNA OF THE QUICKUP DAMSITE AREA

1.0 INTRODUCTION

The Water Authority of Western Australia is proposing to construct a dam on Quickup River in order to upgrade the Denmark town water supply. Quickup River is an eastern tributary of Denmark River which arises in Denmark, Denbarker, Sheepwash and Hay State Forests. The Water Authority has conducted storage investigations for four potential damsites on Quickup River, at 0.8km, 3.5km, 3.8km and 4.7km above its confluence with Denmark River.

This report reviews rare flora and fauna likely to be affected by the project, particularly for the 3.5km and 3.8km options.

2.0 OVERVIEW

Dams at all four potential sites would have reservoirs which would, at least in part, be in Hay State Forest. Most of the reservoir at the lowest site would be on private property which has mostly been cleared. The reservoirs at the highest site and 3.8km would be totally within State Forest which is uncleared except for tracks. Most of the 3.5km site reservoir is in State Forest, and all, or almost all, of it except for tracks is covered with native vegetation.

None of the four reservoirs would intrude into the proposed Denmark State Park (Department of Conservation and Land Management 1987: Table 6 and Figure 6), but the 4.7km damsite reservoir might extend into the road reserve next to an arm of the proposed park. All of the 4.7km damsite reservoir is within the proposed Mt Lindsay National Park (Campaign to Save Native Forests et al. 1987: Figure 7.9), and the upper parts of the the 3.5km and 3.8km site reservoirs are in it.

3.0 VEGETATION AND HABITATS

Vegetation and associated habitats of parts of the region which includes the project area are described by Christensen (1980). The following description of the native vegetation of the project area is based upon Christensen's descriptions, interpretation of 1:20,000 scale colour aerial photographs flown in January 1984, and field inspection of the 3.5km and 3.8km damsites reservoir areas on 13 September 1987. Traverses were walked along existing vehicle and animal tracks, and vegetation was sampled and photographed at the seven points shown on the relevant aerial photograph.

3.1 VEGETATION AND HABITATS OF THE FOUR ALTERNATIVE RESERVOIRS

Types of native vegetation that would be affected by the project are Karri (Eucalyptus diversicolor) High Open Forest, Jarrah-Marri (Eucalyptus calophylla), Open Forest, low open woodlands of Jarrah (Eucalyptus marginata), Yarri (Eucalyptus patens) and Moonah Paperbark (Melaleuca preissiana), Myrtaceous Closed Scrubs of Kunzea ericifolia, Astartea fascicularis, Agonis spp. and Pericalymma ellipticum and sedgelands of Anarthria scabra, Evandra aristata and other species. No granite outcrops or permanent lakes or rivers, except the part of Denmark River downstream of Quickup River, would be affected by the project.

3.2 VEGETATION AND HABITATS OF THE 3.5KM AND 3.8KM DAMSITE RESERVOIRS

Seasonal wetland vegetation (Moonah Paperbark Open Low Woodland, Myrtaceous Closed Scrub and their variations and intermediates) account for approximately 90% of the vegetation in the 3.5km and 3.8km damsites reservoir areas. The remaining approximately 10% comprises Jarrah (-Marri) Woodland and Open Forest, Yarri Woodland or Open Forest and Karri High Open Forest. The very small representations of Yarri and Karri forests are on the east side of the seasonal wetland vegetation in the vicinity of the 3.8km damsite. Otherwise, Jarrah (-Marri) Woodland and Open Forest surrounds the seasonal wetland vegetation.

The dominant seasonal wetland vegetation of the 3.5km and 3.8km reservoir sites corresponds to Christensen's Sedgelands, Closed Scrub, Low Open Woodlands of Melaleuca and Karri High Open Forest understorey shrub community. The vegetation is, however, more diverse and variable than Christensen's descriptions may indicate. The recording of 50 to 60 species of plants in this vegetation during the single, brief site inspection is an indication of its richness and diversity.

Most of the seasonal wetland vegetation in the 3.5km and 3.8km population (stand) would be destroyed by the project, but examination of the aerial photographs suggests that there are other, similar stands nearby in State Forest. Some of these stands are indicated on the accompanying aerial photograph of the 3.5km reservoir site (Figure 1).

Eucalypt forests and woodlands would suffer no significant impacts from the project if the dam is constructed at the 3.5km or 3.8km sites and if the full supply level (FSL) is restricted to the 46m contour or lower.

4.0 RARE FLORA

The more than 50 species found during the field inspection include all of the dominant and the most common and widespread vascular plants of the 3.5km and 3.8km reservoir sites. The more than 50 species also includes a large proportion of the less common perennial plants and a few interesting species such as the Scented Boronia (Boronia megastigma) and an undescribed restionaceus sedge that forms tangled mats along streams in Karri forest and probably provides habitat for Bush-rats and Quokkas.

Four species of flora gazetted as rare (Government Gazette, W.A., 12 March 1982)* have ranges and habitats which might, marginally, include the 3.5km and 3.8km reservoir sites: Grevillea cirsiifolia, G. drummondii, Lambertia orbifolia and Caladenia bryceana (Rye and Hopper 1980; Patrick and Hopper 1982). As these species were searched for during the field inspection, and none found, it is probable that they are not represented at the site.

Other non-gazetted rare, geographically restricted and poorly known species which have been recorded from the Denmark area or have ranges which include the Denmark area are: Amperea volubilis, Andersonia auriculata, Banksia verticillata, Boronia virgata, Hakea elliptica, Hemigenia glabrescens, Latrobea brunonis, Selliera radicans, Senecio minimus, Sphaerolobium alatum, Stylidium exoglossum, Thomasia quercifolia and Thysanotus pseudojunceus (Gillen pers. comm.). These species were also searched for during the field inspection, even though the reservoir sites do not contain habitats for most of them. One species in this group, Senecio minimus, was tentatively identified during the survey at or above the full supply level of the 3.5km damsite. Definite identification was not possible as the plant was not in flower. Senecio minimus is, however, a reasonably widespread and common species.

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* A revised list of rare species is scheduled to be gazetted in late September 1987.

5.0 RARE FAUNA

The project area is at the southern edge and south of the Hay River and Mitchell River catchment areas surveyed by Christensen and north of the northern edge of the Subregion 10 area reviewed by How, Dell and Humphreys (in press).

Christensen (1980) observes that the "full range of [vertebrate fauna] species typically associated with the high rainfall southern forests are present in the area" surveyed by his team. "The vertebrate fauna is more diverse than that of any area surveyed so far [by Christensen's Forest Department team] with the exception of Dryandra and the Perup forest". However, the area surveyed by Christensen's team contains granite outcrops, wandoo woodlands, mallees and other habitats not represented in the Denmark water supply project area.

Western Grey Kangaroo (Macropus fuliginosus) tracks through the more open parts of the seasonal wetland vegetation in the 3.5km and 3.8km reservoir sites are common. Small tunnels and larger, 50cm high tunnels through dense restionaceus understorey vegetation in myrtaceous scrub thickets are also common and are probably made by Southern Bush-rats (Rattus fuscipes) and Quokkas (Setonix brachyurus) respectively. Western Water-rats (Hydromys chrysogaster) probably occur along the river.

Species of mammals and herpetofauna gazetted as "rare, or otherwise in need of special protection" (Government Gazette, W.A., 22 November 1985) which have been recorded in the "near-coastal", on-shore Denmark area are the Ringtail (Pseudocheirus occidentalis) and the Carpet Python (Morelia spilota imbricata) (How, Dell and Humphreys in press). Christensen (1980) located a Ringtail's drey in a Melaleuca tree during his survey and Kitchener and Vicker (1981) list one pre-1981 collection of the Western Quoll (Dasyurus geoffroii) in the Denmark area (M6769, collected in 1964). Although all three species could occur within the project area, the probability of their being there is low.

Christensen (1980) observed that there were no species of particular interest among the 57 species his team recorded during their relatively brief, autumn survey. The one gazetted species Christensen recorded, the Red-eared Firetail (Emblema oculatum), is locally common in paperbark swamps and dense forest undergrowth along watercourses in south-western forests, and it probably occurs in the reservoir site.

There is also habitat in the reservoir area for two relatively uncommon but not gazetted species, the Mourning Skink (Egernia luctuosa) and the Red-winged Fairy-wren (Malurus elegans), but neither was recorded during the site inspection. The Mourning Skink was recorded during Christensen's surveys, in riverine vegetation.

6.0 DISCUSSION

The completeness and accuracy of most lists of rare and restricted flora and fauna tend to be limited. The principal reason for this limitation is 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.

For example, Grevillea drummondii is a plant species originally gazetted as rare (Government Gazette, W.A., 14 November 1980) which has since been found to be more common and widespread than previously believed. Consequently, Grevillea dummondii is not on the 1987 list of gazetted species.

The Red-eared Firetail is more common and widespread than its status as a gazetted species might suggest. The bird is often difficult to see in its dense shrubby wetland and stream-fringing habitats. The species appears to be secure, though under-recorded (Nichols, Watson and Kabay, 1982), but its habitats are vulnerable to clearing, burning and flooding.

The Western Quoll is represented from the Denmark area by a single specimen, collected in 1964, in the Western Australian Museum (Kitchener and Vicker 1981; How, Dell and Humphreys, in press). Nor is there any museum record of the species from the coastal area between Augusta and Albany for at least the last twenty years (How, Dell and Humphreys, in press). The Western Quoll is now considered to be particularly vulnerable. However, in view of the fact that there is only one published report of the species in the Denmark area, that being 23 years ago, the probability of a Western Quoll being in the project area is considered to be very low.

7.0 REFERENCES

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Kitchener, D.J. and Vicker, E. (1981). Catalogue of Modern Mammals in the Western Australian Museum, 1895 to 1981. Western Australian Museum, Perth.

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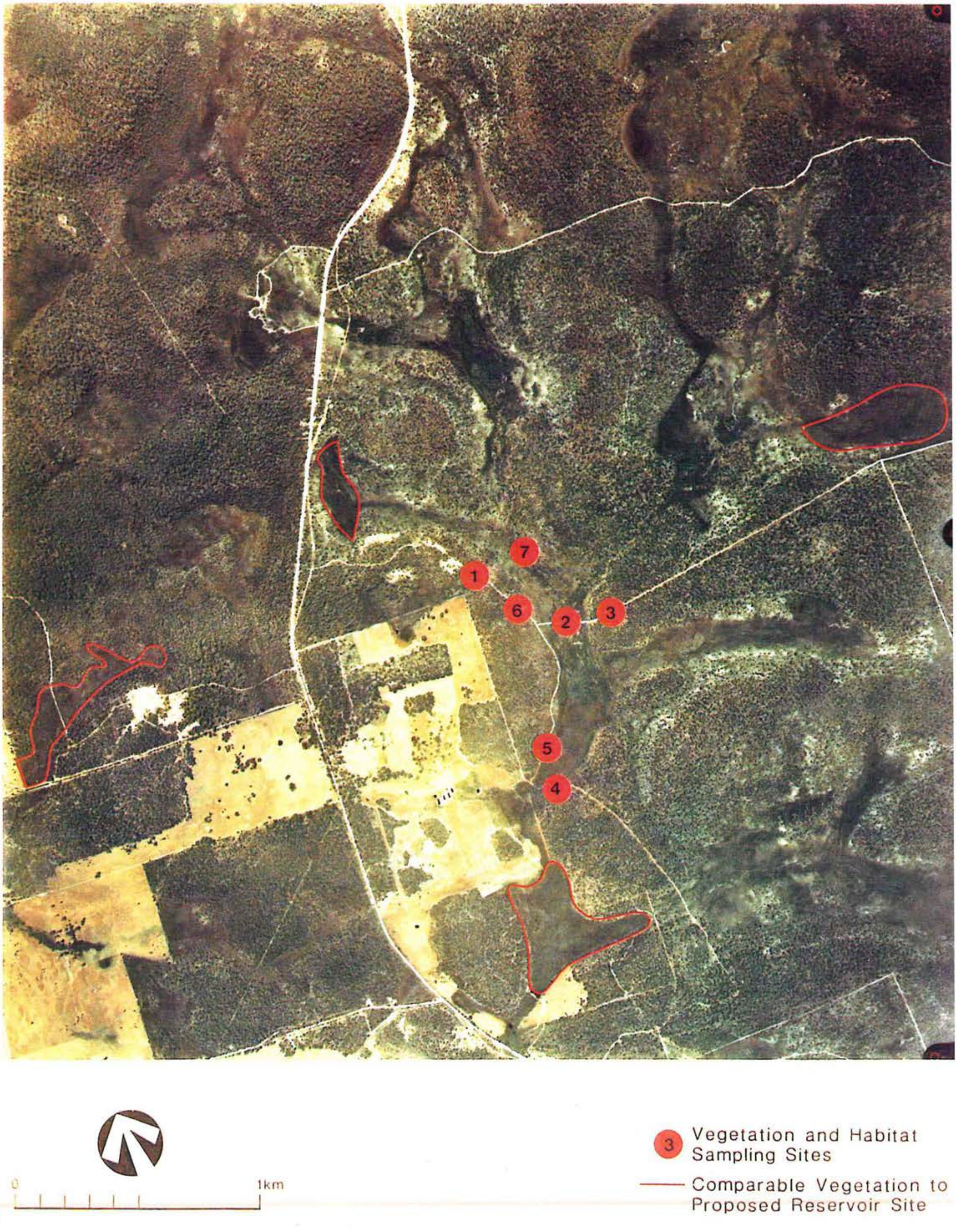

QUICKUP DAMSITE (3.5km & 3.8km) AREA

Dames & Moore

Figure 1

APPENDIX 3

STATEMENT ON ABORIGINAL SITES IN THE QUICKUP DAMSITE AREA

Australian
museum

Francis Street Perth
Western Australia 6000
Telephone (09) 328 4411

Date: 6 October 1987

Your Ref: A 19905

Our Ref: 264/77/3 f 122

The Manager,
Water Resources Planning,
Water Authority of Western Australia,
P.O. Box 100
LEEDERVILLE 6007

Attention : R. Wark

DENMARK WATER SUPPLY
QUICKUP DAM INVESTIGATIONS

I refer to your letter of 21 September 1987.

There are no Aboriginal sites known to this Department to date within the areas concerned.

However, the areas have not been examined and it is possible that sites exist there.

It would be advisable for the Water Authority to arrange a site investigation to ensure compliance with the Aboriginal Heritage Act.

You might like to contact Mr Charles Dortch, Curator of Archaeology, Western Australian Museum, who may be able to undertake this project.

V. Novak,
Assistant Registrar,
DEPARTMENT OF ABORIGINAL SITES.

Branches:
Fremantle Museum
Finnerty Street, Fremantle
Western Australia, 6160
Telephone (09) 335 8211

Western Australian
Maritime Museum
Cliff Street, Fremantle
Western Australia, 6160
Telephone (09) 335 8211

Geraldton Museum
Marine Terrace,
P.O. Box 112, Geraldton
Western Australia, 6530
Telephone (099) 21 5080

Albany Residency
Museum
Residency Road, Albany
Western Australia, 6330
Telephone (098) 41 4844

APPENDIX 4

SUMMARY REPORT ON THE HYDROLOGY OF THE QUICKUP RIVER

APPENDIX 4

WATER YIELD AND SALINITY - QUICKUP RIVER

1. INTRODUCTION

A gauging station was established on the Quickup River in 1985 with a catchment area of 36.4 km^2. Two years of data are available from this station and the run-off at the gauging station and the estimated run-off at the dam site (catchment area 29.2. km^2) are as follows.

TABLE 1: ESTIMATED STREAMFLOW

YEAR	GAUGE	DAM
1985	890	660 (23 mm)
1986	805	600 (21 mm)

The years 1985 and 1986 were relatively 'dry' years. The probability of non-exceedance (PNE) for the 1985 and 1986 annual rainfalls at Denmark P.O., since 1950, were 24% and 11% respectively. Analysis of other streamflow data suggests that a run-off of only 10 mm may have occurred in the very dry year of 1983.

2. RECENT MONITORING

The results of recent monitoring at the damsite and other points on the catchment are shown on Table 2.

TABLE 2: ADDITIONAL STREAM GAUGING 1987

QUICKUP RIVER STORAGE INVESTIGATIONS
SAMPLE POINT RESULTS. T.S.S. Mg/L

DATE	6031059.4 MT BARKER RD	6031057.X DAMSITE 3.5	6031058.7 BELOW DAM	6031060.5 POWLEY RD	603006.3 GAUGING ST.	FLOW EST. AT DAMSITE 3.5
26/06/87		2830			1182	0.003M3/S
14/07/87		2399			1162	0.002
20/07/87	NO FLOW	2217	2017	1076	1080	0.002
24/07/87		1958			892	0.005
29/07/87	302	830	1040	827	753	0.120
31/07/87	276	485	534	503	492	0.250
07/08/87		638			671	0.012
17/08/87		711			812	0.004
20/08/87	392	928	786	782	868	0.004
		581				stage ht.
		674				stage ht
26/08/87		540			682	0.035
		497				stage ht.
01/09/87	377	614	611	637	673	0.015
		601				stage ht.
10/09/87		727			743	0.004

20/08/87 an extra sample taken between pts 6031059 and 6031057 had a salinity result of 546 mg/L.

This data indicates that the flow at the 3.5 km damsite to mid September 1987 amounted to approximately 160 000 m^3. (i.e. approximately 5.5 mm runoff) with an average salinity of 685 mg/L.

Several small farm dams to the north west of the 3.5 km damsite have been sampled. One dam at the lower end of the slope recorded a salinity of 970 mg/L. Those further up the slope recorded salinities of 100 - 200 mg/L.

3. PROBABLE CAUSE OF SALT DISCHARGE

From sample information at the current gauging station and from longitudinal sampling along the water course, it is clear that the small amount of clearing near the damsite (about 0.5 square kilometres in a total of 30) is affecting the stream salinities.

Salinities of order 2000 to 2800 mg/L TSS have been recorded at low flows at the 3.5 km damsite. These salinities are comparable with the range of low flow salinities likely to occur in streams draining areas of clearing in similar rainfall zones. They most likely reflect the local groundwater discharge caused by the adjacent clearing.

4. ESTIMATES OF SALT AND WATER DISCHARGE

Using a simple model of expected salt and water discharge (for a 900 mm rainfall area) the estimates of the likely inflow salinities for a range of years were calculated. These are summarised in Tables 3 and 4.

TABLE 3

ADOPTED WATER AND SALT YIELDS FOR QUICKUP CATCHMENT

Unit Area Figures

YEAR WITH PROBABILITY OF	NATURAL FOREST CONDITIONS WATER mm	SALT kg/m^2	SALINITY mg/L	UNIT AREA EFFECT OF CLEARING ADDITIONAL DEEP GROUNDWATER kg/m^2	SALT LOAD SHALLOW GROUNDWATER kg/m^2	ADDITIONAL WATER mm
5%	7	.0045	640	.159	.006	40
10%	16.5	.009	545	.159	.013	84
50%	50	.015	300	.159	.017	126
90%	150	.030	200	.159	.026	172

TABLE 4

ADOPTED WATER AND SALT YIELDS FOR
QUICKUP CATCHMENT - 3.5 km

- Catchment Area 30 sq km
- Area Cleared - 0.5 sq km

YEAR WITH PROBABILITY OF NON EXCEEDANCE OF	FORESTED YIELDS		ADDITION YIELDS DUE TO CLEARING		FINAL YIELDS		
	SALT 10^6kg	WATER 10^6m^3	SALT 10^6kg	WATER 10^6m^3	SALT 10^6kg	WATER 10^6m^3	SALINITY mg/L
5%	.135	.210	.083	.020	.218	.230	948
10%	.270	.495	.087	.042	.357	.537	665
50%	0.450	1.500	.089	.063	.539	1.563	345
90%	0.900	4.50	.093	.086	0.993	4.586	217

The estimates indicate that, although only a small area is cleared annual salinities of inflow could approach 1000 mg/L in very dry years (probability of non-exceedance - 5%). However, less than 30 percent of years will have salinities in excess of 500 mg/L and the salinity of a median year is only 345 mg/L TSS.

5. CONCLUSIONS

The following conclusions have been drawn:

(i) Salinity problems in a Quickup storage could be kept to manageable proportions if sufficient carry over storage is provided.

(ii) Rough estimates of the end of summer season drawdown from a full reservoir indicate storage deficits of about 400 000 to 450 000 m^3 for an annual draw of 300 000 m^3.. The proposed storage of 900 000 m^3 would therefore be sufficient to provide a reliable supply. However, carry over storage for dilution would be limited to only one year.

(iii) The salinity in dry years could also be limited in the longer term by the planting of a high transpiring tree species in the lower slopes of the cleared land near the proposed storage.

(iv) Reforestation of about 15 hectares would minimise any problems of salinity associated with the Quickup River in dry years.

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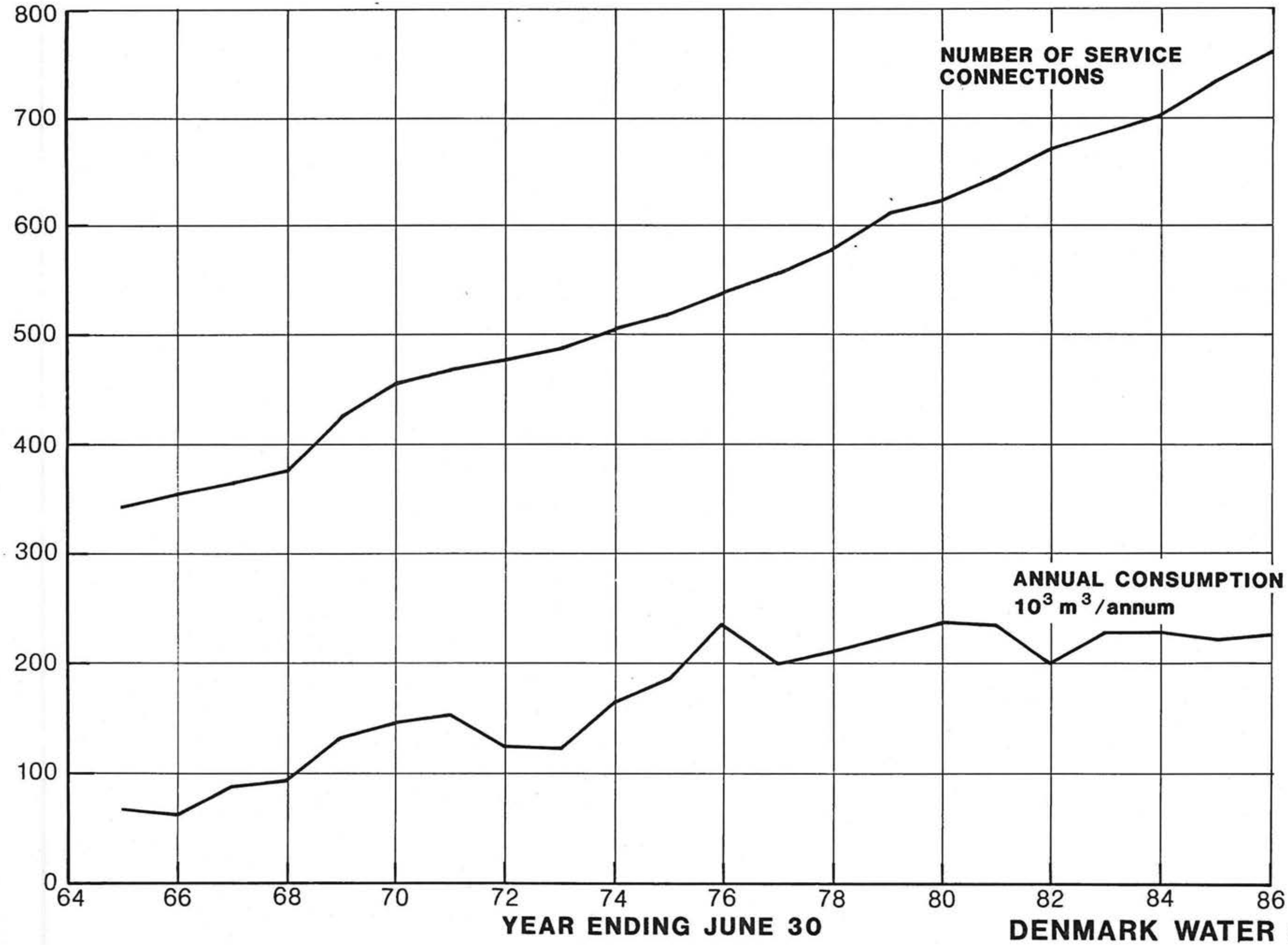
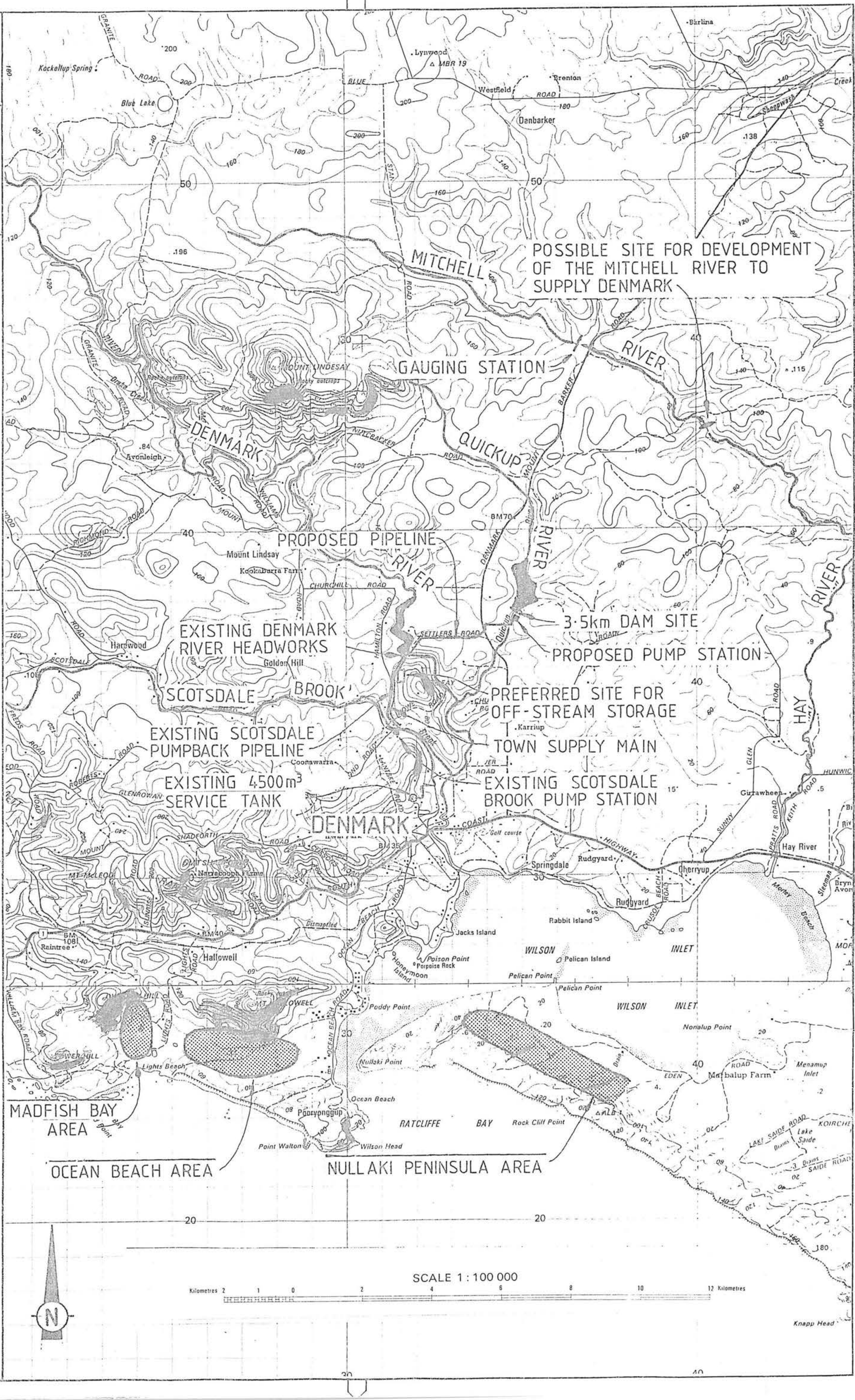


DENMARK WATER SUPPLY
SERVICES AND CONSUMPTION

FIGURE 1

DENMARK WATER SUPPLY AUGMENTATION FOR SALINITY IMPROVEMENT ALTERNATIVE DEVELOPMENT PROPOSALS

FIGURE 2.



ORIGINAL DRAWING SIZE A3

MICROFILMED

DATE

DRN P.v/d W.

CHD

RECOMMENDED

PRINCIPAL ENGINEER DAMS

APPROVED

MANAGER W.R. PLANNING

Water Authority of Western Australia

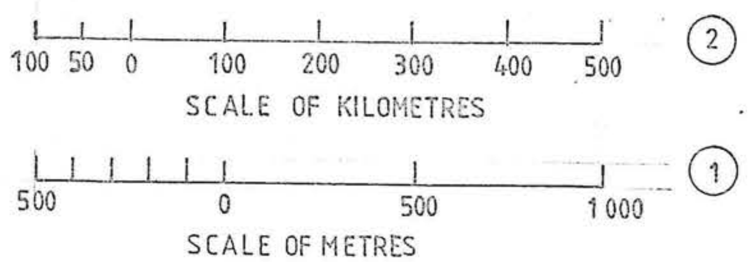
FILE

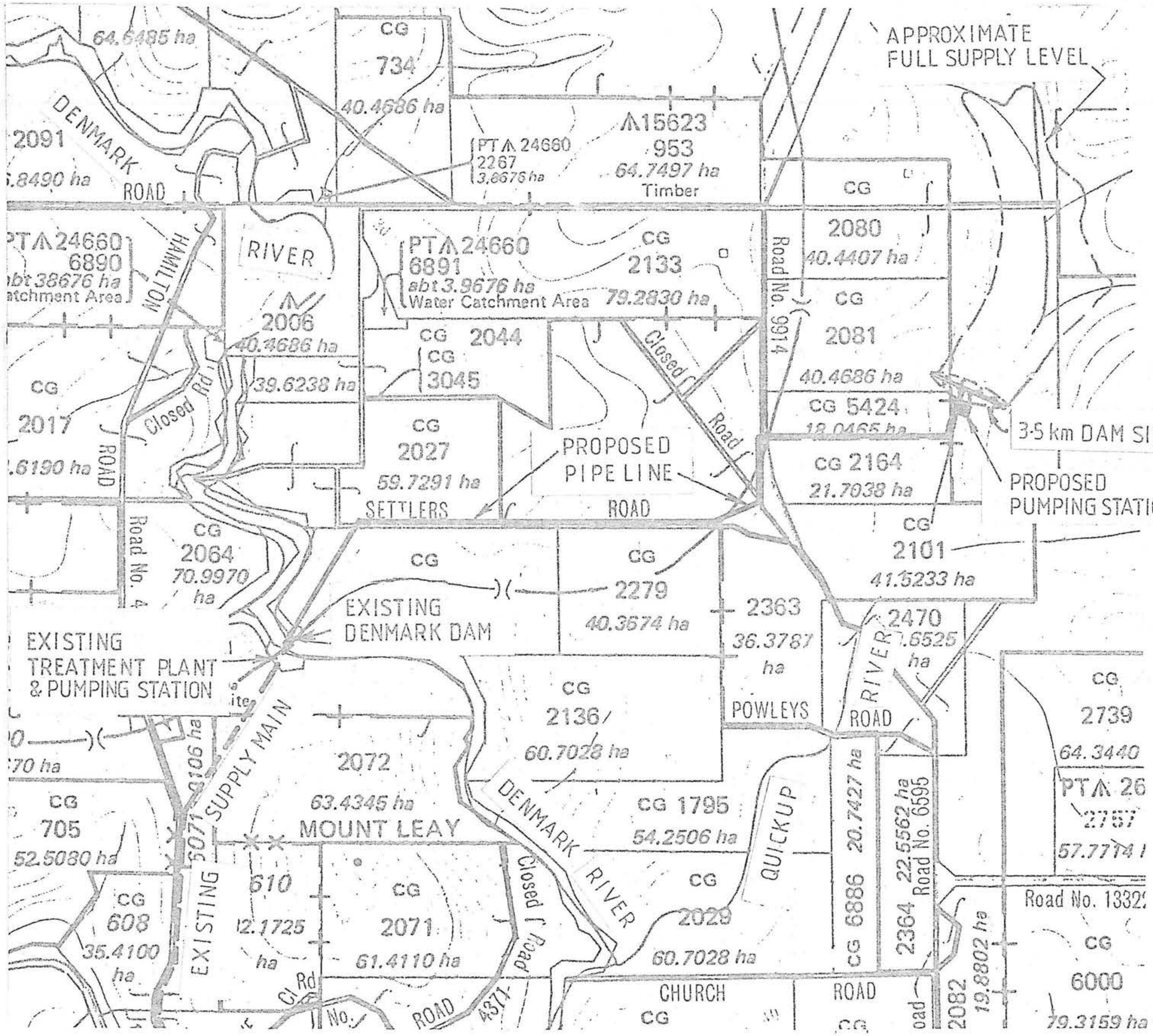
PROJECT

PLAN

ISSUE

LOCALITY PLAN (2)





PLAN (1)

ORIGINAL DRAWING SIZE A3	MICROFILMED		RECOMMENDED	Water Authority of Western Australia	DENMARK WATER SUPPLY
	DATE		PRINCIPAL ENGINEER DAMS		AUGMENTATION FOR SALINITY IMPROVEMENT
	DRN W.R.M.		APPROVED		QUICKUP DAM PROJECT
	CHD		MANAGER W.R. PLANNING		FILE / PROJECT / PLAN / ISSUE — FIGURE 3.

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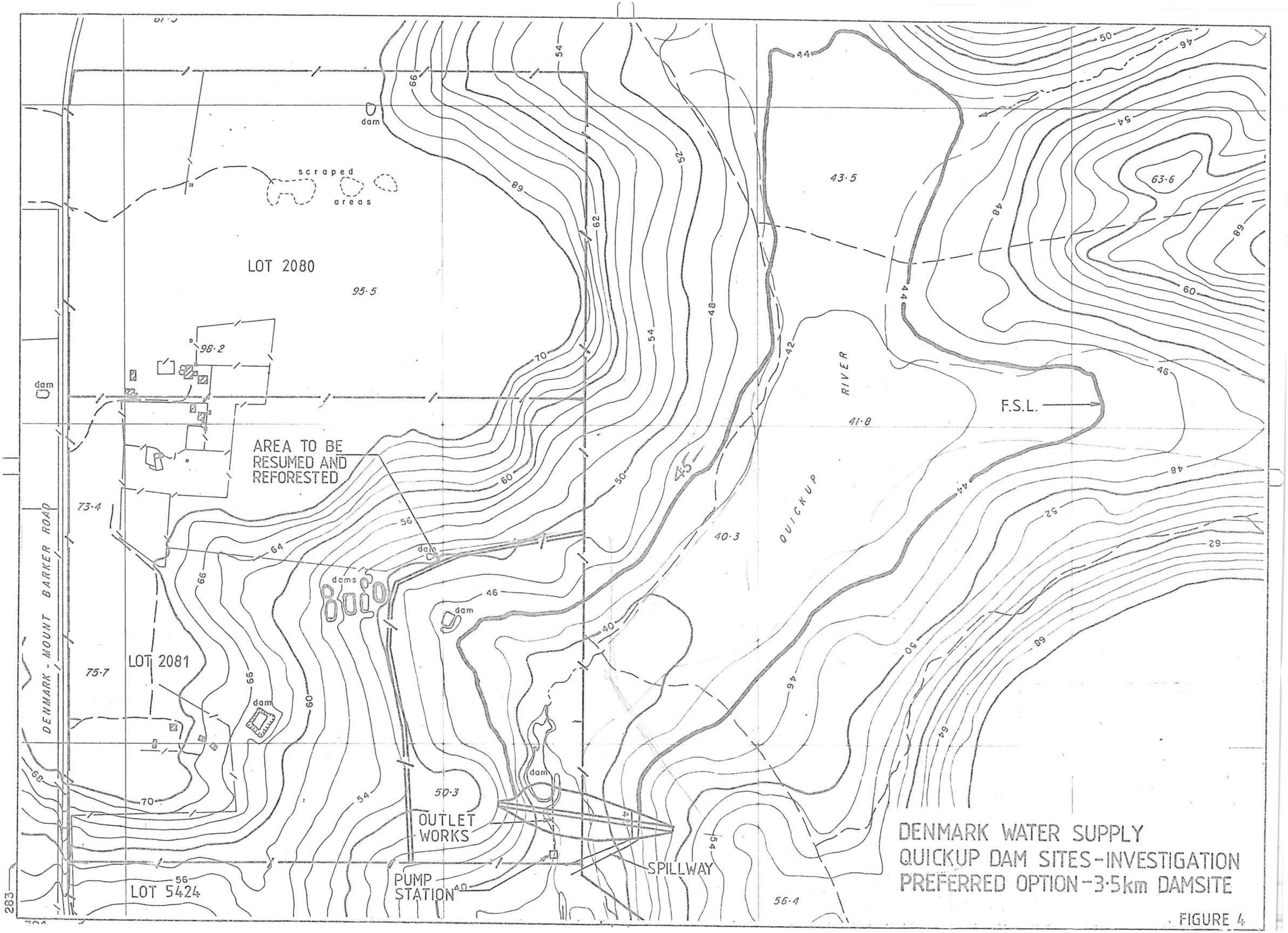

DENMARK WATER SUPPLY
QUICKUP DAM SITES-INVESTIGATION
PREFERRED OPTION-3·5km DAMSITE

FIGURE 4