WATER AUTHORITY
of Western Australia

Harding Dam
Environmental Management Report

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Dames & Moore

October 1985

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WATER RESOURCES DIRECTORATE
Water Resources Planning Branch

Harding Dam
Environmental Management Report

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SUMMARY

This report summarises the environmental management procedures carried out at the Harding Dam over the three year period 1982-1985 by the Water Authority of Western Australia as required by the Environmental Protection Authority (EPA). It briefly describes the major components of the Harding Dam, the monitoring and management programmes, and reviews the environmental management implementation and results to date. The nine environmental reports undertaken before and during construction and after commissioning of the dam, are contained in the separate Volume of Appendices.

Table 1 outlines the management commitments identified during the preparation of the ERMP as well as the EPA recommendations for environmental management. Analysis of this table, indicates that most management guidelines have been adhered to over the past three years.

TABLE 1

HARDING DAM PROJECT
ENVIRONMENTAL MANAGEMENT PROCEDURES

(incorporating ERMP and EPA recommendations)

SUBJECT	ERMP/EPA REFERENCE	REQUIREMENT/ UNDERTAKING	MANAGEMENT PROCEDURE	STATUS OF ACTION
DUST SUPPRESSION	ERMP Section 8.1.1	Minimise dust generation	Vehicular speed limited to 40km/hr near buildings and water spraying on haul roads	Completed
EROSION CONTROL	ERMP Section 8.2	o Minimise disturbance o Recontouring of disturbed surfaces o Construction of banks	Deep ripping of compacted areas and disused haul roads was undertaken at completion of the construction phase and stockpiled topsoil was respread over the sites	Completed
BORROW AREAS	EPA Recommendation 5.1	Minimise borrow areas outside of Reservoir area	Contractor utilised existing borrow area 9 for sand material. Area 2 was utilised for impervious fill material and has been ripped and respread with stockpiled topsoil. All other areas were within the Reservoir area. The filter material extracted from the Recreation Pool has increased the depth of the pool	Completed
REHABILITATION PROGRAMME	ERMP Section 8.3 8.3.1	Respreading of topsoil over disturbed areas	Disturbed areas deep ripped to increase water retention and infiltration	Completed
	8.3.2	Supplementary treatments o Control noxious weeds o Oversowing bare areas o Brush cover to minimise wind erosion	Inspected in October 1985. Requires good rains before effects can be determined	Ongoing
	EPA Recommendation 5.2	No buffel grass to be used	No seed mix has been applied to rehabilitated sites, however, if this becomes necessary, no buffel grass will be used	
CONSTRUCTION FACILITIES	ERMP Section 8.4 8.4.1 Construction Camp	Rehabilitation required on completion of construction activities	Construction camp removed, deep ripping on the contour and rehabilitated once construction was completed	Completed

SUBJECT	ERMP/EPA REFERENCE	REQUIREMENT/ UNDERTAKING	MANAGEMENT PROCEDURE	STATUS OF ACTION
	8.4.2 Access Roads	o Upgrade main access road	Upgrading of existing Roebourne to Cooya-Pooya Road and regular grading undertaken	Ongoing
		o Re-contouring temporary causeways across Harding River	Temporary causeways across the Harding River downstream of the dam graded and re-contoured when no longer required. The permanent causeway at the end of the Recreation Pool has been designed to allow vehicular crossing.	Completed
		o Access to Harding Dam	A sealed all weather road has been constructed from the meteorological station, around the Recreation Pool and public viewing areas at the top of the dam	Completed
	8.4.3 Waste Disposal	o Construction and Operations needed to comply with PHD and Shire of Roebourne provisions	Septic tanks provided at construction camp, removed when camp dismantled. Public toilets provided on northern bank of Recreation Pool. Rubbish disposed in sanitary landfill site	Completed Ongoing
EROSION AND SEDIMENT CONTROL	ERMP Section 8.5	o Destocking of catchment	Undertaken	Completed
		o Annual inspections of reservoir foreshore	Undertaken in May and October 1985	Ongoing
		o Control of soil movement in reservoir	There appears to be very little soil erosion in the catchment	Ongoing
	EPA Recommendation 5.3	o Dust creation	Will be assessed during annual survey of reservoir	Ongoing
WATER QUALITY	ERMP Section 8.6	Criteria to be maintained to NH&MRC standards	Regular water samples taken and analysed	Ongoing
	8.6.1	Water Quality Policy	Chlorination and fluoridation undertaken in water treatment building	Ongoing
	8.6.2	Vegetation clearing in Reservoir	Undertaken to minimise BOD demand when submerged vegetation rotting	Completed
	8.6.3	Withdrawal strategy	Four multi-level screened offtakes incorporated in design of intake tower to ensure the best quality water is utilised from the Reservoir	Completed
	8.6.4	Scouring of Reservoir	Outlet works designed to ensure highly saline water is scoured	Ongoing

SUBJECT	ERMP/EPA	REQUIREMENT/ UNDERTAKING	MANAGEMENT PROCEDURE	STATUS OF ACTION
MILLSTREAM AQUIFER WATER MANAGEMENT	ERMP Section 8.7 EPA Recommendations 5 4 and 5.5	Water management programme to be devised to ensure riverine environment maintained within the conjunctive use strategy for the West Pilbara Water Supply	The Millstream Water Management Programme was undertaken by the Water Authority, CALM and DCE and approved by the EPA in July 1984. The first annual report was submitted in July 1985	Ongoing
DOWNSTREAM ECOSYSTEMS	ERMP Section 8.8	o Water supplementation to Recreation Pool o Monitoring of Pinanular Pool	Water provided from Reservoir and the Ongoing at RL 41.0m See Volume of Appendices, Appendix 4 included quadrats set up at Waranoolar Pool. Piezometers establish to monitor watertable	Ongoing
	EPA Recommendation 5.7	o Additional monitoring to be undertaken	Carried out, see Volume of Appendices, Completed Appendix 4 and 8	
	EPA Recommendation 5.8	o Mangal surveys at mouth of Harding River	Interpretation of aerial photographs of mangals to be carried out at three yearly intervals (Appendix 7). Future flights in 1987 and 1990	Ongoing
RESERVOIR ECOSYSTEMS	ERMP Section 8.9	Flora and Fauna monitoring o Monitoring of Reservoir for weeds o Importation of exotic flora	Volume of Appendices, Appendix 9	Ongoing
	EPA Recommendation 5.6	Monitoring of vegetation prior to construction	Volume of Appendices, Appendix 1,2,3	Completed
PUBLIC HEALTH	ERMP Section 8.10	o Chemical and biological monitoring of water	Current and operational on monthly basis	Ongoing
		o Access control to Reservoir	Restricted access and clear sign posting around Reservoir	Completed
		o Pastoral activities to be phased out and destocking of catchment	Catchment destocked of domestic animals	Completed
		o Arbovirous monitoring in co-operation with PHD	To be undertaken with PHD officers	To be undertaken
		o Fencing of sections of catchment	Carried out on western boundary by December 1985	To be undertaken
		o Monitoring vermin with APB	Monitoring of dingo populations being undertaken. Water Authority contribute financially to dog baiting programme	Ongoing
RECREATION FACILITIES	ERMP Section 8.11	Recreation Pool and associated facilities (car parks, barbeque, seats, toilets, telephone) to be constructed	Full time caretaker to be appointed by end of 1985 to manage recreation area as well as maintenance and cleaning of facilities and rubbish collection and disposal	Ongoing

SUBJECT	ERMP/EPA REFERENCE	REQUIREMENT/ UNDERTAKING	MANAGEMENT PROCEDURE	STATUS OF ACTION
COMMUNITY RELATIONS	ERMP Section 8.12	Regular public information	Regular media releases were organised during construction, commissioning and the official opening of the Harding Dam Reservoir	Ongoing
ABORIGINAL MATTERS	ERMP Section 8.13	o Ethnology	Protection of Aboriginal sites was facilitated by an interdepartmental committee, established to maintain communication with local Aboriginal groups	Completed
		o Archaeology	Consultant appointed and report presented during April 1983	Completed
WATER CONSERVATION	ERMP Section 8.14 EPA Recommendation 5.9	Water Conservation in the Pilbara region	Media coverage and publication of brochures on the value of low water use gardens. Active campaign to increase public awareness of the potential problems of high water consumption	Ongoing Ongoing
ROEBOURNE AQUIFER	ERMP Section 8.15	Management of water extractions on Roebourne aquifer borefield monitored for salinity increases	Roebourne township was connected to West Pilbara Water Supply Scheme in 1983	Completed

SOURCES:

Dames & Moore (1982). Harding Dam Project, Draft Environmental Review and Management Programme. Report prepared for Public Works Department.

Environmental Protection Authority (1982). Harding Dam Project, Report and Recommendations. Dept. Cons. and Environ. Bull. 115.

1.0 INTRODUCTION

This triennial environmental management report on the Harding Dam project is a formal requirement of the Water Authority of Western Australia (Water Authority)* by the Environmental Protection Authority (EPA). The recommendations outlined in the monitoring programme in the Draft Environmental Review and Management Programme (ERMP) were endorsed by the EPA in Bulletin 115 (EPA, 1982). This report outlines the various activities undertaken by the Water Authority during the three year period 1982 to 1985, to comply with the management programme.

The Harding Dam has been built to augment the capacity of the West Pilbara Water Supply Scheme. This scheme now provides industrial and domestic water supplies to the Western Pilbara towns of Dampier, Karratha, Cape Lambert, Wickham and Point Samson. Groundwater supplies from the Millstream Aquifer provided the sole source of water to these towns prior to construction of the Harding Dam and impoundment of water in Lake Poongkaliyarra (the reservoir area formed by the Harding Dam). Roebourne was supplied from a local groundwater source prior to its connection to the West Pilbara Water Supply Scheme in 1983.

The frontispiece of this report shows the Recreation Pool and associated facilities, downstream of the dam embankment.

2.0 CONSTRUCTION AND COMMISSIONING

2.1 CONSTRUCTION SCHEDULE

In 1974 a comprehensive investigation of engineering, environmental and economic parameters was initiated on groundwater and surface water resources in the Pilbara region to augment the West Pilbara Water Supply Scheme.

The Pilbara environment is particularly difficult for the development of surface water supplies due to a combination of factors, including: erractic streamflow, high evaporation rates and poor storage characteristics. To overcome this problem the Water Authority has adopted the strategy of conjunctive use, whereby surface and groundwater sources are jointly used to optimise the volume of water which can be drawn from the system.

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* Prior to July 1985, the Public Works Department was responsible for the country areas water supply. This is now administered by the Water Authority of Western Australia.

One of the benefits of the conjunctive use strategy is that the rate of draw on the Millstream Aquifer is considerably reduced, particularly during the early years of operation. As water consumption has risen over the last decade and the draw from Millstream has increased, aquifer levels have fallen. This has resulted in reduced natural springflows, which in turn stressed the environment. Recent good rainfalls have recharged the aquifer and under the conjunctive use strategy, the reduced draw from the aquifer is expected to maintain aquifer storage and natural springflows at their current levels.

As part of the present developments, the Water Authority, in conjunction with the Department of Conservation and Land Management (CALM) and the Department of Conservation and Environment (DCE) is implementing a comprehensive water management programme for the Millstream environment. The management programme, which was approved by the EPA in July 1984 includes the construction of works to supplement flows at the major springs to ensure that the riverine environment is maintained if aquifer water levels fall in the future. Water use and biological characteristics of the environment will also be monitored as part of that programme. The first annual report was submitted to the EPA by the Water Authority in July 1985.

The State Government authorised detailed investigations and design work to be carried out in June 1981 at the Harding Dam site - selected after a thorough evaluation of the engineering, environmental and economic criteria was undertaken on a wide range of alternative sites. The EPA endorsed the draft ERMP in August 1982.

On 1 February 1983, Cabinet decided that construction should proceed on the Harding Dam project subject to several conditions relating to the protection of Aboriginal sites. A working group comprising officers of the Public Works Department (now the Water Authority), Aboriginal Affairs Planning Authority, National Parks Authority (now part of CALM) and the Western Australian Museum was established to assess relevant Aboriginal issues.

Leighton Contractors Pty Ltd was awarded the construction contract in February 1983, and work started one month later. The embankment was completed in time to store water during the 1984/85 wet season. The pump station and water treatment plant were commissioned in August 1985.

The main embankment was constructed in two stages during the 1983 and 1984 dry seasons. Construction of Stage 1 of the embankment required special flood measures to be incorporated into the design to withstand the intervening wet season. During March 1984 rainfall on the catchment resulting from Cyclone Chloe produced the largest flood ever recorded on the Harding River. The flood was estimated to pass nine metres deep over the protected embankment. Work on Stage 2 commenced in June 1984 and was completed on schedule in November 1984 and the dam commenced storing water with the flows generated by Cyclone Gertie in January 1985. The intake tower, outlet culvert, scour outlet, pump station and water treatment plant comprise the outlet works. The facilities were built over the two construction periods. The intake tower comprises four multi-level screened offtakes to ensure the best quality water can be drawn from the reservoir and utilised by the public.

2.2 ENVIRONMENTAL MATTERS

During the compilation of the ERMP, an environmental management programme was established to alleviate the changes which took place during the construction and operation phases of the project. These management techniques and the EPA recommendations on management undertakings are outlined in Table 1.

Some of the main management undertakings at the Harding Dam were:

o Dust Suppression

During the construction phase, water sprays were used on haul roads and vehicular speeds were limited. This policy ensured that the dust levels at the site were kept to a minimum.

o Borrow Areas

The majority of the earthfill for the embankment was obtained from borrow area 3, just upstream of the embankment. However, three borrow areas were located outside of the reservoir area. These areas have been re-contoured and spread with stockpiled topsoil (Plates 1B, 1D, 1E and 2D). The Contractor elected to use coarse shingle from his borrow areas in the river channel near Pinanular Pool. This area has since been graded.

o Erosion Control and Rehabilitation

Once construction was completed, all temporary buildings were removed, and all temporary causeway constructions across the Harding River downstream of the embankment were removed.

The disturbed areas downstream of the dam embankment, including construction roads, camp and administration areas and borrow areas - have all been rehabilitated by removal of all imported fill material, deep ripping on the contours, and the re-spreading of topsoil over borrow/construction areas. At present there is only minor regrowth on these rehabilitated areas, and there has been minimal wind erosion (Plates 1D and 2A). This requires further monitoring to ensure regrowth continues satisfactorily.

o Regrowth on Shoreline

Appendix 9 of the Volume of Appendices outlines the vegetation species that have re-established themselves on the banks of Lake Poongkaliyarra. The open spinifex plains at the base of Table Hill are subjected to fluctuating water levels of the lake. This area is being revegetated by the prolific growth of annual plant species (Plate 2C and 2F).

o Permanent Roads

The access road in the vicinity of the dam has been sealed to 'all weather' standard, and has been provided with adequate drainage.

o Waste Disposal

The permanent buildings near the Harding Dam - the pumping station, water treatment building, toilets in the recreation area downstream of the embankment and the Ranger's house, have all been provided with waste disposal systems which comply with all statutory requirements. The first three systems are gravity fed to two small pump stations which pump to a waste treatment pond. Waste generated at the Ranger's house is disposed into septic tanks.

o Roebourne Aquifer Management

Prior to 1983 the Roebourne Town Water Supply was supplied solely from bores located adjacent to the banks of the Harding River. However, in 1983 Roebourne's water demand could not be met from water extracted from the aquifer, and Roebourne was connected to the West Pilbara Water Supply Scheme.

3.0 HYDROLOGY

3.1 INTRODUCTION

Hydrological studies undertaken and incorporated in the ERMP (Dames & Moore, 1982a) are referred to in this section of the triennial report, and where possible, additional information is given to update that data.

3.2 DATA COLLECTED AND RESULTS

3.2.1 Climatic Data

Rainfall, temperature, pan evaporation and relative humidity are recorded at the meteorological station at Harding Dam, on the southern bank of the recreation pool (Station 504 028) from 1 February 1985 (Plate 1A).

Prior to this, temperature data had been recorded at the site office for approximately two years. The estimated pan evaporation for the Harding Dam correlates reasonably well with the recorded pan evaporation (the difference for the six months from February - July 1985 is less than 5%).

The climatic data for the damsite is shown in Tables 2 and 3.

The mean annual value of rainfall for the years 1980 to 1983 is consistent with the long term average as shown in Table 2 of ERMP (Dames & Moore, 1982a). The monthly values vary from year to year, and are due to cyclonic thunderstorms that pass through the area.

The mean monthly and annual potential evaporation values from years 1981 to 1983 (Table 3) is relatively lower than the adopted average values as shown in Table 3 of the ERMP (Dames & Moore 1982a).

TABLE 2

MONTHLY RAINFALL (mm)

YEAR	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
1981	47.4	154.6	42.2	5.9	21.7	9.0	48.0	0	0	0.2	0	8.5	337.5°
1982	86.4	83.0	7.3	3.9	86.7	28.1	0.2	0.7	3.2	0.1	0.8	27.2	327.6°
1983	14.2	11.2	13.5	24.2	0	1.9	11.2	0	1.4	0	0.1	0.6	78.3°
			0	14.7	0	14.4	9.3	0	2.2	0	0	1.0	41.6*
1984	94.0	54.1	261.9	9.6	73.4	0	32.8	8.2	0.7	0	NA	NA	534.7°
	37.7	49.8	258.4	0	72.0	0	23.9	4.8	1.4	0	0	12.7	460.7*
AVERAGE	60.5	75.7	81.2	10.9	45.5	9.8	23.1	2.2	1.3	0.1	0.3	12.1	322.7

° Cooya Pooya (1981-84), Station 504 019
* Harding Damsite (1983-84), Station 504 028
Source: Hydrology Branch, Water Authority of Western Australia

TABLE 3

ESTIMATED MONTHLY POTENTIAL EVAPORATION (mm)

YEAR	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
1981	343	227	258	279	195	134	165	200	294	393	407	424	3319°
1982	324	260	308	243	185	143	168	202	243	355	355	420	3206°
1983	422	357	366	250	218	162	170	211	290	402	375	383	3606°
				285	257	203	214	266	342	449	417	395	2828*
1984	360	333	238										931°
	394	325	226	203	185	216	175	219	257	436	442	453	3531*
AVERAGE	362	294	293	257	199	146	168	204	276	383	379	409	3370

° Millstream (1981-84)
* Harding Damsite (1983-84), Station 504 028
Source: Hydrology Branch, Water Authority of Western Australia

3.2.2 Streamflow Data

A record of the water surface level in the storage has been maintained since the completion of the embankment. This record includes the inflow due to the rainfall of the 31 January and the 1 February 1985 resulting from Cyclone Gertie. A total of 155mm of rain fell over an 18 hour period, and by 1 February the water level had risen to within three metres of the full supply level (FSL). The reservoir went from zero storage to a storage volume of $31.42 \times 10^6 m^3$. The data is recorded by chart at station Lake Poongkaliyarra (709 011).

The mean monthly and annual streamflow values for the years 1980 to 1984 are shown in Table 4. In general they appear consistent with the long term average as shown in Table 14 of the ERMP (Dames & Moore, 1982a), except for the month of March where an increase of approximately 100% has occurred over the last 5 years.

The annual average streamflow for the last five years is consistent with the long term (77 year) average for the Harding River.

TABLE 4

HARDING RIVER DAMSITE

MONTHLY FLOWS $m^3 \times 10^6$

1980-1984

YEAR	O	N	D	J	F	M	A	M	J	J	A	S	ANNUAL
1980	0	0	0	1.996	5.422	11.74	.0305	0	0	0	0	0	19.19
1981	0	0	0	.296	2.679	.1027	0	.3096	.00062	0	0	0	3.388
1982	0	0	0	0	0	0	.8583	0	0	0	0	0	.8583
1983	0	0	0	.7139	13.12	127.7	1.884	4.231	1.326	1.362	1.149	.5406	152.1
1984	NA	NA	NA	27.8	6.4	.92	.42	0	0	0	NA	NA	35.54
Average Flow (5 yrs)	0	0	0	6.161	4.964	28.093	.6386	.9081	.265	.2724	.2298	.1081	42.2153
Average Flow (72 years)*	0	0	0.52	9.02	9.39	14.02	2.83	2.42	3.31	0.46	0.10	0.01	42.08
Average Flow (77 years)	0	0	0.52	8.83	9.10	14.93	2.69	2.32	3.12	0.45	0.10	0.02	42.08

* Table 14, ERMP
NA - Not Available
Source: Hydrology Branch, Water Authority of Western Australia

3.2.3 Water Quality

To determine the quality of the water in Lake Poongkaliyarra, samples are taken at approximately monthly intervals on a vertical grid through the centre of the reservoir, with distances of 0.1, 0.6, 1.5, 2.5, 3.5, 4.5, 5.5km from the dam embankment and at depths of 2, 4, 6, 8, 10, 12, 14 and 16m. The samples are analysed for temperature, conductivity, dissolved oxygen, pH, colour and turbidity. Figures 1 and 2 show the chemical parameters graphed over nine sampling periods for the average of two sampling locations (0.1 and 0.6km upstream of the dam embankment), and over two depth ranges (average from surface to 8m and average over entire depth).

Turbidity levels, although initially high, were by the second sampling period (10 days after the first samples were collected) well below the NH & MRC desirable current criteria of 25 NTU.

Colour levels were initially above the preferred colour limit (30 Hazen Units), but within the NH & MRC recommended level (50 Hazen Units). The levels decreased to the acceptable levels within 20 days of the lake filling. Colour appears to be uniform throughout the lake depth by the end of August, six and a half months after filling of Lake Poongkaliyarra (Figure 1).

Vertical stratification of the water column occurred soon after the lake filled, due to heating of the upper layers of the lake. This temperature stratification resisted mixing by the wind and lasted for approximately two and a half months (to the end of April 1985). Dissolved oxygen initially showed a marked gradient between the top 8m of the lake and the average over the entire depth of the lake (Figure 1). This is shown further in Figure 2, where dissolved oxygen is graphed (as percentage saturation) against time and depth. Towards the end of the period of marked stratification of the lake, lower dissolved oxygen levels in the base of the lake were observed. As the water temperature of the lake profile became more uniform, the dissolved oxygen values increased throughout the profile.

Average pH levels in Lake Poongkaliyarra were initially within the desirable current criteria (6.5 to 9.2) as set out by the NH & MRC for the first month of water retention and have since fallen into the long term objective level (7.0 to 8.5) for both depths, i.e. average surface to 8m depth give average pH values of 7.4 to 8.1 and the average pH over the entire lake depth ranges from 7.2 to 7.9.

3.3 WATER AND SALT BALANCES

3.3.1 Introduction

The rainfall event of the 31 January and 1 February 1985 contributed 31.42 x $10^6 m^3$ of water and approximately 2500t of salt as measured in Total Soluble Salts (TSS). Significant rainfall events on the 25 February, 1 March and 17 April and the recession from 31 January and 1 February, increased the total salt load into the Lake to approximately 5100t. From the beginning of March the storage has shown a gradual decrease to 27.4 x $10^6 m^3$ as at the 12 August 1985 (Figure 3).

3.3.2 Water and Salt Balances

Water and salt balances have been calculated from 5 February to 25 July (Table 5). Changes in the lake storage volume and salt load can be accounted for by evaporation and stream inflows. However, higher coefficients of lake to pan evaporation were required than was used by the Snowy Mountains Engineering Corporation (SMEC, 1982). The coefficients used for May and June by the SMEC were 0.72 and 0.57 respectively, while the values calculated from the water balances were 0.87 and 0.83. The lake to pan coefficients used by SMEC assumed a full lake with a mean depth of 5.2m whilst through May and June 1985 the lake was only partly full with a mean depth of 4.6m, which is a 13% difference.

The reservoir salt load has stabilised at approximately 5200t (Figure 4). It is expected that there will be no major salt inputs until the next wet season (January to March 1986). Minor reductions may occur in the salt load as water is pumped for water supply or released into the downstream Recreation Pool.

3.3.3 Salinity of Recession Inflows

The water quality sampling which was done on the Harding River prior to the Lake construction at Cooya Pooya gauging station (709 001), indicated that the TSS concentration varied from 100 to 1500mg/L TSS. Even at high flow rates of 100 to 200m^3/sec, the salinity is approximately 100mg/L, although at very high flow rates of 300 to 1500m^3/sec, the TSS concentration is expected to reduce below 100mg/L to approximately 70mg/L. However, it is considered that the salinity of the lake will consistently remain above 100mg/L TSS except for very short periods subsequent to extreme rainfall events and prior to the streamflow decay.

Comparison of the calculated TSS concentration and flux of the inflows with the water quality analysis prior to the lake construction shows little significant variation. However, it must be noted, that generally the recession inflows for February to April 1985 are at the upper limit of the previously recorded salinities.

3.3.4 Salinity Projection

By extrapolating the storage and salinity curves and calculating a water and salt balance, an estimate on the storage and salinity for January 1986 has been made (Figure 3). At the beginning of January 1986 prior to any major additional inflows, it is estimated that the storage will be in the range 21 to 23 x $10^6 m^3$ and the salinity 220 to 240mg/L.

TABLE 5

WATER AND SALT BALANCES

LAKE POONGKALIYARRA

DATE	WATER SURFACE (m)	VOLUME ($x10^6 m^3$)	SURFACE AREA ($x10^3 m^2$)	RESERVOIR SALT LOAD ($x10^3 t$)	RESERVOIR SALINITY (mg/L)	ESTIMATED INFLOW ($x10^6 m^3$)	ESTIMATED INFLOW SALINITY (mg/L)
5 Feb	56.87	31.52	6907	3.28	104	.81	450
15 Feb	57.1	33.16	7344	3.65	110	1.84 .2	300 800
1 Mar	57.2	23.90	7540	4.30	127	.305 .385	570 1250
15 Mar	57.15	33.49	7430	4.95	148	.65	400
29 Apr	56.81	31.11	6797	5.19	167	-	-
27 Jun	56.44	28.72	6151	5.09	177	-	-
25 Jul	56.34	28.11	5988	5.23	186	-	-

Source: Hydrology Branch, Water Authority of Western Australia

4.0 ENVIRONMENTAL MONITORING

4.1 INTRODUCTION

The ERMP prepared in January 1982 (Dames & Moore, 1982a) for the Public Works Department recommended that monitoring programmes be undertaken to provide information on:

- o Fauna species utilising the area
- o The downstream pools
- o The mangals at the mouth of the Harding River
- o The reservoir ecosystem.

These recommendations were endorsed by the EPA in their report dated August, 1982 (EPA, 1982).

To achieve the objectives of the EPA recommendations, the baseline data collected in previous studies (Dames & Moore 1979; 1982a) require up-grading. The necessary data were augmented by pre-construction surveys undertaken in April and July 1982, March 1983 and July 1984 (Dames & Moore 1982b; 1982c; 1983a; 1984a). These reports are contained in the Volume of Appendices to this report as Appendices 1, 2, 3, and 5.*

Permanent transects were installed at the downstream pools (Waranoolar and Pinanular) in March and July 1983 and resurveyed in July 1984 (Dames & Moore 1983b; 1984b). These reports form Appendices 4 and 6.

A report on the second aerial photographic assessment of the mangals, undertaken in November 1984 (Dames & Moore, 1984c), forms Appendix 7. The first mangal assessment is found in the ERMP (Dames & Moore, 1982a).

Surveys undertaken in 1985, following completion of construction and initial filling of Lake Poongkaliyarra, include an assessment of the downstream pools, Waranoolar and Pinanular Pools (Dames & Moore, 1985a) which is contained in the Volume of Appendices as Appendix 8.

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* Copies of the Volume of Appendices are available for public viewing at the John Tonkin Water Centre, Newcastle Street, Leederville.

The first flora and fauna survey of Lake Poongkaliyarra was undertaken in May 1985 (Dames & Moore, 1985b). This survey appears as Appendix 9.

4.2 PRE-CONSTRUCTION VEGETATION AND FLORA

4.2.1 Vegetation

The vegetation of the reservoir area was described in Dames & Moore (1982a). During July 1982, ephemeral and annual plants were collected (Appendix 2) to add to the known vegetation communities previously recorded.

4.2.2 Flora

The ERMP (Dames & Moore, op. cit.) recorded a total of 173 species of flowering plants within the reservoir area with an additional 7 species around Bamba and Pinanular Pools. Nine of the species recorded during the ERMP survey were introduced species.

The April 1982 survey (Appendix 1) added 26 species to the list while the July 1982 survey (Appendix 2) added a further 31 species to the list which had been commenced in Dames & Moore (1979). No additional species were collected during the March 1983 survey (Appendix 3).

To date, a total of 237 plant species has been collected representing 48 families. The largest family represented is Poaceae (13% of species), with Papilionaceae (10%) and Amaranthaceae (6%) being the second and third largest respectively.

None of the species collected is recorded on the rare or endangered species lists compiled by Marchant and Keighery (1979) or Leigh et al., (1981).

4.3 PRE-CONSTRUCTION TERRESTRIAL FAUNA

4.3.1 Mammals

The baseline survey for the ERMP collected, trapped or observed a total of 15 species. The April and July 1982 surveys added 6 and 1 species respectively. The March 1983 and July 1984 surveys added a further 3 and 1 species respectively.

A total of 26 species of mammals have now been recorded for the project area from 7 orders and 11 families. The largest orders are Marsupialia and Chiroptera each with 8 species.

4.3.2 Herpetofauna

The ERMP survey identified 21 species of lizards, 1 snake and 2 species of frogs. The April 1982 survey added 9 species of lizards, 3 species of snakes and 1 frog.

One species each of frog, lizard and snake was added during the July 1982 survey and 1 species each of lizard and snake during the March 1983 survey.

The most successful follow-up survey was undertaken in July 1984 when 7 lizards and 3 snakes were added to the list.

A total of 4 species of frogs, 41 species of lizards and 9 species of snakes (54 individual species) have now been identified at the site.

4.3.3 Birds

During the ERMP survey, a total of 57 species was observed which included 20 species of passerines representing 12 families, and 37 species of non-passerines representing 17 families. There was a high number of waterbirds, totalling 18 species.

The April 1982 baseline survey (Appendix 1) increased the number of species observed at the site by 12, to a total of 69 species. Nest searching also was undertaken in and around the pools and riverine systems.

During the July 1982 survey (Appendix 2) a further 13 species were added to increase the total to 82 species.

The March 1983 survey (Appendix 3) added 3 new species and the July 1984 survey (Appendix 5) added a further 5, bringing the total to 90 species of birds. These species have increased the recorded number of passerine families to 17 and non-passerines to 23.

4.4 MONITORING OF DOWNSTREAM POOL ECOLOGY

4.4.1 Introduction

Recommendation No. 7 from the EPA (1982), following examination of the ERMP, states - "A monitoring programme should be implemented to determine the effect of the altered river regime on the ecology of the downstream Harding River pools.....".
To satisfy the requirements of the EPA recommendation, a baseline survey of vegetation at Waranoolar and Pinanular Pools was undertaken in July 1983. This survey was followed by further monitoring surveys in July 1984 (Appendix 6) and in May 1985 (Appendix 8).

As outlined in the ERMP (p.137), a programme of pool level monitoring and ground water level monitoring was in operation as part of the management and development of the water resources in the area. The regional water table fluctuates in a cyclic pattern throughout the year. Piezometer water level fluctuations were analysed to determine the mean level of the pools. One piezometer was situated at Waranoolar Pool and four at Pinanular Pool. A mean level of 37.1m (Australian Height Datum) was recorded between December 1981 and March 1985 from Waranoolar Pool and a mean level of 33.6m during the same period for Pinanular Pool. The piezometer levels at both pools fluctuate in response to the seasonal groundwater. During the wet season, recharge of the groundwater results in rises of the piezometer levels, whilst during January and February the goundwater level drops.

4.4.2 July 1983 Survey

The full report of this survey is contained in Appendix 4.

To enable the vegetation to be monitored on a regular basis, permanent quadrats, transects and photographic points were pegged and surveyed into the Australian Survey grid.

The survey concentrated on Melaleuca leucadendron (cajeput) as it was considered to be a primary indicator of habitat changes induced by river impoundment. A condition scale was developed to assess the health of the cajeputs around the pools.

A total of 213 cajeputs were assessed around Waranoolar Pool. The overall condition of the cajeputs was good. However, 12% were in poor condition and 2% were dead. Ten quadrats were located in mixed stands of M. leucadendron, Eucalyptus camaldulensis and E. coolabah around the pools.

4.4.3 July 1984 Survey

The results of this survey are contained in Appendix 6.

The objectives of the survey were to examine the health and stress status of the permanent vegetation around Waranoolar and Pinanular Pools, examine the permanent quadrats around the pools, and to rephotograph at the pegged photographic points.
There was considerable variation in the condition of the vegetation between the two surveys. In March 1984, Cyclone Chloe crossed the coast near Roebourne and heavy rainfall was recorded in the catchment of the Harding River. The highest ever flood levels were recorded during the flood flow which resulted.

The result of the flood was that most small seedling trees were removed, to the extent that 56% of cajeputs were lost at Waranoolar Pool and 13% at Pinanular Pool.

The survey increased the data base available for the pools and has shown that great variation occurs between conditions of drought and flood. Therefore, it will be difficult to assess changes in the vegetation caused solely by the construction of the Harding Dam.

4.4.4 May 1985 Survey

Results from this survey are contained in Appendix 8.

This survey was the first undertaken on the downstream pools since the completion of the Harding Dam Reservoir. Pinanular Pool was not analysed during the May survey as the quadrat and photographic point star pickets had been removed. Analysis of Pinanular Pool occurred in October 1985 after re-surveying of the quadrats and photographic points, and forms an addendum to Appendix 8.

The growth of the previously selected trees over the preceeding nine months was measured and condition ratings given to the 94 remaining cajeputs. Overall, the results showed that the selected trees had grown over the nine month period and that the condition rating of the trees had remained similar. The vegetation boardering Pinanular Pool appears to be showing no sign of deterioration following impoundment of water by the Harding Dam. The condition ratings and photographic assessment show that the cajeputs and river red gums are as healthy as in the July 1984 survey.

Table 6 outlines the recorded water levels at Pinanular Pool, as well as the average groundwater levels, recorded by four piezometers located around Pinanular Pool.

TABLE 6

PINANULAR POOL WATER LEVELS
(STATION Q 709 1075)
AND AVERAGE GROUNDWATER LEVELS
AHD (m)

		PINANULAR POOL	AVERAGE GROUNDWATER
1982	6 April	34.4	33.4
	9 December	32.8	33.1
1983	10 February	31.5	32.8
	22 June	35.7	33.6
	19 August	33.7	33.2
	8 November	31.1	32.4
1984	24 January	34.1	33.1
	2 October	38.7	34.8
1985	28 March	38.4	34.7
	12 September	36.4	33.8

Source: Hydrology Branch, Water Authority of Western Australia

Table 6 outlines the correlation between the pool and groundwater levels. Following heavy rains associated with Cyclone Chloe (March 1984) and Cyclone Gertie (January 1985), the pool level rose and has supplemented the groundwater in the region.

4.5 MANGAL SURVEY

4.5.1 Introduction

The EPA (1982) recommended that vertical colour aerial photographs be flown at three yearly intervals to identify broad changes in the condition of mangroves growing at the mouth of the Harding River. Changes might be expected due to altered conditions of freshwater flow and sedimentation from the Harding River.

The first photography was taken and assessed in 1981 and reported in the ERMP. The second photographic run was undertaken in April 1984 and the report on this assessment (November 1984) is contained in the Volume of Appendices as Appendix 7.

4.5.2 November 1984 Assessment

Recruitment and growth of mangroves between 1981 and 1984 is evident in several areas. Also evident were significant changes in sedimentation patterns. These occured before the dam became operational. Such changes indicate that coastal sedimentation and sediment patterns in the Harding River area are dynamic and can be dramatically altered by major short-term events such as Cyclone Chloe.

It is not expected that either sporadic river flows or the lack of them would have separately measurable effects on any mangroves in the system, due to the highly variable and unpredictable nature of flows prior to dam construction and the confounding influence of marine forces.

4.6 ON-GOING MONITORING PROGRAMMES

4.6.1 Vegetation and Flora

There have been a total of four surveys undertaken, the last in March 1983 which did not add any new species to the 237 flowering plant species found within the reservoir area. The Water Authority does not intend to undertake any further specific flora collections, however fringing vegetation on the open plains at the base of Table Hill will be collected during the bi-annual monitoring of the lake, to ascertain if any weed species are becoming established.

4.6.2 Terrestrial Fauna

The importance of birds as vectors in human diseases has been acknowledged in Section 7.5 of the ERMP. It is relevant, therefore, to monitor changes in bird populations and species present, paying particular attention to those species whose annual migration paths include areas of South-East Asia. Species in this category include the waders (sandpipers, curlews, plovers, etc.), egrets, terns, ibises, and some ducks.

A recommendation by the EPA for a bird census study to be undertaken two to three times a year after the establishment of a permanent water body with each survey period lasting 3-4 days has been implemented by the Water Authority. The first survey was undertaken in May 1985 and is contained in the Volume of Appendices as Appendix 9. This initial period of intensive survey will allow the regular seasonal patterns of abundance and diversity of both resident and migratory species to be determined (Dames & Moore, 1985b).

Once this has been documented, the relationship between bird density and water quality and quantity can be evaluated. Once an understanding of these patterns has been established, data from subsequent surveys can be more accurately interpreted (Dames & Moore, 1982a, page 139). A follow up survey will be undertaken in late October 1985.

Methods used in undertaking each bird census will be similar to those already employed elsewhere by the Royal Australian Ornithologists Union (RAOU). This means that the results of the monitoring programme will be directly comparable to RAOU data which is derived from observers throughout the Pilbara. Consequently, any trends will be much more easily understood and placed in a geographic context.

Discussions with staff of the W.A. Museum have resulted in the above recommendation, and the suggestion that fauna surveys related to other terrestrial vertebrate species would be of limited value to on-going monitoring programmes, as enough information has been gathered on their range and distribution in the region (Dames & Moore 1979; 1982a; 1982b; 1982c; 1983a; 1984a).

4.6.3 Aquatic Biota

The May 1985 survey (Appendix 9) on Lake Poongkaliyarra, included an analysis of the physical, chemical and biological environment. This entailed:

oCollection and analysis of plankton, aquatic plants, fringing vegetation, birds and fish
oAssessment of physical features of the Lake (capacity, surface area and levels)
oWater quality analysis, including major ions and nutrient analyses.

4.6.4 Downstream Pool Vegetation

The transect survey of the pools will be undertaken initially on an annual basis until the effect, if any, of the retention of water behind the dam can be ascertained. This will also enable comparison of surveys between the March 1983 (drought) and July 1984 (flood) surveys.

4.6.5 Mangals

Aerial photographic interpretation will be undertaken in 1986 on Lands Department aerial photographs (if available). The Water Authority proposes to commission vertical aerial photography of the mangals once every three years as recommended by the EPA (1982). This photography is due to be reflown in 1987, and at that stage, interpretation of the photography will be undertaken.

5.0 PUBLIC HEALTH

Based on the premise that the water stored in Lake Poongkaliyarra is available for domestic consumption and industrial usage in the Pilbara region, management techniques were initiated during clearing of the reservoir area, to ensure that the quality of the water is maintained at the best possible level, and falls within t' e NH & MRC standard. Other features incorporated to maintain the desired water quality to meet stringent Public Health criteria include: destocking, the restricted access to the storage catchment, control of vermin, arbovirus monitoring, fencing and water treatment.

Clearing of native vegetation in the Harding River channel was undertaken by sawfelling of the standing vegetation and burning the debris. This was to minimise the biological oxygen demand (BOD) of the water when the bio-mass was decomposing, and ensuring that the tree stumps and root systems were retained to minimise soil erosion in the reservoir area.

Regular monitoring on the chemical and biological quality of the water has commenced (see Appendix 9, Volume of Appendices). As outlined in Section 3.2.3, the water quality in Lake Poongkaliyarra is good. The average salinity of the water supplied from Lake Poongkaliyarra is expected to average 350mg/L, ranging from 100mg/L following a river flow to 1000mg/L in a near empty lake. Before the water from Lake Poongkaliyarra became available, the average salinity of water from the West Pilbara Water Supply Scheme was approaching 1000mg/L. Lake Poongkaliyarra, at the beginning of August 1985 had a storage of $28 \times 10^6 m^3$ and a salinity of 186mg/L TSS.

Apart from chlorination and fluoridation at the water treatment building, no other treatment is required to maintain a water supply quality within the standards set by the NH & MRC.

The quality of the water will also be controlled by utilising the appropriately designed outlet works. The intake tower has four multi-level screened offtakes and this enables the Water Authority to withdraw water of low turbidity to be utilised by consumers. If this practice is not effective in a particular situation, the water supply will be maintained by drawing water temporarily from the Millstream Aquifer, as part of the conjunctive scheme for the West Pilbara Water Supply.

Provision has been included in the design works for removal of water containing excessive levels of dissolved salts. This 'scouring' will be undertaken to avoid the progressive accumulation of salts in the Lake, and to improve the aquatic habitat in the Lake. 'Scoured' water will be aerated to minimise the impact of this water on the recreation pool, downstream of the dam embankment.

All pastoral activities on Cooya-Pooya Station and the rest of the catchment have ceased and the area has been de-stocked. Annual inspections will be undertaken to assess any build up of stock straying onto the catchment from surrounding pastoral stations.

Fencing of portions of the catchment along the boundaries with Woodbrook Station is still to be done. This is programmed to be completed by December 1985.

Other boundaries of the catchment have been inspected in conjunction with neighbouring pastoralists and it has been agreed that the topography of the land provides an adequate natural barrier which will prevent stock straying into the catchment.

The EPA report (EPA, 1982) expressed concern about the dingo populations in the area. The Pastoralists and Graziers Association outlined that the population could increase as a direct result of water availability, with the resulting possibility of higher sheep losses on surrounding stations. Information supplied in Appendix 9 of the Volume of Appendices shows that dingo scalps, collected from nearby pastoral stations, have fluctuated since 1979 but have decreased significantly during the first six months of 1985. The Water Authority is committed to the dogging programme and the Authority contributes financially to the aerial baiting being carried out by the Agriculture Protection Board.

Arbovirus vector and host monitoring has not as yet been undertaken by the Water Authority, but a suitable programme will be devised following discussion with the Public Health Department.

Throughout Western Australia, catchment areas for water supply dams are declared Water Reserves under the Country Areas Water Supply Act, 1947-1982. Water quality can then be protected by the application of the relevant By-Laws. The Harding Dam catchment area was declared a Water Reserve under this Act on March 2, 1984. In response to demand by local people for access to the catchment,the Minister exercised his discretion to modify By-Laws 31, 34, 35 and 36 as follows:

31 Bathing will be allowed in any watercourse more than 300 metres upstream of the high water mark of the reservoir behind the Harding Dam*

34 Cutting of timber for use in camp fires will be authorised

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* High water mark is the same as the FSL - that level at which the spillway starts to overflow.

35 Hunting, shooting and fishing will not be permitted in the area within the high water mark of the reservoir behind the Harding Dam*

36 No further restriction on camping and picnicking will be applied i.e. no camping or picnicking within 300 metres of high water mark*.

In making these modifications the Minister has advised that he will review them if problems are experienced in maintaining water quality in the water supply system to NH & MRC standards.

Figure 5 outlines the land tenure surrounding Lake Poongkaliyarra. The Water Authority resumed approximately 3250ha of Woodbrook Station from its Aboriginal owners in exchange for 16550ha of Cooya-Pooya Station. This land is now a Water Reserve (A35798) under the Land Act, 1933-1972.

6.0 COMMUNITY RELATIONS

6.1 PUBLIC INFORMATION

The Water Authority has ensured that the general public has been informed of the progress of the construction works at the Harding Dam, by media releases through local and state newspapers, television and radio during the past three years. Press releases coincided with major happenings at the site and completion of major earthworks. A pamphlet was issued by the Public Works Department in 1983 and updated in 1984 to outline the main construction developments and environment at the project site. There was an active programme to encourage site visits during the construction phase. The official opening ceremony of the Harding Dam, conducted by the Minister for Water Resources on 28 May 1985, was attended by many local people and the media were on hand to record the event. A 16 page opening ceremony brochure was published outlining an overview of the project and the environment at the site, and is available to the public from the John Tonkin Water Centre.

6.2 RECREATION FACILITIES

A recreation area has been established immediately downstream of the dam, and barbeque and picnic facilities are provided on both the northern and southern banks. A toilet block, shade houses, car park telephone, wooden playground equipment, post and rail fence and two open grassed areas are on the northern bank and a new Ranger's house is built on the southern bank.

The area has been extensively planted with Eucalyptus coolabah trees. The recreation pool has a jetty which will facilitate activities such as canoeing and fishing. The water level in the pool will be maintained by releasing water from Lake Poongkaliyarra through the scour outlet. Although no figures have been collected on tourist usage at the dam, it is well used by locals and tourists as well. No overnight camping is permitted at the recreation area.

6.3 WATER CONSERVATION

The Western Australian Water Resources Council (WAWRC) has considered the promotion of water conservation in the Pilbara as an on-going project since its formation as a statutory body in 1983. A report drawing attention to the high domestic consumption and recommending reductions in the water allowances provided by

employers was prepared by Council in September 1984. With the support of local Members of Parliament, this report has been referred to the Iron Ore Industry Consultative Council where it is presently being discussed.

There has also been a successful campaign to increase local public awareness of water conservation. The efforts by local Water Authority officers in putting on displays during the FENACL festivals (held at Karratha) as well as the production of a video on low water use gardens by the Mining Television Network in October 1983, all facilitate the notion of water conservation. Recently the Water Resources Council produced and distributed a pamphlet titled "Take it Easy in the Pilbara." This pamphlet contains ideas for water conservation in gardens and around the home. The WAWRC has a continuing interest in water conservation and will assist/promote local initiatives whenever possible.

The mining companies utilising the West Pilbara Water Supply Scheme are co-operating in the water conservation programme by installing low water usage gardens.

7.0 ABORIGINAL MATTERS

7.1 INTRODUCTION

Since the commencement of investigations into water supply in the West Pilbara, close liaison has been maintained with the Aboriginal groups. At all times during the construction of the Harding Dam, Contractors and Public Works Department staff were made aware of the traditional importance which the environment in the vicinity of the damsite has had to the Aboriginal people.

When Cabinet gave formal approval for construction of the Harding Dam to proceed on 1 February 1983, it was subject to several conditions relating to the protection of Aboriginal sites. One condition was the establishment of an interdepartmental committee comprising the Public Works Department (now the Water Authority), Aboriginal Affairs Planning Authority, National Parks Authority (now part of CALM) and the Western Australian Museum. This committee was formed to continue negotiations with the Yindjibarndi and Ngarluma people and their legal representatives to formalise arrangements for access to the Harding River catchment area, the storage area (Lake Poongkaliyarra) and the Chichester Range National Park, as well as to seek solutions to other matters of concern to the Aborigines including employment opportunities, tourism and facilities for Aboriginal use of the river.

7.2 ARCHAEOLOGY

All studies for the Harding Dam project have been undertaken in compliance with the Aboriginal Heritage Act, (1972-1980). During the reconnaissance survey to locate all archaeological places within the catchment area (Pearce, 1981), 92 sites were recorded. Of these the Western Australian Museum required the Water Authority to have specific archaeological work carried out at 40 locations. No sampling or salvaging was undertaken and all stone artefacts and other objects examined were left in situ. All sites of importance were protected during construction to the satisfaction of the local Aboriginal Community. Rock carvings removed from the dam site have been relocated to a site as directed by the local Aboriginal people. All recording and reporting on Aboriginal archaeological factors has been satisfactorily completed, and copies of the documentation have been given to the local community.

7.3 OTHER MATTERS

A group of Aboriginal people has been employed throughout the project, particularly on the landscaping of the project of the site. This employment scheme worked most satisfactorily for all concerned. The co-operation by the Aboriginal people have contributed to the success of the scheme. The lease of a large area of the former Millstream Station to the Aboriginal people is being formalised as part of the resolution of the difficulties caused by the loss of sites at the dam and traditional lands excised for the project. An Aboriginal Ranger will be employed by the Water Authority to carry out periodic checks on the entire catchment area to assess such issues as straying stock.

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PLATES

CAPTIONS - PLATE 1

a Meteorological Station at Harding Dam (Station 504 028), showing evaporation pond, rainfall gauge and temperature stand.

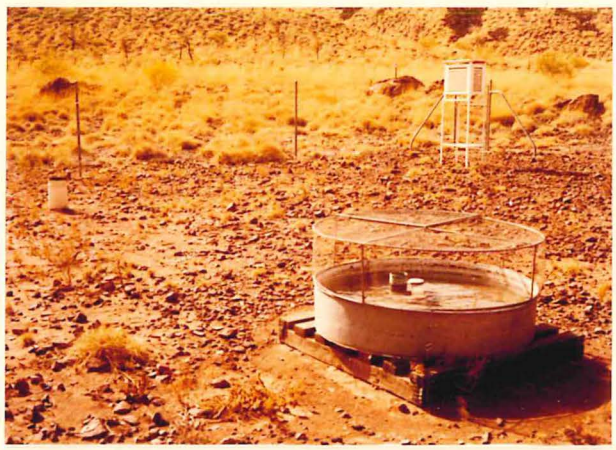
b Rehabilitation work on former main access road to Public Works Department construction camp. Sign posting is evident on all rehabilitated areas. Deep ripping has been carried out on the west and east sides of the area.

c View of Recreation Pool, downstream of dam embankment, pump station, water treatment building and substation.

d View of the former Public Works Department construction camp, now rehabilitated by spreading of stockpiled topsoil.

e Deep ripping along edge of Borrow Area 2 to the northwest of the main access road to the Recreation Pool.

f View from southern bank of the Recreation Pool looking onto recreation area showing carpark and shade houses.



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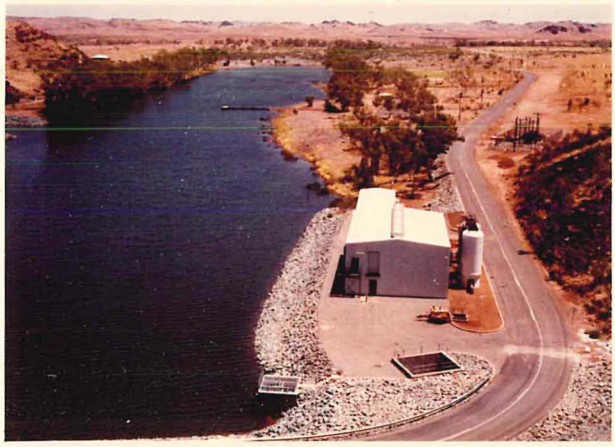

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Plate 1

Dames & Moore

CAPTIONS - PLATE 2

a Borrow Area 9, on the northern bank of Pinanular Pool, approximately 4km downstream of the Harding Dam.

b View of the Recreation Pool, taken from access road on dam embankment. Note the prolific regrowth of Typha species on southern bank, providing an important habitat for waterbirds utilising the pool.

c Prolific growth of annual plant species of grass on the open plains at the base of Table Hill.

d Borrow Area 2, showing re-contouring and respreading of topsoil.

e Deep ripping of access road to former Public Works Department construction camp. Ranger's house in background.

f Growth of annual plant species on damp open former spinifex plain with snakebush Acacia xiphophylla in background.

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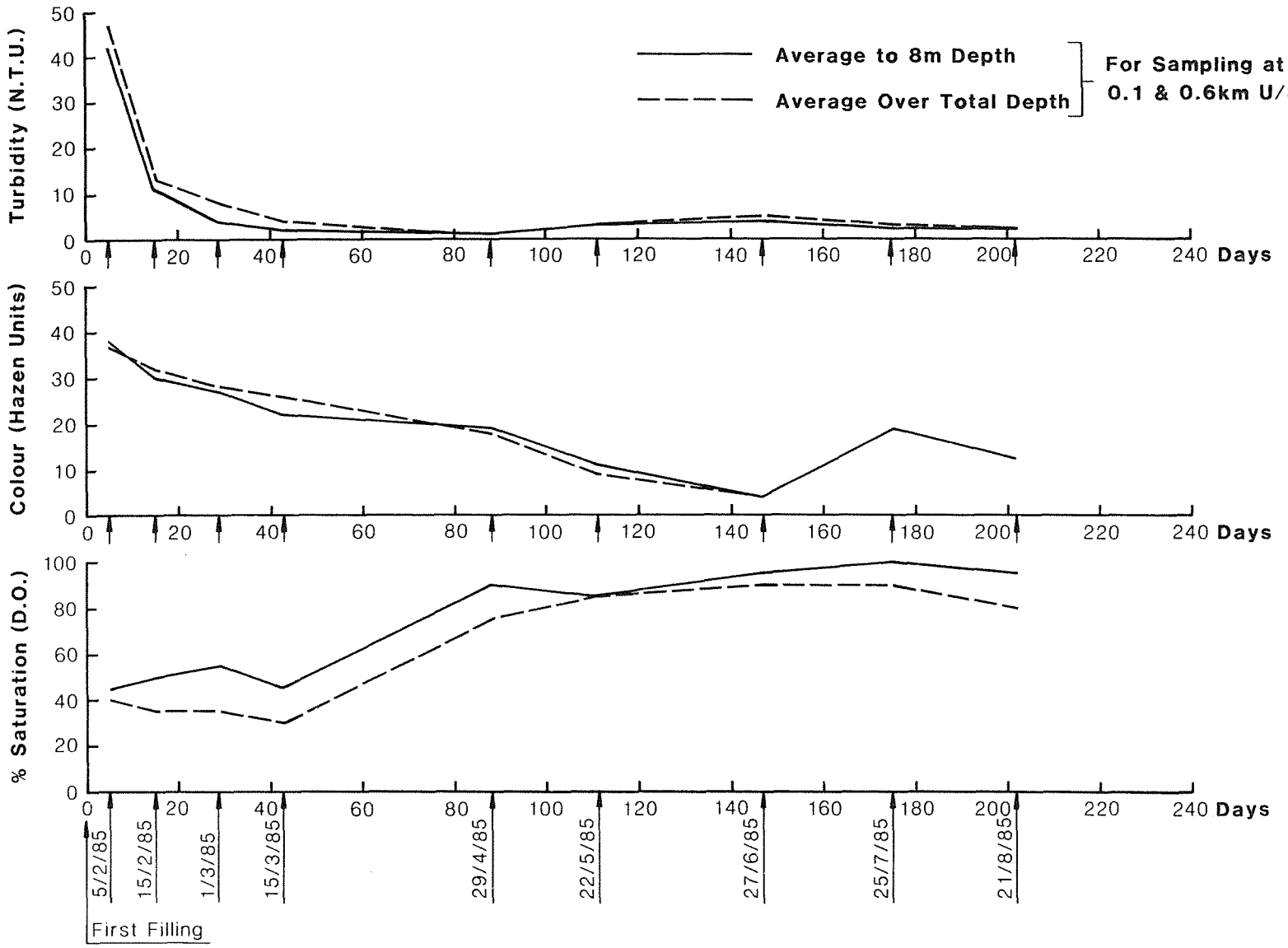
Plate 2

Dames & Moore

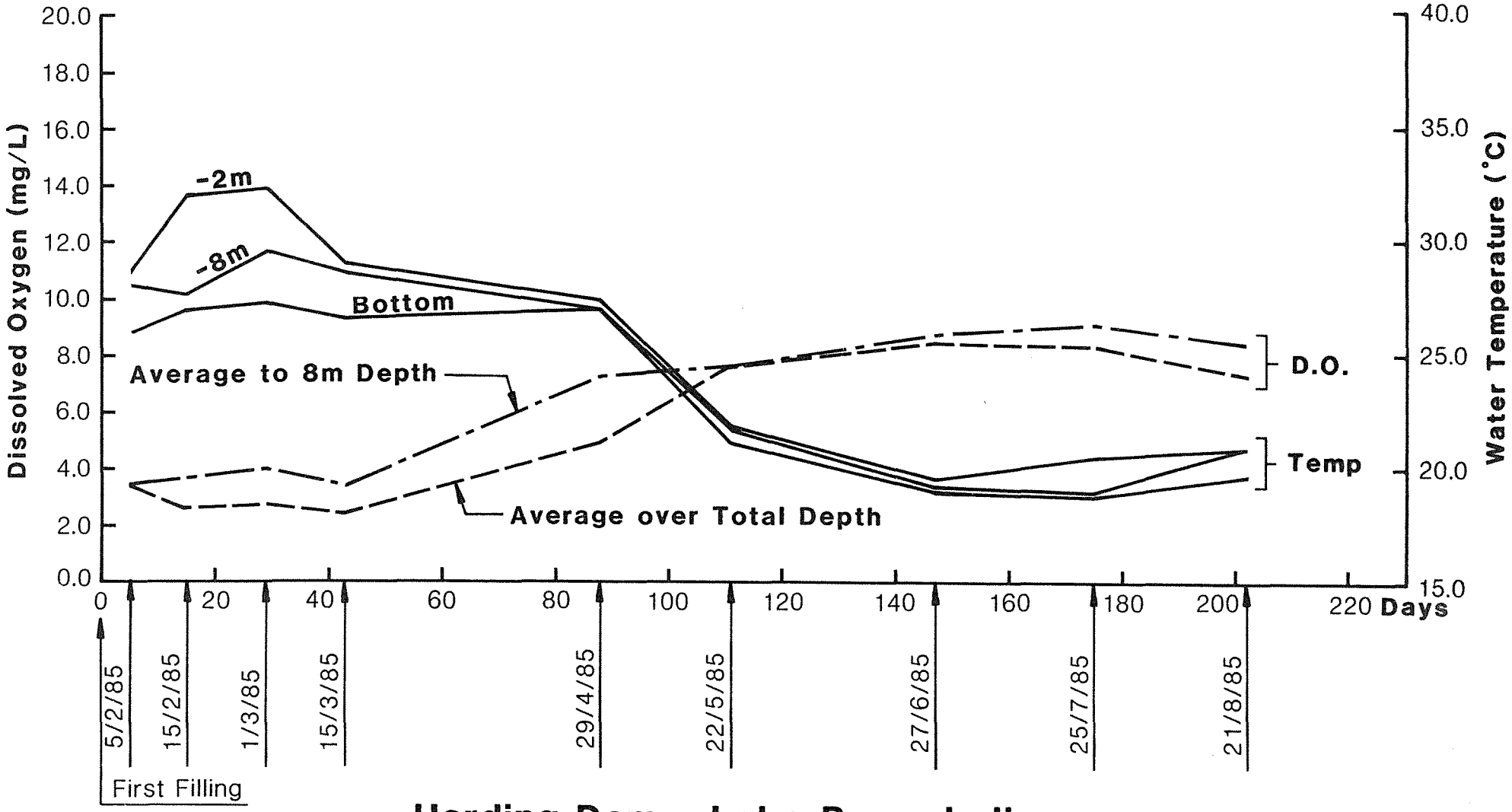
FIGURES



Harding Dam - Lake Poongkaliyarra

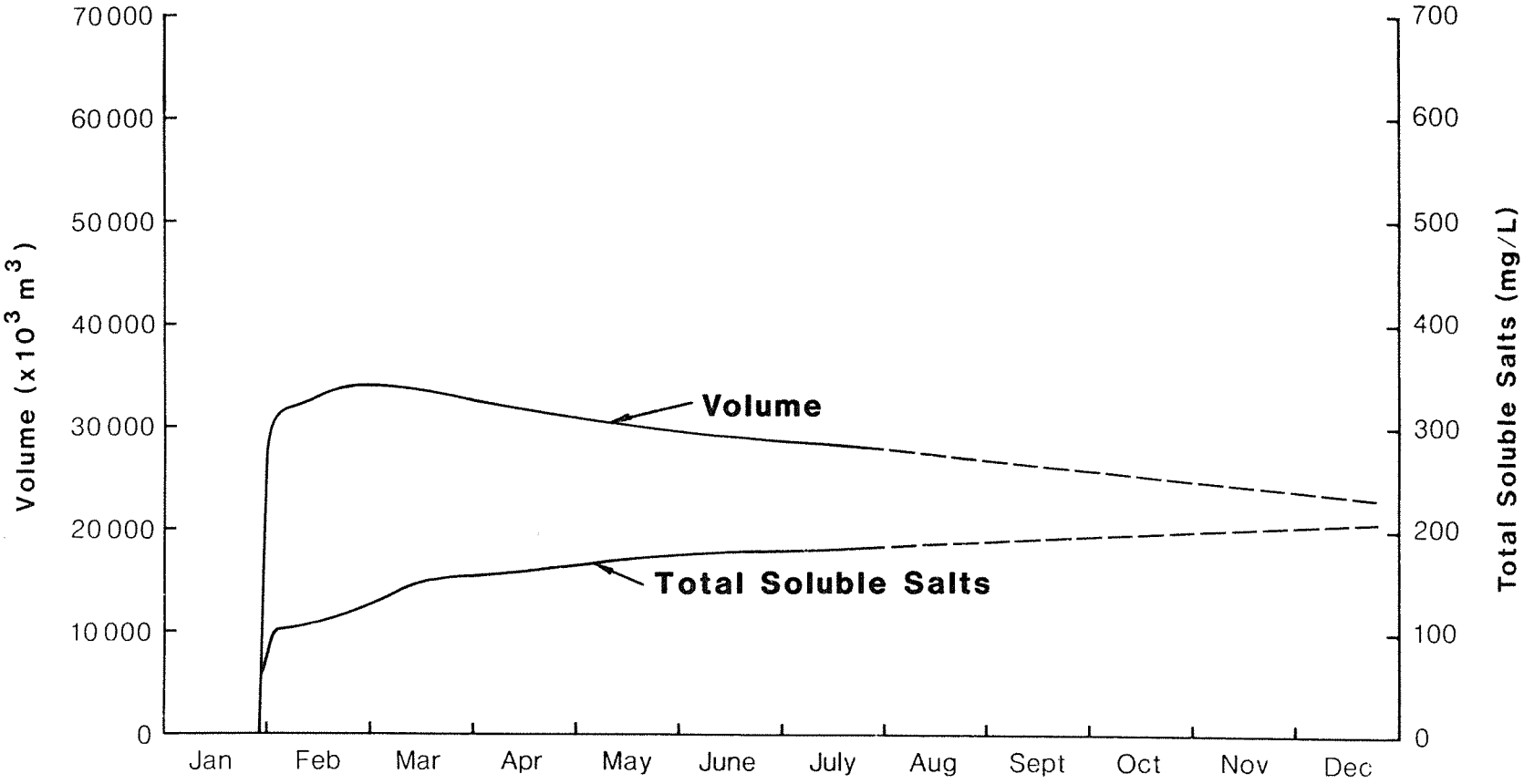
Water Quality - Turbidity / Colour / Dissolved Oxygen

Figure 1



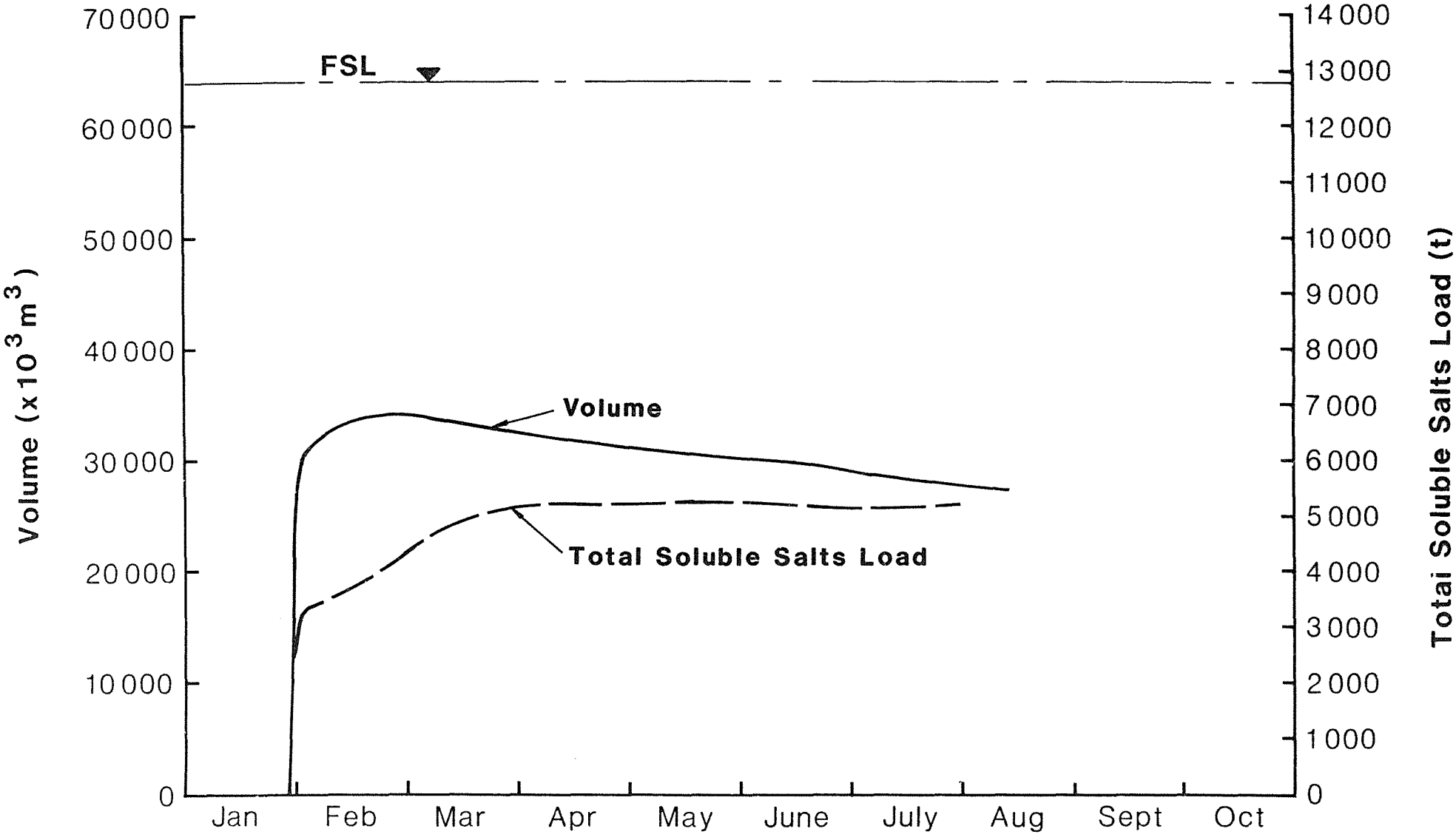
Harding Dam - Lake Poongkaliyarra
Water Quality - Dissolved Oxygen / Temperature / Time

Figure 2



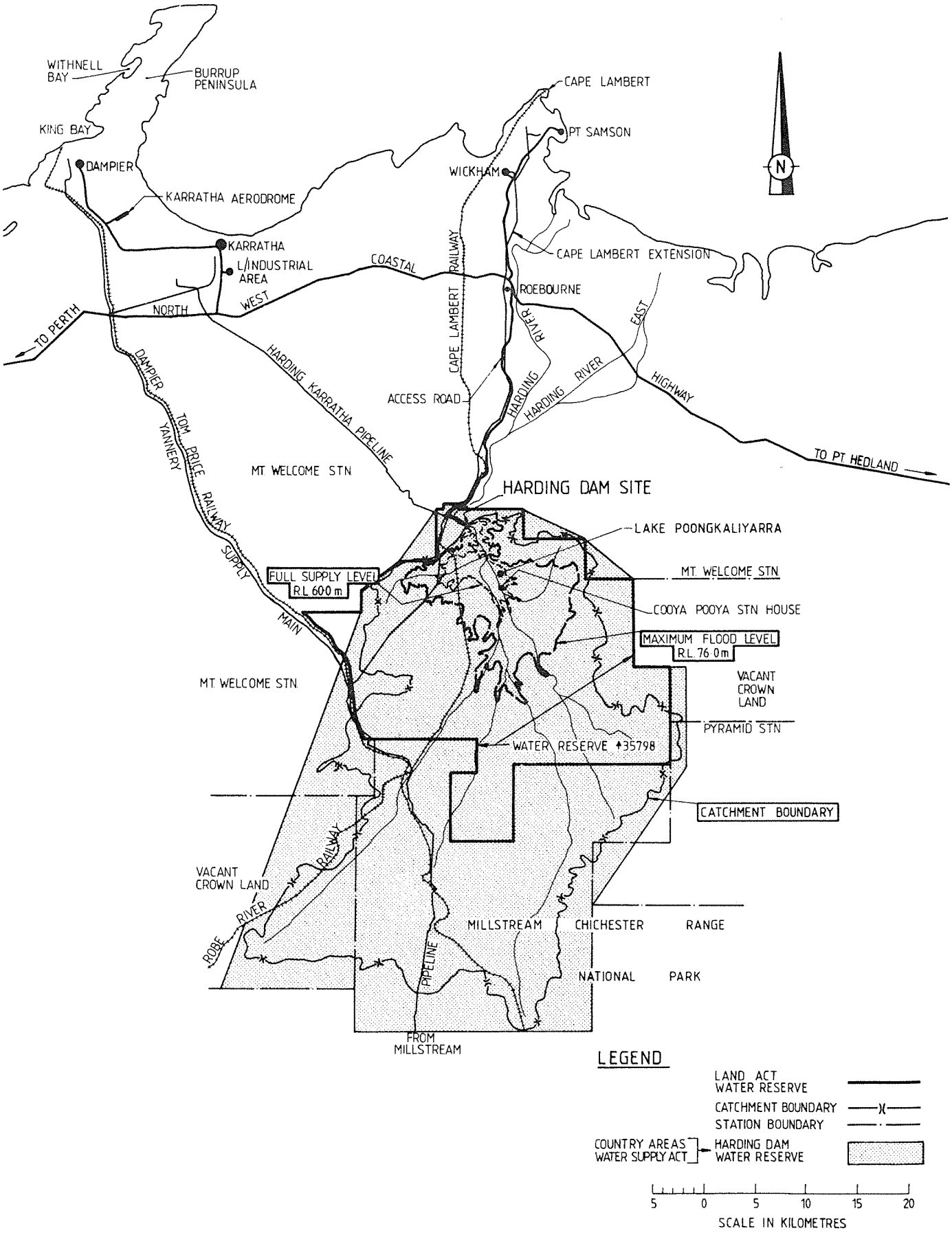
Lake Poongkaliyarra - Storage and Salinity

Figure 3



Lake Poongkaliyarra - Storage and Salt Load

Figure 4



Harding Dam Land Tenure

Figure 5