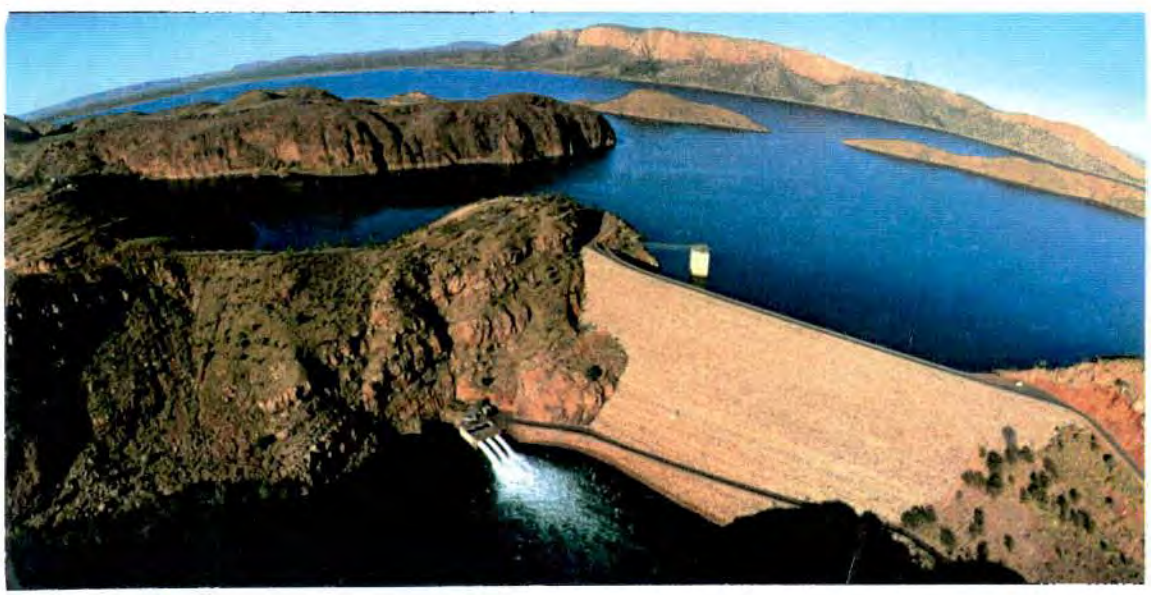
ARGYLE DIAMOND MINES JOINT VENTURE

ORD RIVER HYDRO-ELECTRIC PROJECT

PUBLIC ENVIRONMENTAL REVIEW



EMBER 1991

PUBLIC ENVIRONMENTAL REVIEW
ARGYLE DIAMOND MINES JOINT VENTURE
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This Public Environmental Review ("PER") for a proposed hydro-electric station and an associated transmission line in the east Kimberley region of Western Australia has been prepared by the proponent, Argyle Diamond Mines Pty. Limited acting on behalf of the participants in the Argyle Diamond Mines Joint Venture, in accordance with Environmental Protection Authority ("EPA") procedures and guidelines (see Appendix 12.2). The document will be available for comment for a period of eight weeks commencing 14 October, 1991 and finishing 9 December, 1991. The EPA invites submissions on the proposal.

Comments from government agencies, and from the public will assist the EPA in the preparation of an assessment report, and in the development of recommendations to Government. On receipt of these comments, issues raised will be addressed by the proponent in consultation with the EPA before finalising the report and submitting to Government.

Reasons for Submissions

A submission is a method by which interested people can provide information, express opinions about the project and suggest courses of action, including any alternative approach. Suggestions to improve the proposal will be welcome.

All submissions received will be acknowledged.

Developing a Submission

Submissions may agree with, disagree with, or comment on, general or specific issues discussed in the PER. It will assist the EPA in its assessment of the PER if reasons are given for conclusions and if conclusions are supported by relevant data. Submissions may make an important contribution by suggesting ways to make the proposal more environmentally acceptable. Comments on specific proposals in the document should:

- be clearly expressed;
- indicate the source of information; and
- suggest recommendations, safeguards or alternatives.

The analysis of submissions is enhanced if:

- a summary of the submission is included;
- the issues are listed;
- each point in the submission includes a reference to the appropriate section in the PER;
- discussions on different sections of the PER are separated to avoid confusion;
- factual information is attached with references to the source; and
- information is provided on whether the submission can be quoted, in part or in full, by the EPA in its assessment report.

The name and address of the person making a submission should be included on the submission along with the submission date.

The closing date for submissions is 9 December, 1991.

Submissions should be addressed to:

The Chairman
Environmental Protection Authority
1 Mount Street
PERTH W.A. 6000

For Attention: Mrs Katrin Wilson

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1.0 SUMMARY

1.1 PROJECT DESCRIPTION

Acting on behalf of the participants in the Argyle Diamond Mine Joint Venture ("the joint venturers"), Argyle Diamond Mines Pty. Limited ("ADM") proposes to construct a hydro-electric station at the Ord River Dam to supply electricity for the Argyle diamond mine. The project comprises three main elements: the construction and operation of hydro-electric power generating works with 40 MW capacity; the construction and operation of a 132 kV overhead transmission line to the Argyle diamond mine approximately 120 km to the south; and the construction of a weir in the existing spillway.

There is only one possible location for the power generating facility as the tunnels are already in place. However several alternative transmission line routes were examined. The transmission line route selected will have the least environmental impact of those examined. The alternatives were all rejected because of a combination of environmental, engineering and economic factors.

A camp to accommodate the workforce required for construction will be located near the existing Argyle Tourist Village.

The project is expected to be operational $2^1/_2$ - 3 years following project approval. The type of equipment to be used generally has a life of about 30 years, which is far in excess of the expected life of the mine.

1.2 PROJECT BENEFITS

A decision to use this energy source has been made because of the advantages to the company and the community at large. These include:

- the long-term cost savings in power generation compared to using non-renewable liquid fossil fuels;
- hydro-electric power is widely accepted as being the most environmentally friendly power source;
- the virtual elimination of gaseous emissions from the diesel generators at the mine site;
- the creation of up to 200 jobs during the two-year construction period; and
- hydro-electric power will be available for other purposes after the diamond mine ceases operation.

1.3 ENVIRONMENT OF THE AREA

The project area is located within the Kimberley region of Western Australia and falls within the semi-arid climatic region. Accordingly, climatic parameters are highly variable. Average annual rainfall is about 800 mm but is restricted to the summer months. The mean maximum temperatures generally exceed 35°C and mean annual evaporation rates exceed 3000 mm. Landforms include mountains, hills and plains, each with a distinctive pattern of soils, vegetation and hydrology. As a general rule, soils of the mountains and hills are shallow and stony, while soils of the plains are more complex and show higher levels of development. Apart from the Ord and Dunham Rivers, there are no permanent streams in the project area. Runoff is generally rapid throughout the area.

The project area lies within the Gardner Botanical District but extends south into the Hall Botanical District. There are no declared rare flora or priority species recorded in the project area, but a number of significant species are recorded in the southern end of the area. Twelve species of vertebrates, gazetted as rare or endangered, have been recorded or are believed to occur in the project area or its vicinity.

1.4 ENVIRONMENTAL IMPACT

Potential environmental impacts have been identified and levels of significance determined. The majority of environmental impacts will be ameliorated by either engineering design or environmental management programmes. A key factor in the impact assessment is the high level of disturbance to aquatic ecosystems that has already occurred as a result of the construction of the Ord River Dam and the extensive overgrazing by cattle on rangelands through which the transmission line will pass. The prior changes to ecosystem structure and function are undocumented.

The effect of the hydro-electric station and spillway weir on the environment will not be significant because operation of the completed works will result in water levels in Lake Argyle that fall within the levels experienced in the past. The transmission line has been designed to have minimum impact on the environment. Single concrete poles used for the transmission line will have less visual impact than other transmission line structures in the region. A direct impact could be the possible loss of small areas of vegetation and habitat as a result of powerline construction.

There will be no significant change to the water available to present users or to potential users of the Ord River scheme within the lifetime of the project because, after passing through the turbines, the water will flow into Lake Kununurra as it does now.

The traditional custodians of the land have been consulted and have visited the project area and assisted with the alignment of the preferred transmission line route. As a result, there will be no impact on sites of ethnohistorical significance. No archaeological sites were located in the area of the proposed hydro-electric station. Some sites were recorded during the field investigation of the transmission line route but they are not on the proposed route and will not be disturbed by construction work.

1.5 ENVIRONMENTAL MANAGEMENT

ADM is committed to a programme of environmental management designed to minimise the effects of the project on the environment of the area. The components of that management programme address the power generating facility, the spillway weir, project work areas, the construction camp, the contract workforce and the transmission line. ADM will supervise all aspects of the project that relate to environmental management and will be accountable for the supervision, implementation and completion of rehabilitation programmes. The commitment to the Environmental Management Programme will continue during operation of the hydro-electric facility and transmission line.

ADM will implement the proposed Ord River hydro-electric project using reputable engineering and construction contractors. Appropriate conditions will be included in all construction contracts to ensure that contractor activities are consistent with the Environmental Management Programme. Care will be taken to ensure that all construction work complies with the appropriate State regulations and is consistent with the high standards exhibited by previous contractors at Argyle. Strict adherence to work practices governed by the Occupational Health, Safety and Welfare Act 1984-1987 and compliance with other rules and regulations associated with the construction industry, should ensure that any impact on the project workforce during construction will be insignificant.

The use of vehicles during construction will be restricted to limit the mobility of the worforce. Employees will work long hours during their periods on site and will be transported to their point of hire for recreational leave. Consequently the impact of the workforce on the enviornment will not be significant.

All areas involved during construction will be rehabilitated and strict control will be exercised to control surface runoff, dust and noise emissions. Separate project disposal facilities will be developed for the construction camp to ensure the complete removal of all project waste.

The proponent is committed to a programme of consultation and liaison with commercial organisations in Kununurra. The effect will be to minimise any significant impacts on the social environment of the project area.

All areas containing items of significance to the traditional Aboriginal custodians of the land have been avoided along the proposed transmission line route. Careful management of the transmission line construction activity will minimise its potential impact on the environment.

A decommissioning programme for the Ord River hydro-electric project cannot be developed with certainty at this time. Prior to the cessation of mining, ADM will liaise with the State Energy Commission of Western Australia ("SECWA") and the Water Authority of Western Australia ("WAWA") on alternative uses for the power and associated infrastructure.

1.6 CONCLUSIONS

The Ord River hydro-electric project will not have a significant adverse impact on the environment and any impact will be minimised by the environmental management programmes to be followed by ADM.

The project will largely replace the use of fossil fuels at the mine site and will result in the creation of up to 200 jobs during the construction period.

When the Argyle mine ceases operations around the year 2005 the power generation facility will be available for other purposes for at least a further 20 years.

2.0 INTRODUCTION

2.1 LOCATION

The proposed Ord River hydro-electric project is located in the east Kimberley region of Western Australia. The project is centred on the Ord River dam, located approximately 75 km by road south of the town of Kununurra on the Ord River (see Figure 1).

2.2 BACKGROUND

The Ord River irrigation project was developed jointly by the Commonwealth and Western Australian Governments to harness the water of the Ord River to irrigate the extensive alluvial plains in the vicinity of Kununurra and ultimately to generate hydro-electric power.

Interest in the project can be traced back to research commenced in 1941 by the State Government which demonstrated the potential of the area for irrigated agriculture. This led to the construction of the Kununurra diversion dam in 1963-64 and the much larger Ord River dam in 1969-72 to provide a reliable water supply to a potential irrigation area of 75,000 hectares.

Included in the design of the Ord River dam was provision for a hydro-electric station to supply electricity to the area when justified by demand. The dam incorporated tunnels for a power station as well as for irrigation.

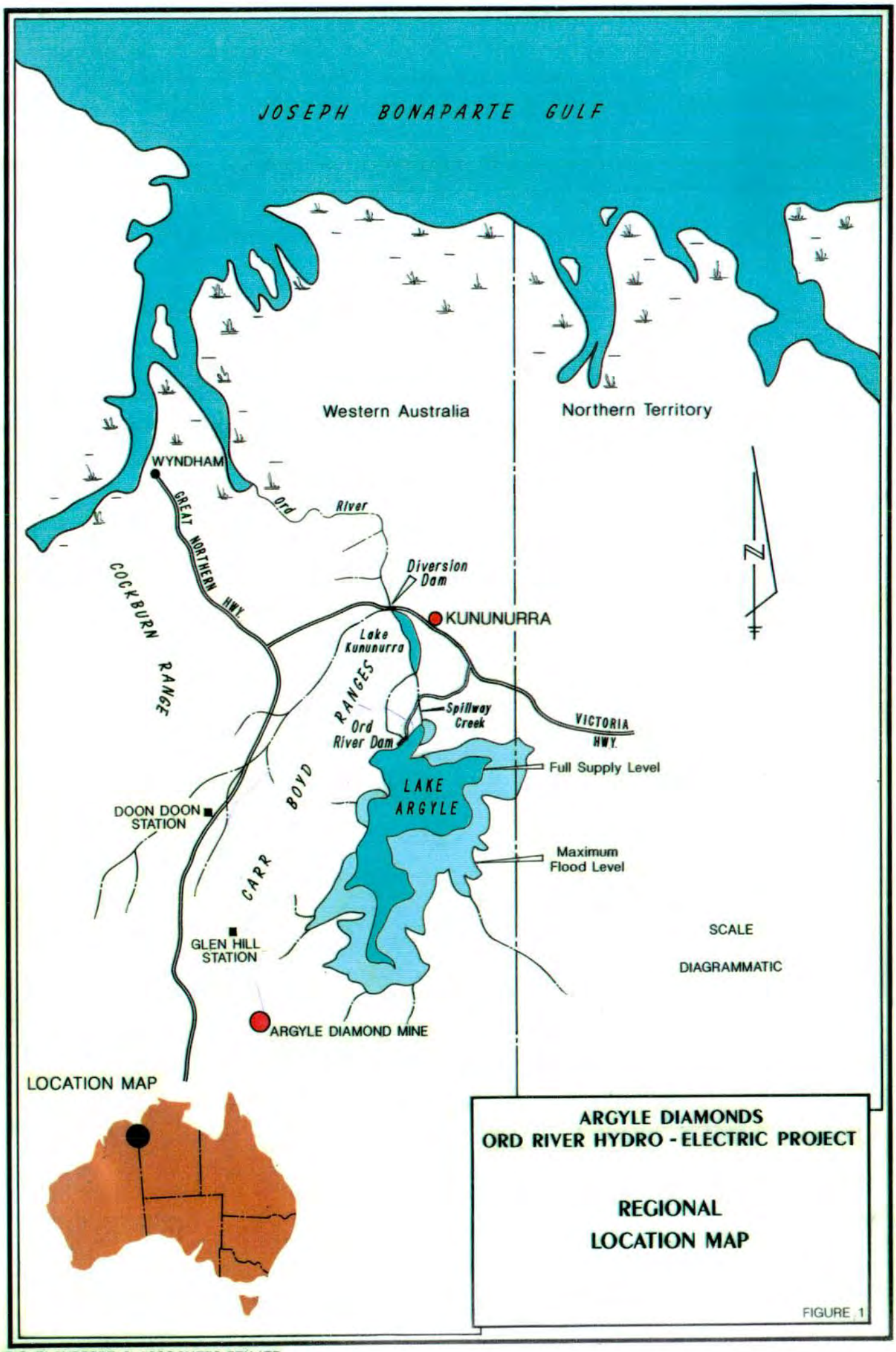
The Ord River Irrigation Area ("ORIA") remains under-utilised. Development has been slow and more difficult agronomically than originally envisaged.

In an attempt to utilise the potential for hydro-electric power generation, several studies have been conducted over the last 15 years. These studies included:

- In 1976 SECWA investigated the building of a hydro-electric power facility on the Ord River dam. However it decided not to proceed because the demand was insufficient to justify the project.

- In 1979/80 SECWA and the Northern Territory Electricity Commission conducted a joint study and submitted an Environmental Review and Management Program ("ERMP") to construct a 60 MW power station at the Ord River dam to supply peak power to Darwin. Environmental approval was obtained but the project did not proceed because the use of a long-distance, lightly-loaded transmission line was not viable.

- In 1982, the Argyle joint venturers funded a $750,000 study by SECWA and the Snowy Mountains Engineering Corporation ("SMEC") to assess the feasibility of constructing hydro-electric power facilities to supply the Argyle mine.



D.C. BLANDFORD & ASSOCIATES PTY LTD

- In 1985 a study was conducted by SECWA to assess the feasibility of generating hydro-electric power at the Kununurra diversion dam.

- In 1986, ADM again re-evaluated the hydro-electric power option with Merz Australia Limited.

These studies and others carried out by private developers all failed to establish the economic viability of constructing hydro-electric power generating facilities on the Ord River dam or diversion dam.

In 1989 ADM requested CRA Business Development (WA) ("CRA") to review hydro-electric power options in the Ord River region with the main objective of supplying electricity to the Argyle mine. During 1989/90, CRA investigated the feasibility of establishing its own power generating facilities on the Ord River dam and the Kununurra diversion dam to supply electricity to Argyle and SECWA.

Considerable work was undertaken including the preparation of a draft PER document which was submitted to the EPA in late 1990 for preliminary comment.

At the end of 1990, CRA decided not to proceed with the project and transferred the results of its studies to the Argyle joint venturers.

ADM wishes to build a hydro-electric facility on the Ord River dam to generate electricity for supply to its mine site only. As the long-term energy requirements of its mine closely match the continuous generating potential of an Ord River dam hydro-electric facility, it does not propose to supply power to other parties. This change of project scope does not preclude the future development of a hydro-electric station on the Kununurra diversion dam.

The EPA had no major concerns with the draft PER prepared by CRA. This document has been prepared by ADM and reflects the change of scope by excluding discussion of the hydro-electric facility on the diversion dam and the transmission line between the Ord River dam and the diversion dam.

2.3 OBJECTIVE

The objective of the project is to provide a viable alternative energy source for the Argyle mine. To achieve this objective, it is proposed to:

- construct a 40 MW hydro-electric power facility adjacent to the Ord River dam;

- construct a 132 kV transmission line from the hydro-electric station to the mine, a distance of approximately 120 km; and

- raise the level of the existing spillway by approximately 6 m.

2.4 PROJECT BENEFITS

The hydro-electric facility will provide benefits to the community and to the Argyle mining operation. The project would improve the cost efficiency for the remaining 10-11 years of life of the Argyle mine, and provide a power generating facility that could significantly contribute to the development of the east Kimberley region after the mine ceases operation at around the year 2005.

Electricity at the mine is currently generated by a fully-automated 28 MW diesel-fired power station consisting of 10 generating units. Future mine plans call for increased energy usage. If the hydro-electric station does not proceed, the diesel-fired station at the mine site will be expanded to around 40 MW by the mid 1990's.

The economic viability of the hydro-electric project will be greatly influenced by the timing of its completion. The feasibility of constructing a hydro-electric station on the Ord River has been investigated several times since the dam was completed. None of these studies has shown the project to be viable. The high capital cost requires a substantial base load power demand over a relatively long period. The projections of SECWA's electricty demand are not sufficient to justify the high construction cost if ADM does not proceed with the project.

The project will provide a number of benefits to the state and the community. These include:

- a long-term source of low-cost energy which will encourage and support further development of the east Kimberley region;
- the creation of up to 200 jobs during the two-year construction period;
- the substitution of hydro-electric power for the non-renewable liquid fossil fuel currently consumed at the Argyle mine;
- the virtual elimination of gaseous emissions from the diesel generators at the mine site; and
- a reduction in foreign currency payments for imported diesel fuel.

2.5 THE PROPONENT

The proponent for the proposed power project is:

Argyle Diamond Mines Pty. Limited
Private Bag No. 11,
WEST PERTH W.A. 6005

ADM is the manager of the Argyle Diamond Mines Joint Venture ("ADMJV") which was established in 1982 to provide for the development, mining and management of the diamond interests of the joint venturers. The participants are Australian resource-based companies, CRA Limited and Ashton Mining Limited which hold 56.8 per cent and 38.2 per cent respectively of the ADMJV. The balance of five per cent is held by the Western Australian Diamond Trust ("WADT").

From the initial establishment in 1982 to the present day, ADM, on behalf of the joint venturers, has made a considerable contribution to the Kimberley. The contribution to the Kununurra infrastructure in particular has been substantial, the most noticeable improvements being the development of a recreation and leisure centre and extensions to the local hospital and school. Annual expenditure in Kununurra as a result of the Argyle mining operation is currently estimated to be $7-8 million, which comprises personal spending by employees, the purchase of mine supplies, the use of local contractors, and direct funding for community projects.

ADM maintains a "good neighbour policy" with the neighbouring Aboriginal communities, in particular the Mandangala (Glen Hill), Warmun (Turkey Creek) and Woolah (Doon Doon) communities. Approximately $0.6 million has been contributed so far in 1991 as part of this policy. In addition ADM expertise is utilized by these communities and neighbours. This expertise includes structural repairs and maintenance on housing and school buildings, repairs and maintenance to facilities and equipment such as diesel power generators, general advice and help in relation to community infrastructure and development, and advice in relation to grazing activities and pastoral lease management. ADM has an active policy of providing employment for local Aborigines. At the present time, 43 Aborigines are employed at Argyle. Of these, 14 are award workers on commute, 4 are Argyle staff, 18 are trainee permanent contractors, and 8 are day labourers from Turkey Creek. Of the 18 trainees, 6 are being trained in the operation of heavy earth-moving equipment and are directly involved in civil and environmental works.

ADM has displayed an awareness of environmental issues and is committed to environmental management. The environmental impacts identified in the Dames & Moore (1982) ERMP have been addressed and continue to be addressed in current operations. An environmental department on site has fulfilled this monitoring function for several years, and continues to ensure that sensitive activities, for example the rehabilitation of mining areas and waste disposal, are handled efficiently. ADM, as a responsible member of the Kimberley community, will ensure that all aspects of the hydro-electric project will be handled with the same degree of professionalism that has been exhibited in the past.

2.6 TIMING OF THE PROJECT

The present schedule and construction programme allows for construction to commence in 1992 with power being generated and transmitted to the Argyle mine during 1994.

2.7 EXISTING FACILITIES

The Ord River dam, first contemplated in 1939 and finally completed in 1972, forms the basis, not only of the Ord River Irrigation Project, but also the proposed hydro-electric project (Plate 1a).

From an intake structure (Plate1b) in Lake Argyle, irrigation water is conveyed by a tunnel under the abutment to a valve block at the toe of the dam (Plate 2). During construction of the dam, provision was made for hydro-electric facilities by constructing two tunnels between the intake structure and the proposed location of the power generating facilities adjacent to the irrigation valve block.

One of the two tunnels is bifurcated into one branch feeding the irrigation valves and another branch for the power station. The second tunnel will feed water direct to the turbines. As this second tunnel has not yet been used, a lining of concrete and steel will be installed to reduce friction loss and to ensure structural integrity.

A spillway located 8 km north-east of the dam directs flood flows down Spillway Creek and Stonewall Creek and finally into the Ord River and Lake Kununurra (see Plates 3 and 4 and Figure 8).

2.8 STATUTORY REQUIREMENTS

The project was referred to the EPA which determined that it would be formally assessed under S40 of the Environmental Protection Act, 1986. The EPA determined that a PER was the level of assessment required and it nominated three decision-making authorities, WAWA, the Department of State Development ("DSD") and SECWA.

The Commonwealth Department of Arts, Sport, the Environment, Tourism and Territories ("DASETT") was consulted in terms of its requirements under the Commonwealth Environment Protection (Impact of Proposals) Act, 1974. As a result of this consultation, and discussions between CRA and the EPA, DASETT contributed to the guidelines for the PER.

On completion, the PER will undergo public review for a period of eight weeks. The proponent will respond to submissions received as a result of public review and the document, together with the proponent's responses will then be assessed by the EPA which will report to the Minister. Subject to appeals, the Minister will set conditions based on the proponent's commitments and recommendations of the EPA. Final approval for the project will be given by the Minister to the decision-making authority which will then issue the proponent with authority to proceed.

2.9 SCOPE OF THE PER

The purpose of this document, defined as a Public Environmental Review, is to:

- define the main features of the project;
- describe the technical aspects of the project;
- examine possible alternatives to power generation and transmission line corridors;
- describe the existing environment and identify and assess potential environmental impacts resulting from project implementation;
- detail environmental management strategies proposed to eliminate or minimise environmental impacts; and
- outline ADM's commitment to environmental management.

The PER presents a summary of the studies undertaken during a programme of assessment and investigation into the feasibility of using hydro-electricity as an alternative power supply to the fossil fuels presently used at the Argyle mine. Appropriate technical data are included in this document.

PLATE 1

(a) The wall of the Ord River Dam is almost 100 m high and contains approximately 1.5 million m^3 of rock fill. Discharge valves for irrigation are at the toe of the wall.

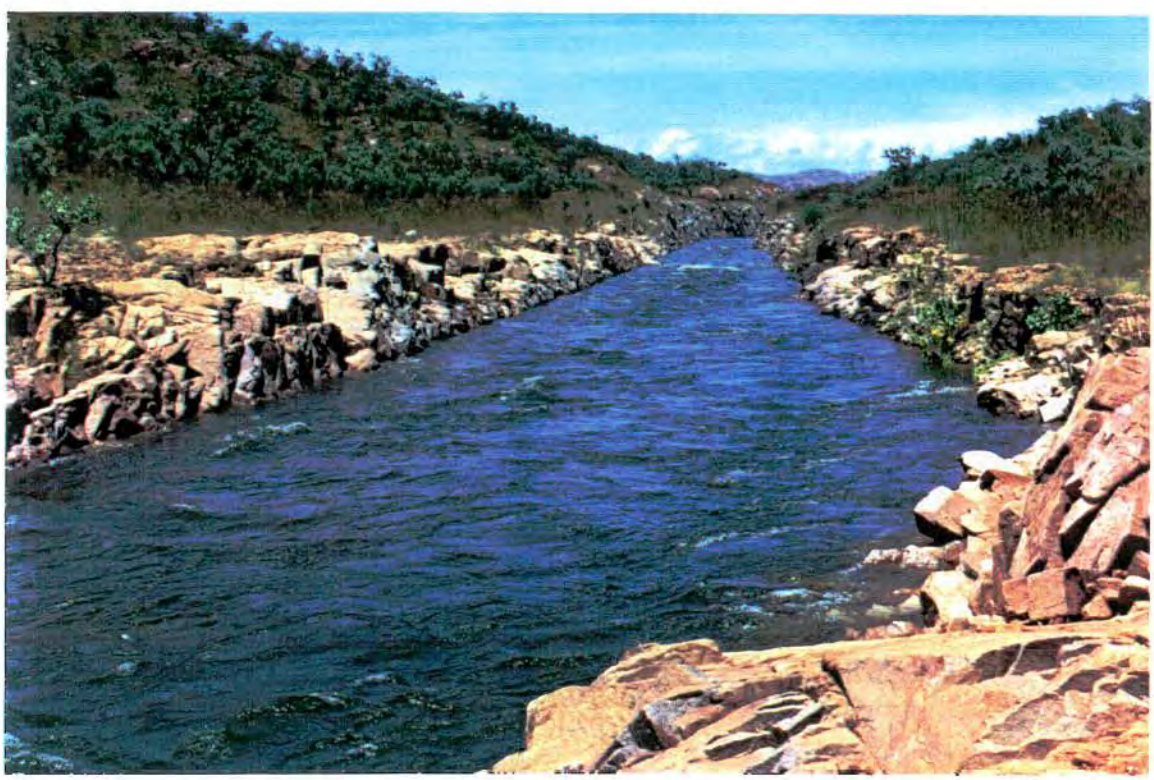
(b) Intake structure for irrigation and hydro-electric station outlet tunnels.

PLATE 2

The irrigation valve block located at the toe of the Ord River Dam. Discharge can be regulated from one or all valves, and at the time of the photograph all three valves were open 5%.

PLATE 3

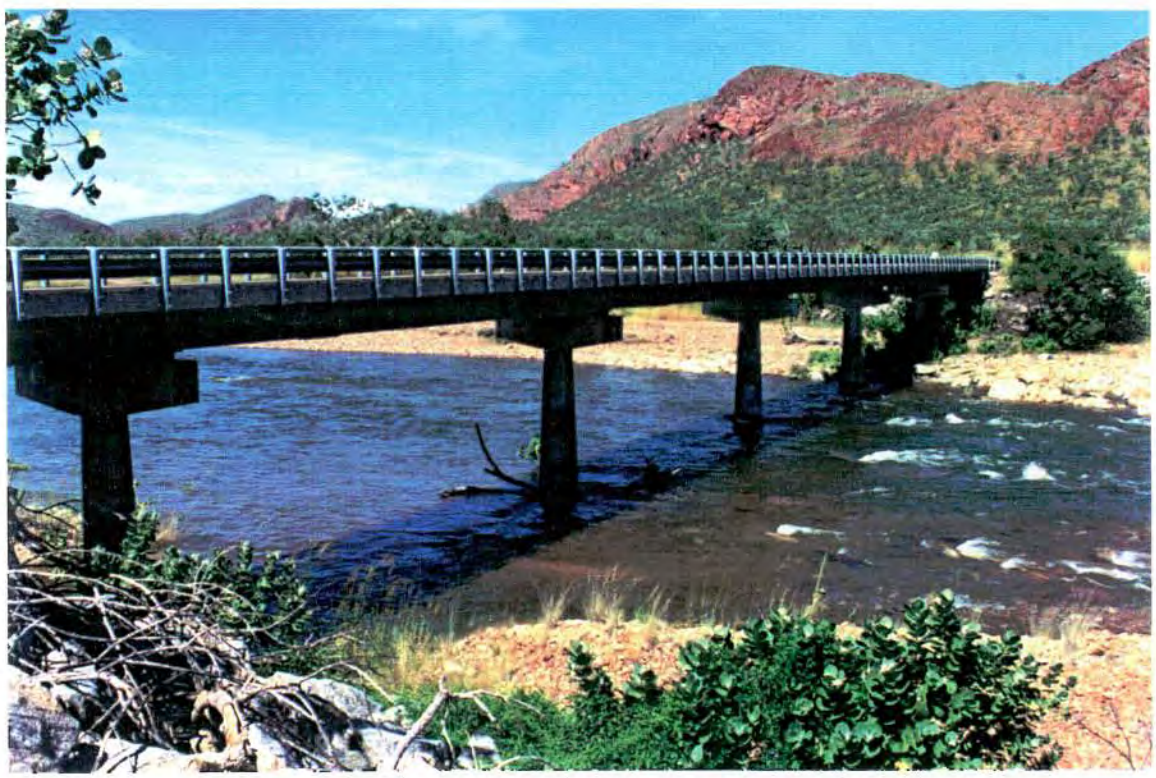
(a) Entrance to the spillway and the start of the main spillway cut with the waters of Lake Argyle in the background.



(b) Discharge in the spillway immediately north of the main cut. Depth of flow is 2.5 m.

PLATE 4

(a) Discharge down Spillway Creek.



(b) Flow down Spillway Creek at the traffic bridge on Parker Road, the main access road to the dam.

3.0 PROJECT DESCRIPTION

3.1 INTRODUCTION

The Ord River hydro-electric project comprises three major activities:

- the construction and operation of a power generating works adjacent to the existing irrigation release valves;
- the construction and operation of a transmission line to the Argyle diamond mine; and
- the construction of a weir across the existing spillway.

Water now released from Lake Argyle through the irrigation valves, will be released through the power station to generate electricity. The rate at which water will be released will be determined by the demand for electricity, the level of water in the lake and the demand for water by other users. Historically, the demand for water from Lake Argyle has been far less than its capacity to supply. Studies have determined that the demand for power can be met in the long term by the inflow of water to Lake Argyle from the Ord River catchment area.

3.2 PROJECT IMPLEMENTATION AND LIFE

Implementation time from environmental approval to project operation is expected to be $2^1/_2$ - 3 years, with construction activity commencing within three months of project approval and diminishing to a low level of activity after two years. It is anticipated that the spillway plug and the transmission line will be built over a period of about six months.

The expected life of equipment in a hydro-electric facility is usually about 30 years, while the life of the civil engineering structures is of the order of 50-100 years. Operational life of the transmission line is expected to be in the order of 40 years.

After the Argyle diamond mine has ceased operations, there may be a demand for the power and operating infrastructure, e.g. at Kununurra or Wyndham or by further rural or industrial development.

At the appropriate time, ADM will liaise with the relevant state and local authorities on the future of the hydro-electric scheme.

3.3 HYDROLOGY

Predicting the behaviour of Lake Argyle water levels after installation of the spillway weir, and with the power station operating, is complex. The water level at any time is a function of outflow (hydro-electric station releases, irrigation valve releases, evaporation losses and spillway discharge) and inflow (river/stream inflow and rainfall onto the lake surface). Water inflow into Lake Argyle will be the same with or without the project. Therefore outflows become the only variables.

The effect of raising the spillway weir by approximately 6 m will be to allow more water to be retained in Lake Argyle instead of it being discharged down the spillway. The flow into Lake Kununurra from the spillway will therefore be less frequent and at a lower flow rate. Instead, this extra water retained in Lake Argyle will be discharged into Lake Kununurra from the power facility. The volume of water that is now discharged from the irrigation valves will mostly be discharged through the tunnels. Overall, the diversion of the water which would normally have flowed down the spillway or through the irrigation valves, to the hydro-electric station, will not alter the average annual flow into Lake Kununurra.

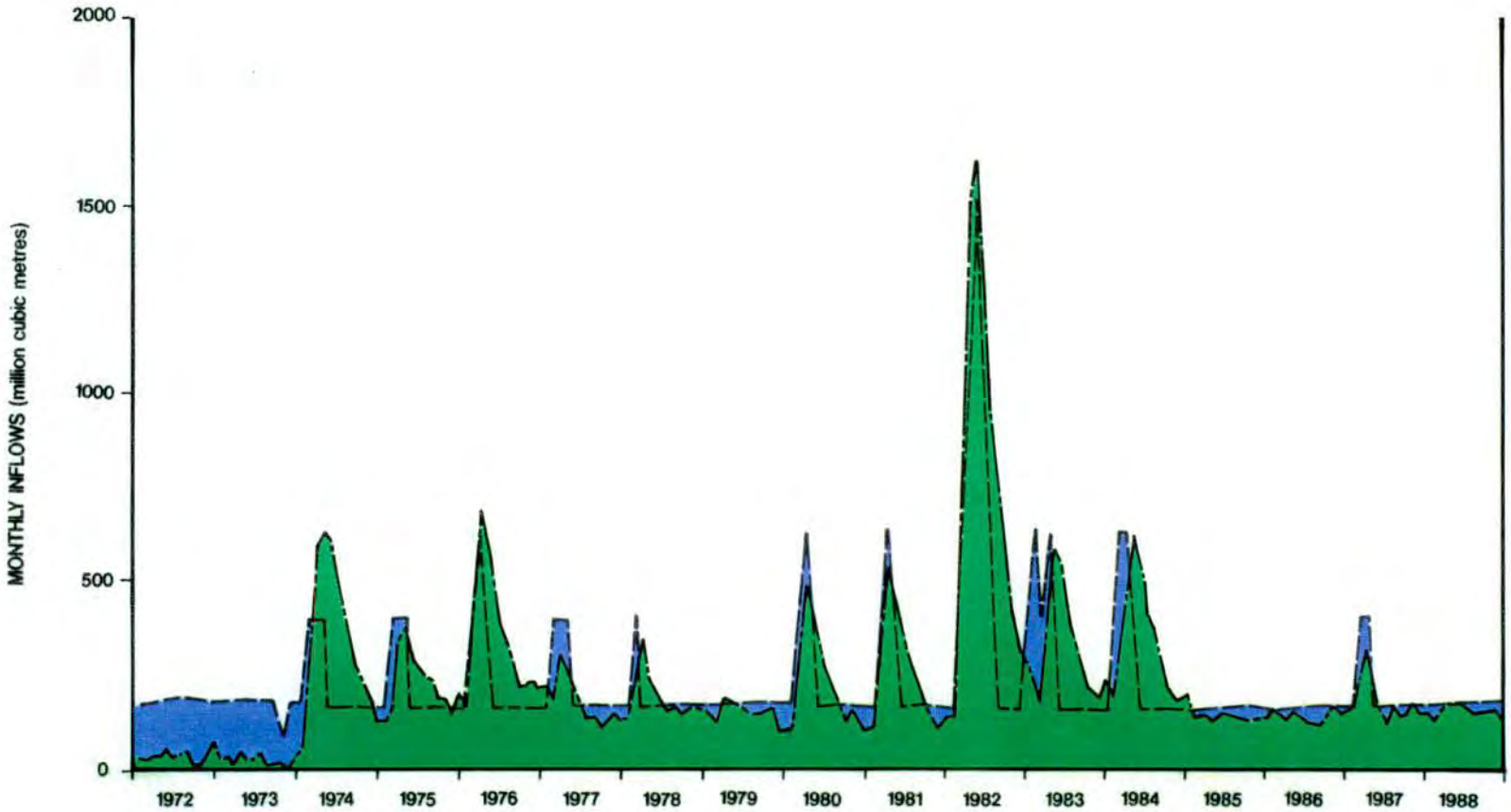
This is clearly evidenced in Figure 2 which shows the estimated volumes of Lake Kununurra inflows, with and without the project. To further substantiate this evidence, SMEC simulated water levels in Lake Argyle with and without the project. This showed that average water levels are expected to be similar to those that have occurred to date (see Figure 3).

Releases through the turbines will be more than sufficient to satisfy downstream demand without special irrigation valve releases. The proposed operating rules governing the use of the water from Lake Argyle, to be agreed with WAWA, will ensure:

- the release of sufficient water downstream to provide for irrigation;
- the control of the lake level to allow for the provision of flood storage; and
- the conservation of water for downstream users by restricting releases from the hydro-electric station at very low lake levels.

The rules proposed by SMEC to meet both the irrigation and hydro-electric requirements, based on the premise that the spill level rise to 92.2 m with the construction of the weir across the spillway are:

- Above 92.2 m all irrigation valves will be fully opened and power generation will not be restricted.
- Above 78 m, and below 92.2 m there will be no restriction on hydro-electric power generation but releases through the irrigation valves may be reduced.
- Below 78 m all releases from the dam will pass through the turbines and WAWA will gradually commence restrictions.



LEGEND

Lake Kununurra inflows based on recorded releases from Ord River Dam and spillway discharges

Simulated Lake Kununurra inflows based on raised spillway weir crest at 92.2m AHD and operation of the HYDRO-ELECTRIC Station (40 MW at 50-60% capacity)

ARGYLE DIAMONDS
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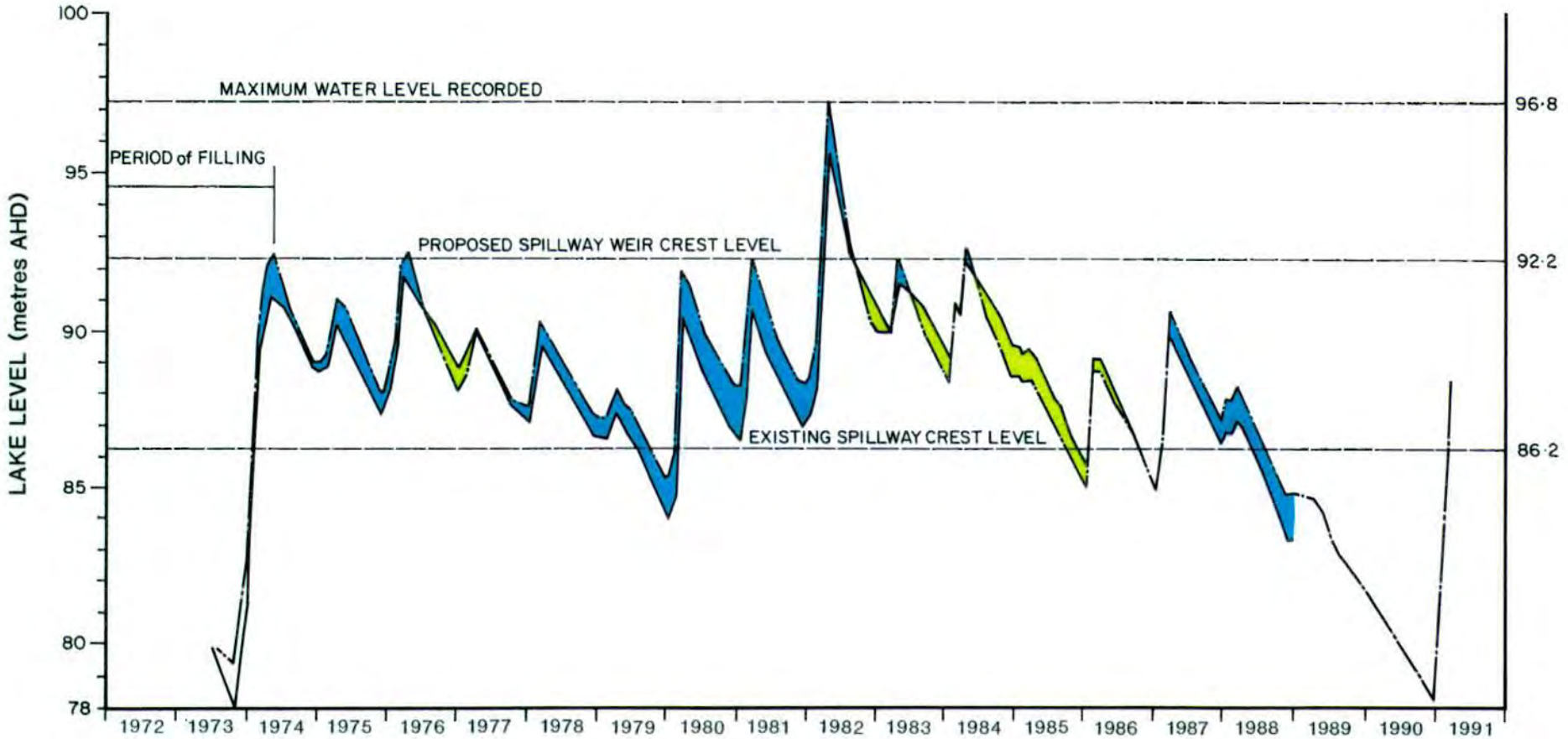
HYDRO - ELECTRIC PROJECT

LAKE KUNUNURRA INFLOWS
WITH AND WITHOUT PROJECT

FIGURE 2

Source : SMEC



Recorded levels without project

Simulated levels with spillway weir and operation of Hydro - Electric Station (40 MW at 50-60% Capacity)

Periods where recorded lake level without project exceeds simulated lake level with project

Periods where simulated lake level with project is greater than recorded lake levels without project

Note: April 1991 lake level was 88.5

ARGYLE DIAMONDS
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COMPARISON OF LAKE ARGYLE LEVELS WITH & WITHOUT PROJECT

FIGURE 3

- Below a dam level of 72 m there will be no releases for irrigation or power generation.

3.4 POWER GENERATING FACILITIES

The hydro-electric facility will be located at the downstream toe of the dam, adjacent to the existing irrigation discharge valves (see Figure 4).

Two turbines will be installed with a combined generating capacity of 40 MW at a lake level of 82 m AHD or greater.

The majority of the facilities will be below 'datum ground level' which is the level of the existing irrigation discharge block. The superstructure, transformers and the switching station will be located above this level.

3.4.1 Construction

The hydro-electric station will be situated alongside a stilling pond which is currently flooded by water discharged from the irrigation valves (see Plate 5).

This site will be de-watered by constructing a temporary coffer dam across the Ord River approximately 100 m downstream of the irrigation outlet. A section of the stilling pond will be partitioned off with a 'caisson' wall between the coffer dam and the irrigation valve block to allow the station site to be pumped dry. The coffer dam will also act as a causeway providing temporary vehicular access to the downstream side of the construction site. Releases from the irrigation valves will pass through culverts in the coffer dam (see Figure 5). Although these releases will be less than at present, adequate supplies will be available for irrigation and other downstream users. Releases will remain under the overall control of WAWA.

Further excavation for the facility foundations will be required. This work will also expose the ends of the existing tunnels so that lining can be completed and steel conduits extended into the hydro-electric station.

The hydro-electric station will be constructed progressively up to datum ground level. The superstructure will be built of concrete up to the level of a rail-mounted travelling crane. Above that a steel-framed structure clad with metal sheeting will be constructed. It will measure approximately 50 m in length, 15 m in width and 11 m in height.

An electrical switching station containing switchgear and other equipment mounted on concrete or steel structures will be constructed adjacent to the hydro-electric station. The site will be approximately 25 m by 23 m with the tallest item of equipment, a gantry, being around 16 m high.

A partially-buried water tank is to be installed at the carpark on the headland near the northern end of the dam wall. This is required to supply a fire protection system and it

is proposed to incorporate a public viewing platform on top of this tank. Water pipes to the station, together with service ducts, will be installed either down the rock outcrop or the dam face.

3.4.2 Construction Camp

A workforce of up to 200 people is forecast for constructing the power facility and spillway weir, and for installing plant. This workforce, which will peak approximately 18 months after start up, will be housed in a new camp adjacent to the Argyle Tourist Village. The workforce size will vary as some construction activities will be restricted to the dry season. Accommodation will be a typical construction camp, including mess and recreational facilities.

The preferred location for the construction camp is at the southern end of the Argyle Tourist Village (see Figure 6, Site A). This site is on an area previously used during the construction of the Ord River dam, and is convenient to water and power supplies. Two other potential sites, B and C, are not considered as suitable (see Figure 6). Site B is remote from water services and is near the village diesel power station with its associated noise. Site C, on the northern boundary of the Argyle Tourist Village, would require vegetation clearing and site levelling.

Water supply will be obtained by tapping into the pipeline from the main water tank on the southern side of the Argyle Tourist Village. The size of the water pipe to the storage tank will be increased, if necessary, to cater for supplying both the village and construction camp.

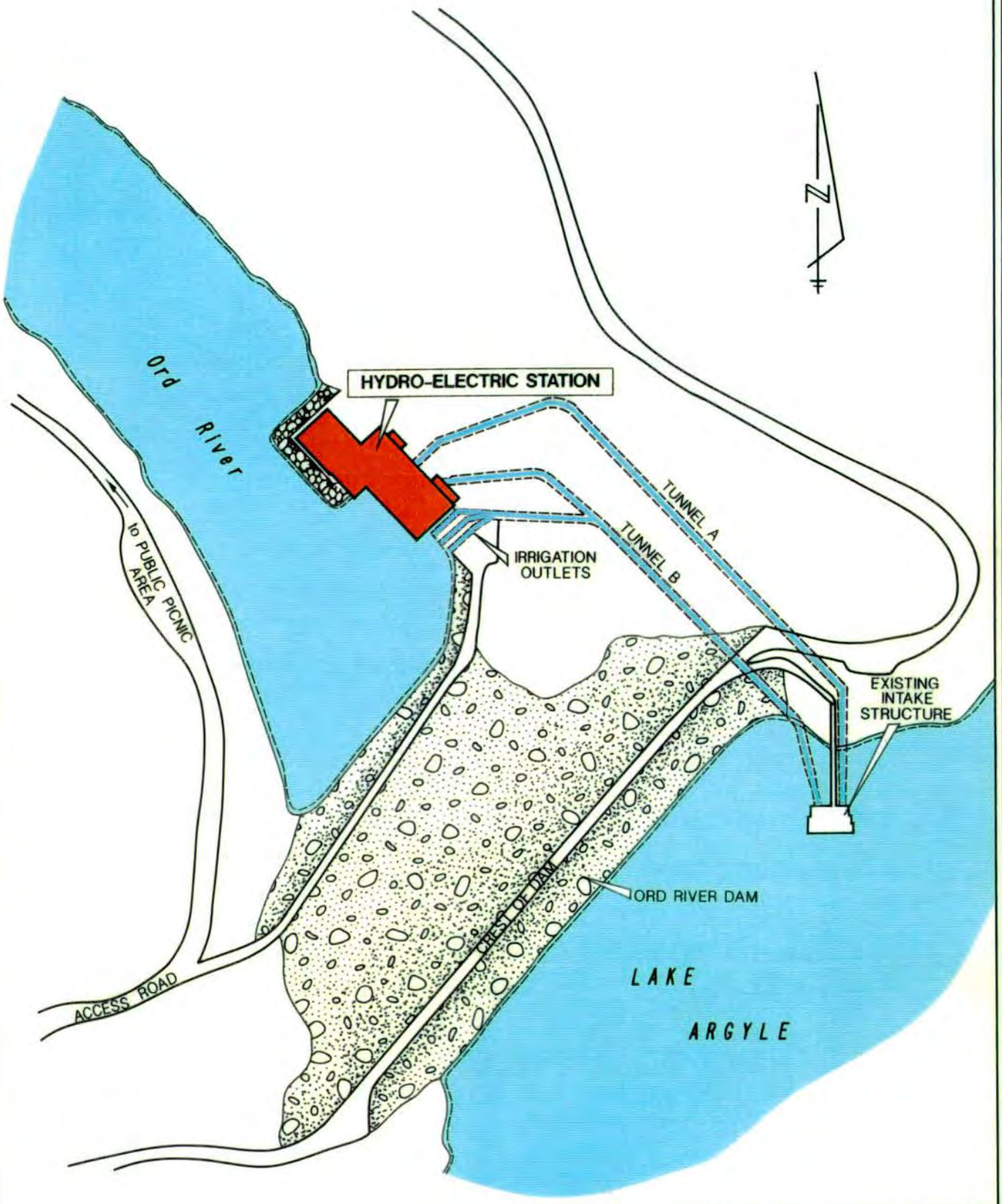
Electricity for the camp will be supplied by a diesel generator, installed by ADM. Separate sewerage facilities will also be installed because the existing Argyle Tourist Village system will be inadequate for the camps needs.

A specialist contractor will be appointed to manage and operate the construction camp. One of its responsibilities will be the maintenance of harmonious relations with the Argyle Tourist Village management and the public.

Camp rules will be prepared, similar to those used successfully by ADM during construction of its mine project but incorporating specific requirements for the new camp. The rules will be explained to all personnel at mandatory site induction sessions. As part of their employment conditions all contract personnel will be required to sign an undertaking to comply with the rules. The rules will be written to control or prohibit: the consumption of alcohol; the use of drugs; gambling; noise; pets; firearms; fighting, and the use of private vehicles. Specific rules to protect the environment will be included.

Ensuring that the various contractors comply with the camp and environmental protection rules, will be the responsibility of the Argyle appointed camp manager. Appropriate action as a result of non compliance will be enforceable under the conditions of employment contained within each contract.

SOURCE : SMEC



ARGYLE DIAMONDS
ORD RIVER HYDRO - ELECTRIC PROJECT

LOCATION OF HYDRO - ELECTRIC STATION

FIGURE 4

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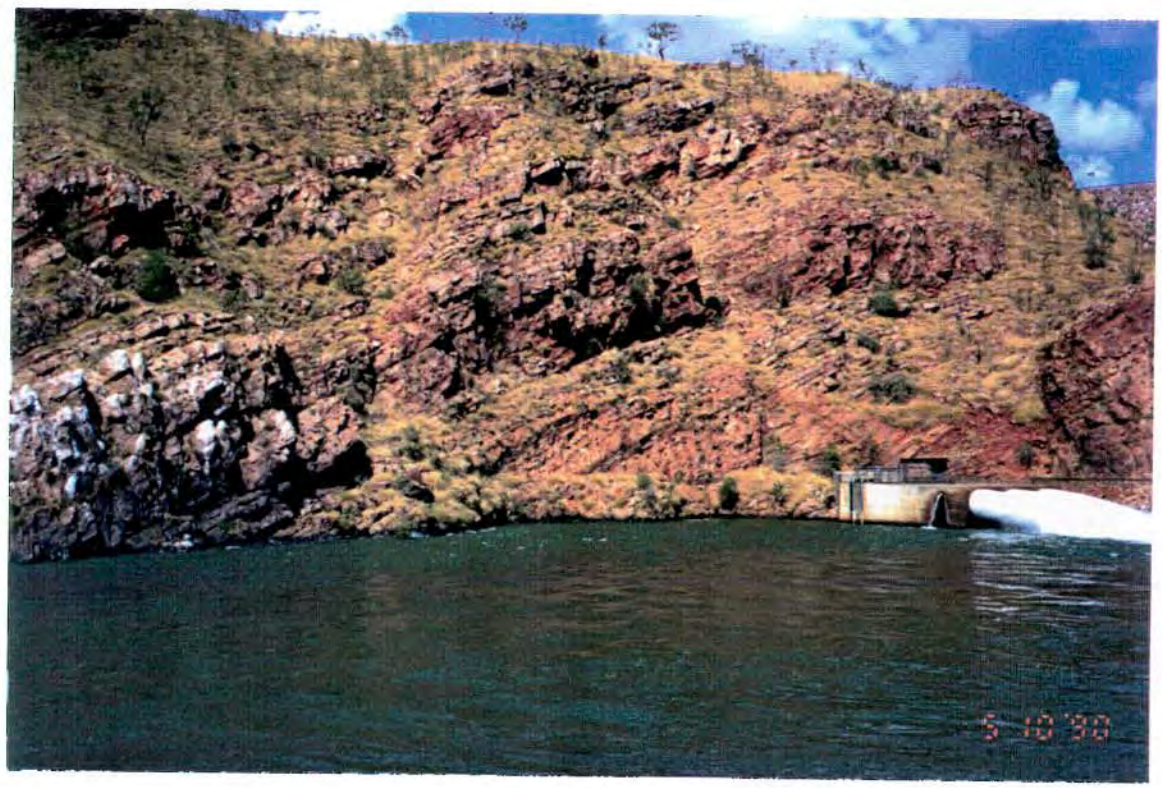
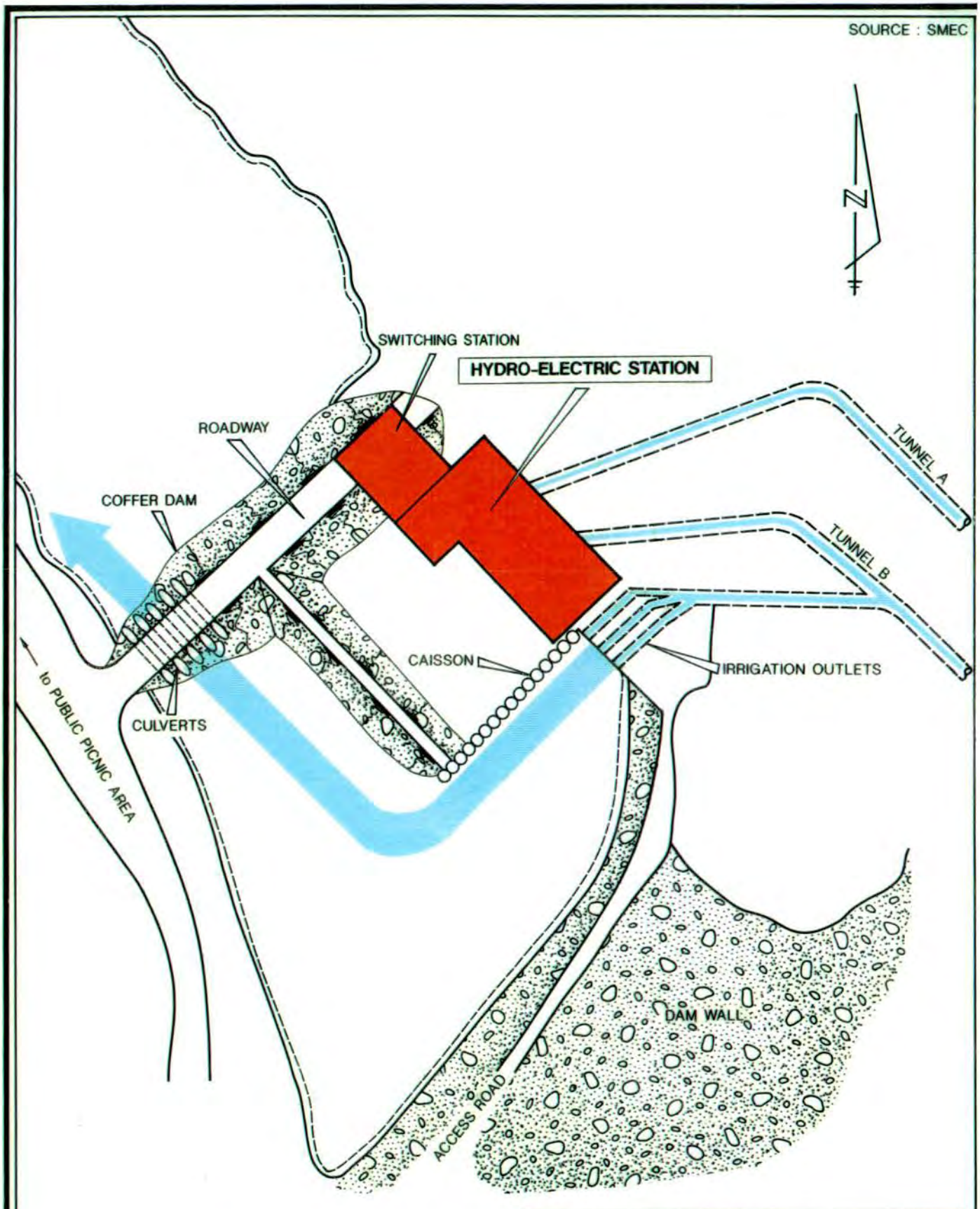
PLATE 5



The location of the hydro-electric station is to the left of the irrigation valve block.

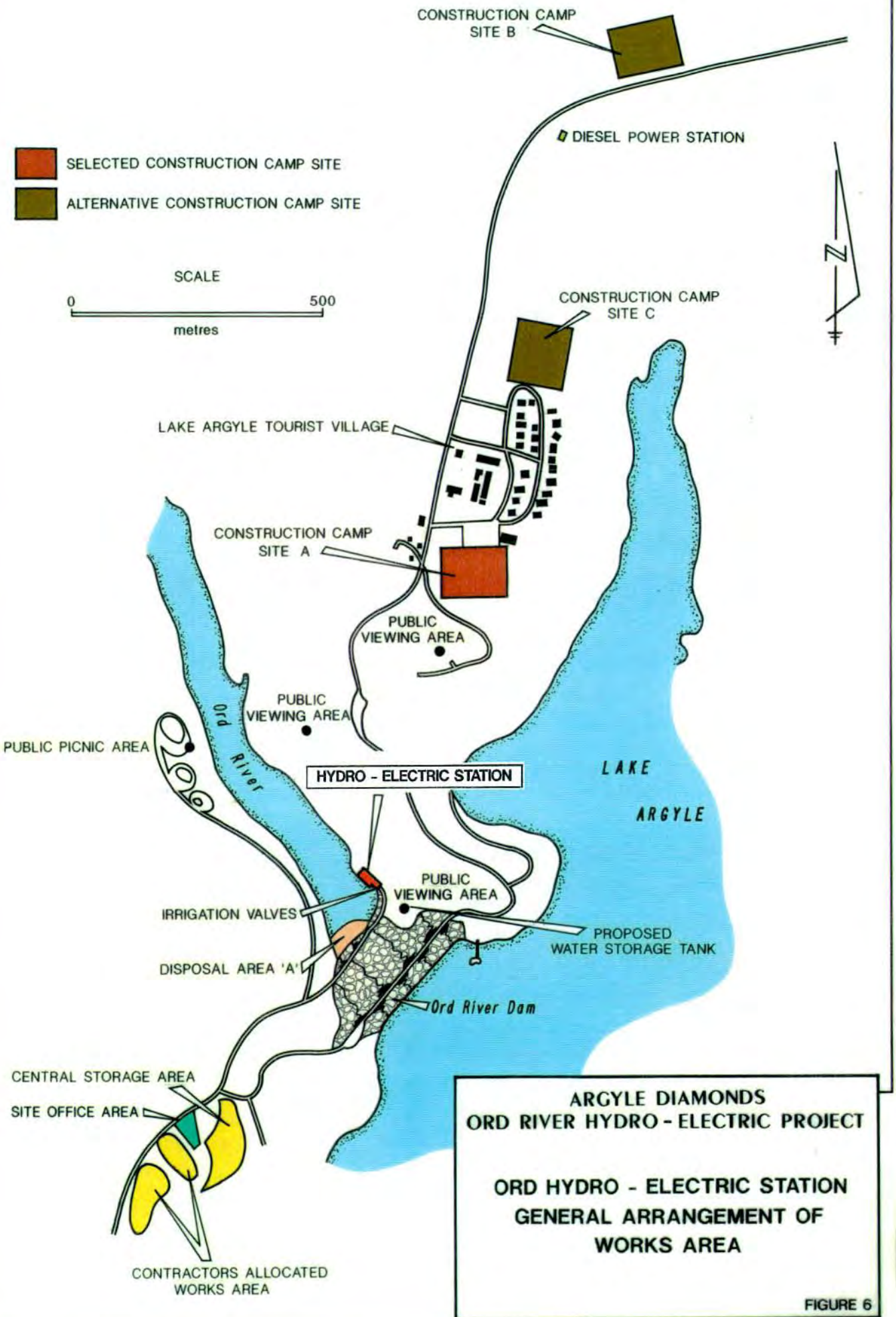


ARGYLE DIAMONDS
ORD RIVER HYDRO - ELECTRIC PROJECT

CONSTRUCTION SITE LAYOUT

FIGURE 5

SOURCE : SMEC



ARGYLE DIAMONDS
ORD RIVER HYDRO - ELECTRIC PROJECT

ORD HYDRO - ELECTRIC STATION
GENERAL ARRANGEMENT OF WORKS AREA

FIGURE 6

Vehicles on site will be restricted to employees of ADM and its contractors. This will limit the mobility of the workforce. Employees will work long hours during their extended period on site. ADM, or its contractors, will be responsibile for transporting the employees to their point of hire for their recreation leave. As it is expected that most of the workforce will be sourced from outside the region, the construction workforce will, therefore, not have a significant impact on Kununurra.

3.4.3 Works Areas

The quarry site located immediately south-west of the Ord River dam wall and used as a source of construction material for the dam, is still essentially bare and will provide a convenient area for workshops, aggregate processing, concrete batching plants and other construction plant storage. The principal site office will also be located in this area.

3.4.4 Borrow Areas

Construction of the power station will require rock and sand material for concrete aggregate and for free-draining backfill.

The most accessible aggregate suitable for making concrete is from Spillway Creek immediately downstream of the Spillway Creek bridge. Some 15,000 to 20,000 m^3 will be required for concrete, plus an additional 20,000 m^3 for free-draining backfill behind the power station.

Borrow materials will be excavated, crushed and stockpiled during the dry seasons for use during construction.

The preferred option for coffer dam construction is to use river-bed materials from the immediate vicinity to form the core and then face this with rock. If the river-bed material proves unsuitable, it will be necessary to seek an alternative source of material. Material from stockpiles created during the initial construction of the spillway could be transported to the coffer dam site for use as construction material.

3.4.5 Waste Rock Disposal During Construction

Waste rock from the hydro-electric station foundations and coffer dam will be placed on the south bank of the river at the toe of the dam to provide bank armouring against erosion during periods of high discharge from the irrigation valves. Material from the river bed used for the coffer dam will be spread into deeper parts of the stilling pond below the base of the dam on completion of construction.

3.4.6 Access and Road Use

No new access roads will be required for any of the works. As all construction materials will be stored near the works areas south west of the wall, the road between the hydro-electric station and the works areas will experience the heaviest traffic. The access road to the dam from the Spillway Creek bridge to the works area will also experience periods of heavy traffic during delivery of construction materials. Approximately 130,000 t of materials including concrete, steel, earth and rock, gravels, and permanent plant will pass along this road during the construction period, with a peak in the order of 2,000 t per day over a four-week period. It is expected that heavy construction activity will extend over a period of about 18 months.

3.4.7 Operation

The hydro-electric facility will generate electricity continuously, except during forced shutdowns. It will not be permanently staffed, but will be operated by remote control from the Argyle diamond mine. Remote control of hydro-electric stations is common practice, with the control signals being transmitted via the transmission line using power line carrier communication. While this procedure is standard, other systems such as radio or fibre-optic cables may be used. The remote control will generally consist of stopping and starting units. Voltage and load will be regulated automatically at the station in response to demand. Voltage control will be carried out at the generator, and the governor will control the load by opening and closing the inlet guide vanes to the turbines, thus regulating the flow of water through them and into the Ord River.

For the majority of the time the Ord River power facility will be the only power supply to the mine operation. The load demand at the mine is roughly uniform throughout the day and therefore the water releases will be consistent. Should there be a large change in demand, a change in downstream flow will result. However this will not be obvious because of the slow response of the river. The travel time between the Ord dam and the diversion dam is approximately 20 hours, so short fluctuations in flow will be dampened out by the time the water reaches the diversion dam.

The hydro-electric station will have automatic 'failsafe' features which will switch plant items off in the event of a fault, and relay information about the type and location of the failure to the mine site.

The station will have routine maintenance inspections, and during the first year of operation there will be frequent inspections so that any plant commissioning problems can be checked and addressed promptly.

Forced shutdowns simultaneously affecting both generating units, therefore greatly affecting the water release downstream, are improbable. If all generation does cease, say because of a failure of the transmission line, the turbines will still allow some flow. In such a case, the mine site operators will immediately know of the failure and will contact WAWA. Depending on the circumstances WAWA will decide if it is necessary to open the irrigation valves to ensure adequate water to downstream users.

3.5 POWER TRANSMISSION

3.5.1 Overview

The project involves the construction of a 132 kV transmission line, approximately 120 km in length, from the hydro-electric station to the Argyle diamond mine. Switching stations at the station and at the mine will be required. The construction of these facilites will occur over a period of about five months.

The 132 kV transmission line will be supported by hollow concrete or hollow steel poles. The poles will be installed in augured holes with tension and angle poles where necessary being back-stayed using galvanised wire rope. Further stay reinforcement will be carried out between approximately every tenth to fifteenth pole. This is necessary to restrict cascade structure failure should it occur during cyclonic activity. The powerline will be designed to withstand winds of 41 m/s (Australian Standard AS1170 Part 2 1989 Terrain Category 3).

A typical pole will be approximately 20 m high (see Plate 6) with a span of approximately 300 m between poles. The span length and pole height will vary depending on the local topography.

The transmission line will have minimum ground clearances in compliance with SECWA and Electricity Supply Association of Australia ("ESAA") standards. The intention is to have a higher clearance of 11 m for sections over permanent water to minimise injury to flying water birds. The easement for the 132 kV line will be approximately 20 m either side of the centre line. Vertical clearances between the conductors and the ground are typically 6.7 m where there is no possibility of vehicular access under the line, and 7.6 m elsewhere.

3.5.2 Transmission Line to the Argyle Diamond Mine

The selected route is well suited to transmission line engineering, access and operating requirements, including the use of pole support structures. The proposed route for the transmission line is shown in Figure 7.

The line originates from the switching station and will rise up to a support structure at the top of the ridge. From this first structure the line travels north-easterly for approximately 2.5 km. It then turns in a north-westerly direction to cross the Ord River 12 km downstream from the dam. It continues across the Ord River valley and then in a south-westerly direction into Coolamon Pocket. The line continues in a north-westerly direction across open country in Coolamon Pocket around the northern end of the Carr Boyd Ranges, standing off from the foot of the hills by approximately 1 km.

Once west of the Carr Boyd Ranges, the route runs parallel to, and slightly away from, the face of the ranges before heading south-west. It meets the access track to Glen Hill station near the junction with the Great Northern Highway and Wild Dog Bore. From

there it follows the Glen Hill access road before passing to the east of the Glen Hill station homestead. It continues south for a further 7 km, then follows an existing track system out of the Glen Hill valley and into the open area west of the Argyle diamond mine airstrip. It follows the eastern slopes of a low range of hills, then turns south-west to follow the existing access road into the mine site area.

3.5.3 Construction Camps

A work force of approximately 30 people will be required to construct the transmission line. Accommodation will be in mobile camps, temporarily located at selected sites along the route. Each camp will be located in existing disturbed areas, where possible, and occupied for a period of about two months.

3.5.4 Works Areas

Construction materials such as poles, conductors and insulators will be stored at the construction camp areas or at either end of the line sectors. During construction, smaller temporary stockpiles of materials at intervals of a few kilometres may be formed using existing disturbed areas wherever possible.

3.5.5 Access and Road Use

Rather than a continuous access track along the transmission line route, existing roads and four-wheel-drive tracks will be used, supplemented by additional tracks where necessary. Generally, the country is readily traversed by four-wheel-drive vehicles during the dry season without the need to construct tracks. However it is difficult, if not impossible, to traverse in the wet, even if tracks are constructed. All access for transmission line construction will be restricted to rubber-tyred vehicles and plant. It is planned that construction will take place during a single dry season.

3.5.6 Operation

Once in service the transmission line will require little maintenance, with bi-annual inspections from the air at the beginning and end of the dry season, followed by ground inspections as necessary. The insulators can be replaced without the need for heavy machinery. The main potential sources of damage are lightning strikes and vandalism. The provision of an overhead earthwire along the length of the line will minimise faults due to lightning.

Spare parts, typically consisting of spare poles, conductor drums and fittings, will be stored at the Argyle diamond mine.

PLATE 6

A typical power line pole and insulator arrangement, similar to that proposed for the transmission line to the Argyle diamond mine.

3.6 SPILLWAY WEIR

3.6.1 Location and Access

The weir required to improve the storage efficiency of Lake Argyle will be a concrete structure, approximately 6 m high, located towards the Lake Argyle end of the existing spillway in an area of favourable foundation conditions. The spillway weir will be approximately 8 km north of the main dam site (see Figure 8). Access to this construction site will be along the existing road to the spillway.

3.6.2 Description

The existing spillway cut is 2.1 km in length and has a bottom width of 12 m. The majority of the spillway is cut through granitic rock and it is proposed to locate the weir at a point upstream of the public viewing area. Presently this spillway flows when the level of Lake Argyle rises above 86.2 m AHD.

Construction of the weir across the spillway will increase the water head for power generation, and when the water level of Lake Argyle reaches 92.2 m AHD, water will flow over the rounded crest of the weir and into the existing spillway channel as it does at present. A concrete apron on the downstream side of the weir will provide erosion protection for the floor of the channel. In addition, the sides of the channel adjacent to the weir will be protected by concrete.

The proposed weir will be approximately 14 m thick through the base and will be appropriately anchored to the existing spillway.

PROPOSED ROUTE

ORD RIVER DAM

HYDRO - ELECTRIC STATION

ARGYLE DIAMOND MINE

LAKE ARGYLE

SCALE 1 : 250 000

0 10 kilometres

ARGYLE DIAMONDS
ORD RIVER HYDRO - ELECTRIC PROJECT

TRANSMISSION LINE PREFERRED ROUTE

FIGURE 7

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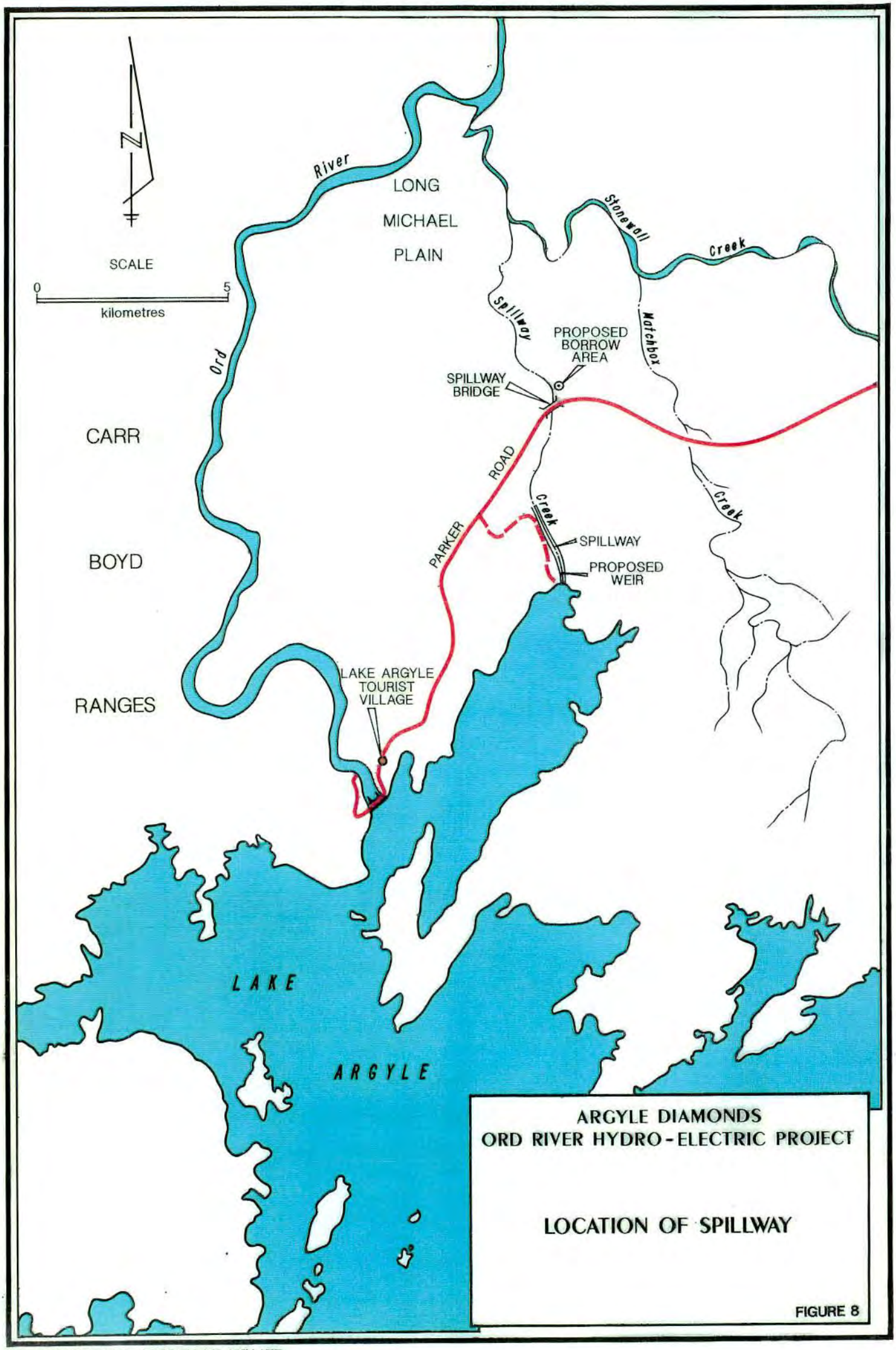

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PROPOSED ROUTE

ALTERNATIVE C (1)

ALTERNATIVE C (2)

ALTERNATIVE C

ALTERNATIVE B

ALTERNATIVE A

ORD RIVER DAM

HYDRO - ELECTRIC STATION

ARGYLE DIAMOND MINE

Coolamon Pocket

LAKE ARGYLE

SCALE 1 : 250 000

0 10

kilometres

ARGYLE DIAMONDS
ORD RIVER HYDRO - ELECTRIC PROJECT

ALTERNATIVE TRANSMISSION LINE ROUTES

FIGURE 9

4.0 EVALUATION OF ALTERNATIVES

The feasibility study for an alternative energy source for the Argyle diamond mine has not considered in detail all potential sources. Because of the provision of tunnels in the Ord River dam and the established technology in electrical power transmission, the hydro-electric station was the only option evaluated in detail. However, it is appropriate to comment on the alternative energy sources such as solar energy, wind power and natural gas.

4.1 ALTERNATIVE ENERGY SOURCES

4.1.1 Solar Energy

Solar energy is a very safe energy source, but at the present time there are a number of disadvantages that preclude serious consideration of this option. Solar energy technology is still in the development stage for large-scale power generation and the option can only be exercised in areas that have plentiful year-round sunlight. Because the energy source is not available at night or on cloudy days, a large storage system would have to be installed together with another energy source back-up system. In addition, a solar source has a low nett useful energy yield because dispersed solar energy must be highly concentrated. This could be achieved by an extensive array of parabolic lenses. The environmental impact of the development and operation of 'reflector farms' and energy delivery systems in the project area would be significant due to the huge area which is required to generate 40 MW of power. Solar energy is thus not a viable option.

4.1.2 Wind Power

Wind power is an indirect form of solar energy and is an almost unlimited, clean and safe source that has a moderate nett useful energy yield. The technology of low-yield wind turbines is well developed and since electric power generation increases with the square of the rotor diameter, large wind turbines are more efficient than small ones (Hayes, 1977). Accordingly, a turbine with a 30 m rotor would generate four times the power of a turbine with a 15 m rotor. In addition, wind power increases as the cube of wind velocity, so that a 16 km/hour wind has eight times as much power as an 8 km/hour wind (Chase, 1978).

However, there are a number of disadvantages that, like solar energy sources, preclude serious consideration of wind as an alternative energy source. Continuous high velocities are required and the technology for large-scale power generation is not yet developed. The large-scale and continuous generation of power required for Argyle would require extensive wind turbine farms and an alternative energy source as a back-up system. Extensive wind turbine farms would have to be developed and this development, together with operation and maintenance requirements, would result in significant environmental impacts. As with solar-thermal energy, wind energy is not a

viable option at this time because of the high costs and the low wind-energy environment.

4.1.3 Natural Gas

Natural gas has been discovered in the Weaber Plains area of the Northern Territory but, as yet, proven reserves are insufficient to warrant commercial exploitation. Of all the fossil fuels, natural gas is the easiest to process and transport in pipelines. It burns hotter than other fossil fuels, with lower pollution, although carbon dioxide is produced. Apart from the potential for air pollution, development of natural gas as an energy source includes impacts associated with gas field development, establishment of a pipeline delivery and distribution system, and potential risks associated with the operation and storage of gas fuel supply systems.

Natural gas is not a viable alternative energy source for the Argyle diamond mine because of the lack of local supplies, costs of infrastructure development and potential environmental impacts.

4.2 HYDRO-ELECTRIC STATION LOCATION

The location of the hydro-electric station at the Ord River dam is determined by the existing tunnel outlets and no alternatives were considered.

4.3 POWER TRANSMISSION

4.3.1 Introduction

Several routes for the transmission line were identified and assessed on the basis of cost, engineering, effect on the landscape and cultural environment (see Figure 9). The alternative alignments were evaluated based on detailed consideration of environmental factors, and issues identified through correspondence and meetings with Federal, State and Local Government agencies and community groups, including Aboriginal communities with an interest in the area.

4.3.2 Overhead Transmission Line Versus Underground Cables

The transmission of electrical power from the hydro-electric facility to the Argyle diamond mine may only be achieved through conventional overhead transmission lines. Such lines are the most efficient in terms of system performance, construction, capital and operating costs.

4.3.3 Selection of Support Structures

In selecting the support structures for the transmission line, consideration was given to design requirments, cost and their effect on the landscape and environment generally. Support structures for 132 kV transmission lines have traditionally been lattice steel towers but more recently, hollow steel or concrete poles have been successfully developed and utilised. Lattice tower transmission lines would require four rather than one foundation to be excavated for each tower. Towers would be higher than poles and would have greater span lengths.

Hollow concrete poles have been selected because it is considered that they have the least effect on the environment in terms of foundation requirements, visual landscape intrusion and maintenance requirements.

4.3.4 Exit from the Hydro-electric Station

Consideration was given to several alternatives in selecting the line exit route from the station. The proposed exit route is considered to be the best alternative in terms of environmental effects and cost.

One alternative considered was a right-angle departure from the hydro-electric station, spanning the Ord River to the hill by the south bank and then re-crossing the river to the north shore to follow the proposed route to the Argyle diamond mine. This arrangement would have no specific environmental benefits and would require two unnecessary crossings of the Ord River.

It would be feasible to exit the station with buried cables. However, the use of cables would result in excessive visual and physical impacts on the immediate dam site environment, present engineering difficulties and have high construction costs. Cables of either 11 or 132 kV would be run from the station up the north bank to a location at the cliff top. They would need to be carried by a galvanised steel cable tray covered with a reflecting sun shield to minimise solar effects on the efficiency of the cable. The support work for such a cable tray would involve numerous excavations in the weathered rock, alteration to the vegetation and introduce a major visual detraction. Eleven kV cabling would also involve the entire substation being relocated from the hydro-electric station to the top of the cliff near the most frequented public viewing area overlooking the Ord River, downstream of the dam. A 132 kV cable tray system would also require a fenced area at this location to restrict access to its terminals and surge arresters.

4.4 OPTIONS FOR TRANSMISSION LINE ROUTE

4.4.1 Introduction

The selection of the transmission line route took account of a number of factors that dictate operational efficiency. The cost of a transmission line is proportional to its

length. Vulnerability to lightning strikes and the down-time required for maintenance are also a function of length. An increase in transmission line length also increases the resistance, and if this reaches an unacceptable level, it may be more economic to operate at a higher voltage and therefore a lower current. However, to achieve this, it would be necessary to use more expensive transformers, switchgear and transmission lines.

Areas prone to flooding are avoided for transmission line poles or towers because the potential for flooding greatly increases the cost of foundations. In many low lying 'flood-prone' areas, not only is flooding itself of concern, but the soils present also pose special problems for foundation engineering.

4.4.2 Alternative Routes

Alternative B (Figure 9) is the most direct route to the Argyle diamond mine. This route which passes through the Carr Boyd Ranges has been identified in previous studies by SECWA, and this present study has confirmed that a transmission line route through the ranges is possible. The extremely rugged nature of the northern part of the Carr Boyd Ranges has suffered little disturbance by grazing and this makes this route undesirable because of the potential environmental impact. The route would require a semi-permanent access track to be constructed in an identifiable wilderness area. In addition, the rugged terrain would substantially increase construction costs and would impose restrictions for maintenance access. The elevated location would increase the risk of lightning strikes and because of the increased vegetation as a result of minimal grazing, there could be an adverse impact from increased incidence of fires.

The possibility of a submarine cable across Lake Argyle, and buried elsewhere, was also considered. This route is shown as Alternative A on Figure 9. The environmental impacts of cable installation and the risks associated with having a submerged oil-filled cable would be significant. The cable option was also impractical in terms of transport requirements, installation complexity, operation and maintenance requirements and installation cost. It was concluded that this option was both uneconomic and environmentally unacceptable.

Alternative C on Figure 9 offers a route option that does not transgress the boundaries of the proposed Lake Argyle and Carr Boyd Ranges National Park. From the station, this route trends in a north-easterly direction to the northern face of the Carr Boyd Ranges where it passes from the Ranges across Nigger Hill Plain and on to Maxwell Plains. From here, the route would cross the Ord River and Packsaddle Plain before swinging south-west to the Dunham River flood-plain.

The Alternative C transmission line route has a number of disadvantages. These are:

- The route is longer than the selected route. This reduces the reliability of the system and increases both line losses and construction and maintenance costs.

- Potential delays and difficulties are likely to occur as a result of the line passing through land being re-developed for irrigation agriculture and passing through land proposed by the Wyndham-East Kimberley Shire as conservation and environmental protection reserves, as outlined in its Rural Planning Strategy.

- The route crosses a broad section of Lake Kununurra approximately 8 km south of the Kununurra township. Such a crossing would require a long span between tall towers. These towers would be highly visible in this location. Potential impact on waterbirds using Lake Kununurra will be greater than for the proposed route due to the number of birds using this body of water.

- The crossing point on the Dunham River is close to a significant fauna site, Flying Fox Waterhole. Access to this area would increase as a result of people using the powerline construction access track.

There are two sub-alternatives associated with Alternative Route C. The route referred to as sub-alternative (1), while avoiding the proposed national park, will require two crossings of the Dunham River. These crossings would require larger towers and reinforced foundations for protection against flood flows. Each crossing would require clearing of the fringing riverine communities and substantial access tracks would be required to transport construction materials to the tower sites.

Sub-alternative (2) is located between the Dunham River and the western flank of the northern Carr Boyd Ranges massif, and accordingly passes through the proposed national park. This sub-alternative would impact on the woodlands/savanna woodlands present in this area and on the flood-plain pools with their associated rich fauna.

In addition to these constraints, there is the potential for isolation of approximately 13 km of the transmission line west of the Dunham River during periods of flooding. There are also potential adverse impacts on plant communities as the route passes through the relatively rich Dunham River levee forest.

Alternative Route C, and the sub-alternatives (1) and (2) are considered to be unacceptable because of the potential significant environmental impacts and penalties in cost, reliability, and energy losses.

A further possible transmission line route was examined to avoid transgressing the proposed national park. This route skirts the northern end of Lake Argyle south of Mt Brooking before passing into the Northern Territory. Approximately 10-15 km of the route would lie within the Northern Territory border before passing back into Western Australia. The route would cross the Behn River north-east of Mt Quirk and then proceed towards Lissadell Station and the Argyle diamond mine. A major crossing would be required over the Ord River, at a point which represents the southern extension of Lake Argyle at full supply level. Low-lying terrain, major catchment areas,

and the potential for flooding would require tall lattice towers, with large foundations and flood-protection works. The visual impact of a line along this route would be significant as the line would be silhouetted against the sky for much of the route. This route has not been considered in detail and was rejected because of the high cost, engineering constraints, and the potential for significant adverse environmental impacts.

4.5 SPILLWAY

A spillway weir is necessary to optimise the hydrological capacity of the dam. The size and position have been determined by WAWA and no alternatives were considered.

5.0 DESCRIPTION OF THE EXISTING ENVIRONMENT

5.1 INTRODUCTION

A description of the existing environment must not only define the limits of the project, but also the limits of the environment that will be affected by project operations. The local environment of the project area is confined to the hydro-electric station and its surrounds and to the transmission line corridor extending to the mine. For purposes of environmental characterisation, the corridor is taken to have an average width of 2 km.

One of the key issues in assessing project feasibility is the supply of water for release through the hydro-electric station. Accordingly, the catchment of Lake Argyle and its environmental complexity is important at both the regional and local scale. The catchment area of the Ord River dam straddles the WA/NT border, extends for approximately 300 km south of Kununurra and covers an area of approximately 46,000 square kilometres (see Figure 10).

Within this area, rainfall decreases as the distance south increases. In addition, there are distinct changes in the physical framework and in the inter-relationship of geology, landform, soils, hydrology and vegetation. No attempt is made here to define in detail the individual components of the regional framework within which the project is located. However, it is appropriate to identify the regional features of the environment as a basis for a more detailed description of the project environment.

5.2 REGIONAL SETTING

The project area is located within the Kimberley Basin, a sub-division of the general morphotectonic division of Western Australia known as the Kimberley Region. The greater project area defined here as being the Lake Argyle catchment area, also extends into a second sub-division of the Kimberley Region known as the Halls Creek Province.

Three major geomorphological divisions occur within the greater project area. These are:–

- The Leopold-Durack Ranges – prominent ranges of dipping quartzites bordering the main Kimberley Plateau to the south and east;

- Halls Creek Ridges – ranges and rounded hills on granite and metamorphic rocks;

- Ord-Victoria Plateaux – dissected plateaux, mainly basaltic but partly of sandstone and with local lateritic cappings.

TABLE 1

Regional Climatic Data - Summary

Mean Rainfall

Station	Annual (mm)	No. of Wet Days
Wyndham (1)	735	63
Kununurra	813	64
Turkey Creek	681	57
Halls Creek	517	62

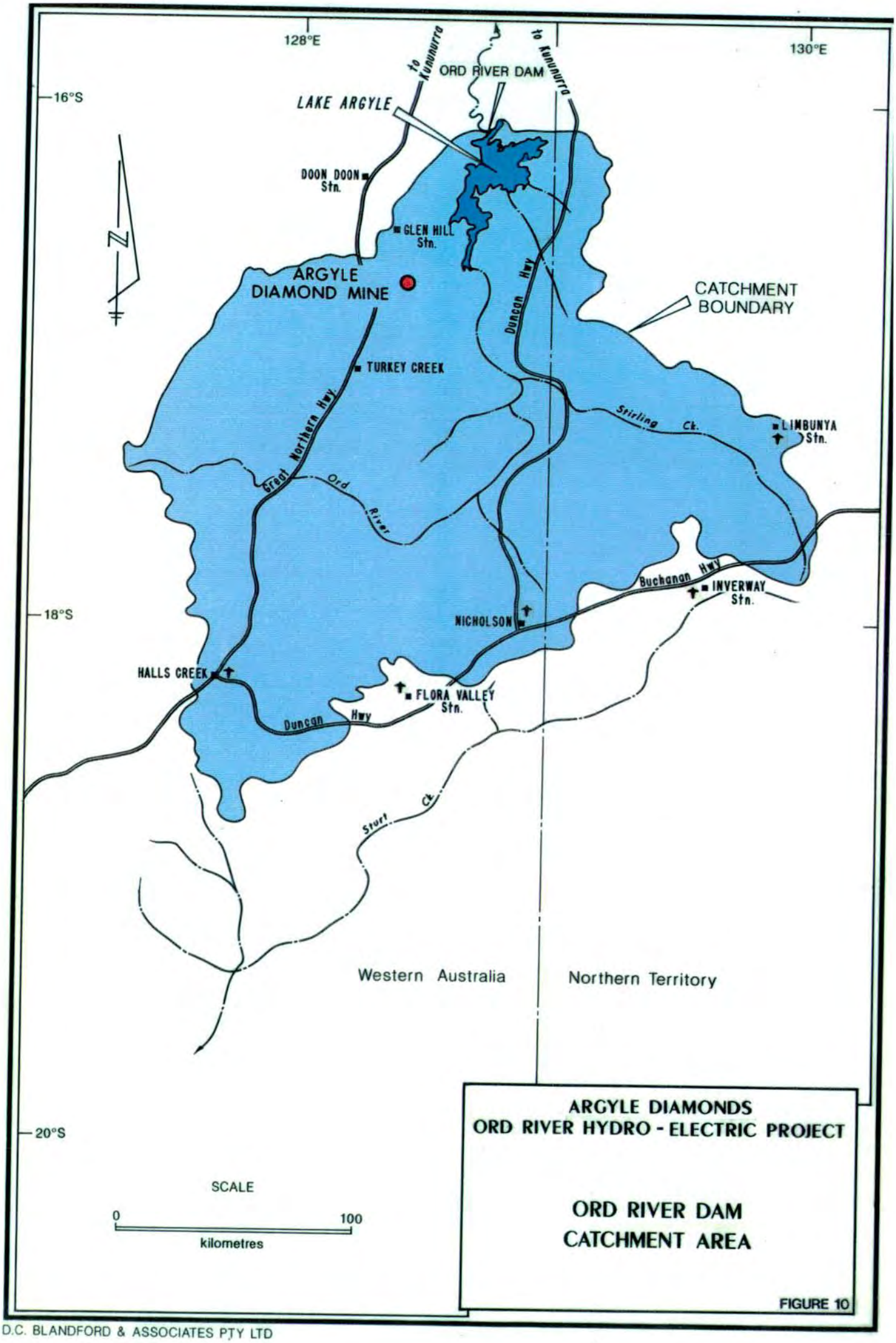
Mean Temperature

Station	Maximum	Minimum
Wyndham(1)	35.5°C	23.1°C
Kununurra	35.4°C	21.5°C
Turkey Creek	35.3°C	20.2°C
Halls Creek	33.8°C	19.9°C

Mean Evaporation

Station	Annual (mm)
Wyndham	2800
Kununurra	3097
Halls Creek	3301

Source: Bureau of Meteorology
Note: (1) New Site – established 1983



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The greater project area falls within the Köppen semi-arid climatic region in which there is a dry winter and at least one cool month (Gentilli, 1972). As can be expected in such a large area, there is considerable variation in climatic parameters. Mean annual rainfall varies from 813 mm at Kununurra to 517 mm at Halls Creek while mean evaporation at Halls Creek exceeds that at Kununurra by 204 mm.

Regional climatic data are summarised and presented in Table 1. Rainfall at the Argyle diamond mine is given in Table 2. The regional location of the project results in much of the annual rainfall occurring from short-duration, high-intensity storms. The intensity of rainfall from these summer storms is high, and exceeds the infiltration rate of soils, resulting in runoff in the catchment and into Lake Argyle.

TABLE 2

Argyle Mine Site - Monthly Rainfall (mm)

	1985	1986	1987	1988	1989	1990
January	68.7	237.7	287.0	72.6	91.6	135.3
February	85.3	43.6	229.7	79.1	82.8	67.4
March	139.0	11.0	0.0	90.4	310.8	68.0
April	21.5	0.0	3.6	0.6	7.4	13.4
May	0.0	0.0	0.0	25.0	0.0	0.0
June	7.0	20.8	4.6	0.0	0.0	0.0
July	0.0	28.2	0.0	0.0	0.0	0.0
August	0.0	0.0	0.0	0.0	0.0	0.0
September	0.0	5.2	3.6	4.0	0.0	2.8
October	42.4	11.4	20.8	19.0	0.0	6.4
November	24.4	33.2	80.0	51.2	13.8	47.8
December	110.2	17.0	159.0	194.0	109.0	62.8
Total	498.5	408.1	788.3	535.9	615.4	403.9

Source: ADM

In addition to short-duration summer storms, the region is also prone to cyclonic activity and in the period 1905 to 1988, 20 cyclones have passed through the Ord River dam catchment area (Bur.Met.,1981). Not only can cyclonic activity bring heavy rainfall, but also, in the case of a decaying cyclone, the associated rain depression may result in widespread and prolonged low-intensity rain.

Rainfall intensity-duration curves have been developed for the Argyle diamond mine site and these are given in Figure 11.

The majority of the greater project area lies within the Northern Semi-arid Pasture Region. This region is the drier inland extension of the Monsoon zone and rainfall is

restricted almost exclusively to the summer months. However, the southern boundary of the catchment area lies within the northern boundary of the Australian Arid Zone, which is characterised by a very low and erratic rainfall.

In keeping with the geologic and topographic complexity, the greater project area also has great variability in soil types. The hills and ridges of the Halls Creek and Leopold Range mobile zones contain shallow lithosols and shallow sandy soils underlain by rock. Away from the ridges, deeper loams and duplex soils occur.

Finely-structured, self-mulching clays occur in low-lying, low-relief land around Kununurra and south of Lake Argyle. Structured earths may also occur in association with these self-mulching clays. South of Turkey Creek, much of the catchment area is composed of shallow loamy soils, while on the southern boundary of the catchment area, there are extensive areas of both self-mulching clays and massive earths.

5.3 PHYSICAL ENVIRONMENT

5.3.1 Geology

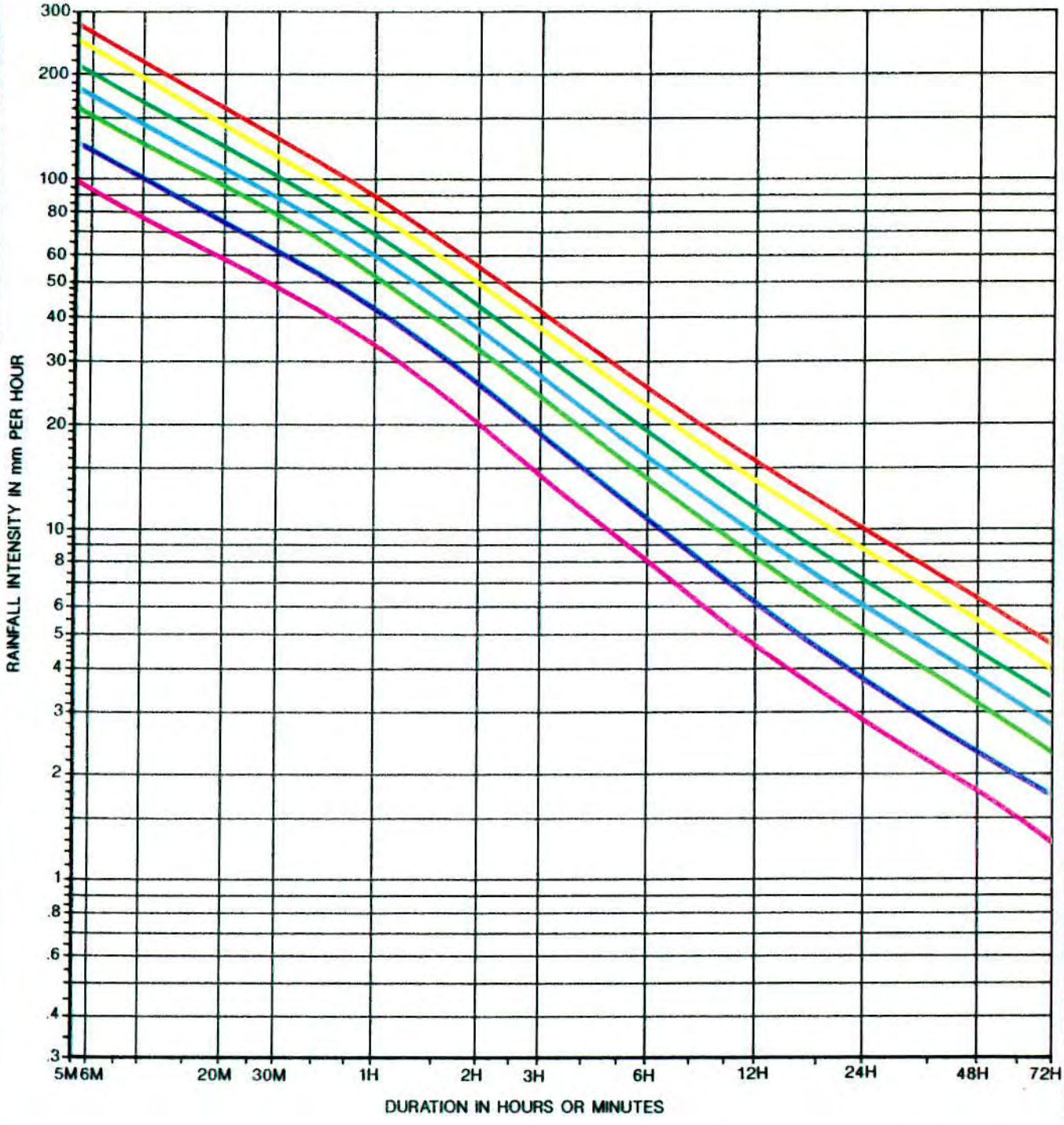
The project area lies within the Halls Creek Mobile zone. This zone, one of three major regional tectonic divisions, is bounded on the west by the Kimberley Block and on the east by the Sturt Block. The Halls Creek Mobile zone is strongly faulted and folded, and is composed of igneous, sedimentary and metamorphic rocks. The older rocks have been deformed by regional stresses resulting in complex fold patterns, but faulting dominates the structure. The Halls Creek Fault forms the eastern boundary of the zone and the Greenvale-Lianna Faults define the western boundary (Griffin and Grey, 1990).

The geology of the Carr Boyd Ranges within the vicinity of the Ord River dam is composed of lithologies of the Carr Boyd Group of sediments of Middle Proterozoic age. Outcrop is dominated by the Golden Gate Siltstone and the Lissadell Formation. Both these formations contain shale, sandstone and siltstone as principal lithologies. Geological structure, typical of the Carr Boyd Ranges is shown in Plate 7.

The transmission line route passes across these rock types and the outcropping Glenhill Formation before leaving the mountains.

From the mountains, the route crosses Coolamon Pocket, a plain developed on Quaternary alluvium. From this plain, the route swings south west around the flank of the Carr Boyd Ranges where it crosses undifferentiated surface sediments of Cainozoic age. These surface sediments are generally unconsolidated and are associated with the Dunham River drainage system.

From the Glen Hill station turnoff on the Great Northern Highway, the route passes into a narrow valley, the floor of which is undulating to low rolling hills formed on Antrim Plateau Volcanic of Lower Cambrian age. These volcanics include basalt, agglomerate and minor sandstone.



AVERAGE RECURRENCE INTERVAL (Years)

- 1
- 2
- 5
- 10
- 20
- 50
- 100

SOURCE : HYDROMETEOROLOGICAL ADVISORY SERVICE
BUREAU OF METEOROLOGY

ARGYLE DIAMONDS
ORD RIVER HYDRO - ELECTRIC PROJECT

RAINFALL INTENSITY DURATION CURVE
ARGYLE DIAMOND MINE SITE

FIGURE 11

PLATE 7

Typical geological structure and associated landforms of the central Carr Boyd Ranges massif.

South of Glen Hill, the valley narrows and the route turns to the south east across a low watershed developed in the Ragged Range Conglomerate Member of Late Devonian age. This unit, dominated by friable red conglomerate, quartz sandstone, and silty quartz-sandstone forms the characteristic 'hill' terrain shown in Plate 9.

The transmission line route continues to the south-south-east within the Ragged Range Conglomerate until it turns westward towards the mine.

The final several kilometres of the route pass through outcropping units of the Revolver Creek Formation of Early Proterozoic age within this unit. Lithologies are dominated by sandstones and siltstones.

5.3.2 Landforms

The landforms of the project area can be divided into three simple types. These are:

- Mountains;
- Hills; and
- Plains

Mountains

Mountain landforms are characterised by those occurring in the Carr Boyd Ranges, the Ragged Range, and along the Blatchford Escarpment. The terrain is generally strongly dissected with deeply-incised drainage lines and local relief exceeding 150 m. Hill slopes range from vertical free faces down to steep slopes at 35°. Lower hill slopes characteristically have angles of 25-30° . The mountains are typically rugged and provide the spectacular scenery associated with the Kimberley region (see Plates 7 and 8).

Hills

This group of landforms typically represents the transition zone between the mountains and plains. As such, local relief is low, hillslopes rarely exceed 30° and drainage lines are well defined but are rarely deeply incised. The terrain has a rolling character in isolation such as that displayed by the southern extension of the Ragged Range, immediately north of the Argyle mine site [see Plate 9(a)].

Plains

The plains present in the project area are either gently undulating to flat or are low rolling plains. Despite low relief, drainage lines are usually well defined, particularly in outwash zones adjacent to hills or mountains.

The plain developed east of the southern extension of the Ragged Range is a gently-undulating colluvial plain, with low local relief and defined drainage lines. Slopes on this type of plain range from 2% to less than 1%.

Other extensive plains within the project area occur at Coolamon Pocket [see Plate 9(b)] and along the western boundary of the Carr Boyd Ranges north of the Blatchford Escarpment. The plain here is a colluvial plain, sloping gently west towards the Dunham River drainage system (see Plate 10).

Weston (1991) describes two additional landform units which he identifies on the basis of soil types and seasonal inundation. However, the morphology of these two units is not sufficiently different from the overall plain morphology to warrant a landform class of their own.

5.3.3 Soils

The soils of the project area can be identified by their landform relationship and the degree of development present in the profile. No attempt is made here to identify and describe the range of soils present throughout the project area. Rather, the major soil landscapes are identified and the main soil characteristics and key profile features are described according to Northcote (1971) and Stephens (1962).

The soils of the mountains and hills landform units are grouped together for the purpose of soil descriptions. As a general rule, runoff is rapid in this type of terrain and weathering material is rapidly removed down slope. As a result, soils in upper slope positions may be non-existent as on dip slopes of the Lissadell Formation, or they may form a thin veneer over the country rock where they may be protected by a surface layer of lag gravels. In these situations soils are dominated by lithosols and they are characteristically shallow in depth (less than 60 cm) and have loamy (medium) textures.

These mountains and hill soils have profile development that is limited to small colour and textural changes and a diffuse horizonation with increasing depth. Gravel and stone contents vary and range from nil to in excess of 60%.

A second group of soils can be identified in mountains and hilly terrain. These are the siliceous sands or lithosols. These soils have uniform but coarse-textured profiles showing little, if any, profile development apart from the accumulation of organic matter at the surface. Subsoil material is coherent and firm when moderately moist.

These two groups of soils are inherently stable in an undisturbed state. However, disturbance to the vegetative cover (often spinifex) and disturbance of the surface lag gravels, predisposes them to accelerated soil erosion.

PLATE 8

(a) Typical landforms along the western flank of the Ragged Range. The plateau surface is strongly dissected with deeply-incised drainage lines.

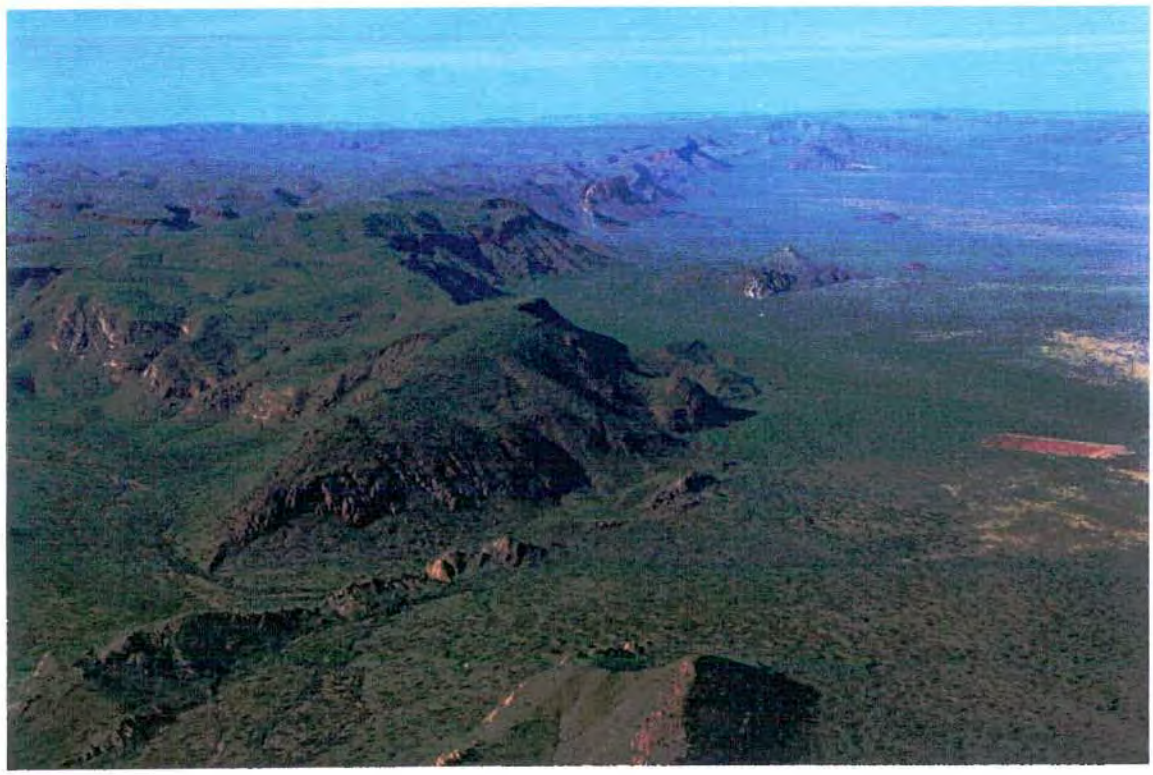
(b) An abrupt transition in landform from the Carr Boyd Ranges to Coolamon Pocket. Gorges are micro-environments with distinctive assemblages of plant species.

PLATE 9

(a) Rolling hill terrain on the southern end of the Ragged Range. Drainage is typically dendritic.

(b) The flat to gently-undulating plain forming Coolamon Pocket. Landform changes are abrupt from the surface of the plain to the steeply-dipping quartzites of the Carr Boyd Ranges.

PLATE 10



(a) The western flank of the Carr Boyd Ranges and the gently-sloping colluvial plain draining west towards the Dunham River.

(b) An undulating colluvial plain forming a major landform type west of the Blatchford Escarpment.

A further but minor group of soils can be identified in undulating hilly terrain. These soils are characterised by coarse-textured profiles, high to moderate gravel contents, and have pale A2 horizons overlying reddish-brown subsoils. Profile depth is dependent on slope position and the soils tend to be permeable, well drained, and are stable in an undisturbed state. However, disturbance to the surface will result in accelerated soil loss.

The second major group of soils in terms of soil landscapes is associated with plains, and the lower more gentle slopes of hilly terrain. Soils present in this group are more complex and generally show advanced levels of profile development. The soil landscape of the plains is characterised by duplex and gradational primary forms. However, minor areas of self-mulching clays occur in isolated pockets. The duplex soils are dominated by red podzolic and chocolate soils. These soils, characterised by texture contrast between the A and B horizons, have pedal clayey B horizons that are whole coloured (uniform in colour) and have reaction trends ranging from acid to alkaline. These soils tend to be permeable and well drained and have moderate to high inherent fertility. As with other soils in the project area, they are relatively stable in an undisturbed state. However, any form of surface disturbance predisposes them to accelerated soil erosion.

Gradational soils in the project area are dominated by structured earths. These structured earths, typical of soils south of Glen Hill station, on basaltic rocks, have gradational texture profiles that are not calcareous, have a rough ped fabric and are whole coloured. These soils are fertile and moderately permeable and the well developed rough ped fabric tends to increase their resistance to erosion in a disturbed state.

5.3.4 Hydrology

The surface hydrology of the project area is dominated by a highly seasonal and variable rainfall, complex geologic structure, and a complex surface morphology.

Apart from the Ord and Dunham River systems, the majority of surface streams within the project area are ephemeral, but some of the larger creeks may revert to a series of pools in their lower reaches.

On a regional scale, drainage patterns are typically dendritic in form and are usually well developed. However, geologic structure plays an important role in dictating landform and resulting drainage patterns within individual project areas. South of Glen Hill station transverse valleys are present with cataclinal drainage well developed. Further south towards the Argyle diamond mine, longitudinal valleys with monoclinal streams occur.

In the mountain areas, drainage systems have been rejuvenated and tend to be deeply incised resulting in a strongly-dissected surface. These are areas of high hydrologic response where runoff and stream discharge are rapid.

Away from the hills and mountains, the surface hydrology is dominated by plain morphology.

Drainage systems are not deeply incised but are well developed. Patterns are still dendritic but systems tend to develop according to regime energy. Anabranching is common in the lower reaches of systems such as Smoke and Flying Fox Creeks and individual system dynamics are strongly influenced by rainfall patterns, seasonal growth response and the level of disturbance present in the catchment area.

Water quality is generally good in streams in the southern end of the project area, and selected parameters are given in Table 3.

TABLE 3

Surface Water Quality

Location	pH	Ca	Na	SO_4	NO_3	TSS
Smoke Creek	7.4	0.8	3.5	0.6	0.7	33
Limestone Creek	7.6	1.6	5.2	1.3	0.4	49
Gap Creek	7.0	0.5	2.6	0.6	0.4	30
Flying Fox Creek	7.0	0.6	2.6	0.1	0.5	16
Lake Argyle	8.1	23.0	41.0	4.0	-	-

Source: Dames & Moore (1982)

Notes: All samples other than pH in mg/l
TSS = Total Soluble Salts
Data recorded in 1981 for all locations

5.4 BIOLOGICAL ENVIRONMENT

5.4.1 Aquatic Systems

The Ord River, a highly seasonal watercourse prior to damming, can be divided into five hydrological, environmental sections. Each of the five sections has particular hydrological characteristics and functions.

(1) Lake Argyle Catchment

The largest section of the system is the catchment area above the Ord River Dam, an area of approximately 46,000 km^2 (see Figure 10). The summer monsoons generally result

in intense rainfall within the catchment. As a result, many of the tributaries of the Ord, as well as the Ord River itself, may flood.

In contrast, during the dry season when there is no significant flow for six to eight months, the Ord River headwaters diminish to a series of pools. The average annual catchment discharge into Lake Argyle is approximately 4,000 million m^3. There are large variations in the overall wet season rainfall, and therefore river flow from year to year. The monthly variation in river flow is extreme. Values are given in Table 4.

TABLE 4

Lake Argyle Inflows - million cubic metres

Month	Average	Maximum on Record	Minimum on Record
January	1,180	10,700	8
February	1,346	8,759	27
March	824	7,162	6
April	171	1,432	0
May	46	496	0
June	12	86	0
July	5	135	0
August	2	52	0
September	2	159	0
October	13	163	0
November	58	978	0
December	342	2,731	0
Annual Total	4,002		

Source: Extracted from extended river flows (1905-1988) for the Ord River at Coolabah Pocket.

(2) Lake Argyle

Lake Argyle is the reservoir formed behind the Ord River dam. Since construction, the Ord River dam has been operated by WAWA to satisfy irrigation demands and to control floods in the Ord River system.

Lake Argyle was created when the Ord River dam was constructed at Coolabah Pocket on Argyle Downs Station between 1969 and 1972. Two wet seasons, 1972-73 and 1973-74, were required to fill the reservoir. At Full Supply Level (FSL) of 86.2 m AHD, the lake stores 6,123 million m^3 of water with a surface area of 704 km^2, or 13 times the capacity of Sydney Harbour. At maximum probable flood level (MPF) the lake covers approximately 2,070 km^2.

The Ord River dam was designed to store the highly variable wet season flows and thus allow a controlled discharge for downstream use. The seasonal filling and drawdown of Lake Argyle result in water levels typically fluctuating in the range of 3 to 5 m each year, with extreme cyclic differences exceeding 10 m.

The Ord River dam was constructed to eventually supply, in conjunction with the Kununurra diversion dam, an irrigation area of around 75,000 ha. Comparison of the levels of Lake Argyle in Figure 3 confirm that under conditions of maximum irrigation development (75,000 ha), water levels in the reservoir would have been similar to those which would have been experienced had the hydro-electric project been in operation. Although the Ord River irrigation project has not yet reached its full development, the quantity of water discharged from the dam to date has been more than sufficient for the maximum development of 75,000 ha.

Due to low irrigation demand, Lake Argyle has not operated as originally planned, and lake levels have generally been higher than originally expected. This has resulted in more water passing over the spillway than would have been the case had higher irrigation releases been made.

The upper catchment of the Ord River has experienced increased erosion and sediment movement since the introduction of cattle grazing. WAWA estimates that 24 Mt of sediment is deposited into Lake Argyle each year .

The majority of the sediment load carried in floods from the catchment area is deposited in the upper reaches of the lake, whilst a small quantity is carried further into the reservoir. Surveys of the floor of the reservoir basin were carried out before and after the construction of the dam. A follow-up survey undertaken between 1985 and 1987 by WAWA indicated close agreement between the measured sediment deposits and the initial estimate of 24 Mt per year. This has been despite a substantial programme of catchment erosion management undertaken since 1960, including reduced cattle stocking rates and revegetation. The nett effect of sediment deposition in the reservoir since 1972 has been a 6% nett loss of lake storage volume calculated at the 86.2 m AHD Level. While it is anticipated that the loss of storage volume over the next 15 years will increase this to approximately 12% of original storage capacity, only a small proportion of this is located at elevations above 75 m AHD and therefore within the lake's active storage volume.

Lake Argyle currently develops a strong thermocline at a depth of around 20 m between January and April (Imberger and Patterson 1979). During this period, water temperatures at the bottom of the lake can be 7°C cooler than at the surface, and oxygen levels become depleted below the thermocline. Between May and June the surface water cools inducing vertical mixing. By July the lake is generally well mixed throughout its depth.

(3) Ord River Between Lake Argyle and Lake Kununurra

The 15 km section of river below the Ord Dam has experienced highly altered flow patterns since construction of the dam. Large floods no longer pass down this section of the Ord River and irrigation releases are now a common feature of the river's behaviour at a time of year when it would previously have been a series of pools.

Overflow through the Ord River Dam spillway, located 8 km to the north east of the dam, runs into a channel excavated through a granite saddle and discharges into a previously minor creek now known as Spillway Creek. Spillway Creek flows into Stonewall Creek which joins Lake Kununurra 31 km downstream of the Ord River Dam.

The pattern of spillway flows recorded from 1972 to 1988 is shown in Figure 12. The frequency and volume have been higher than anticipated due to low irrigation demand and resultant lower dry season releases from the irrigation valves. Spillway flows into Spillway Creek have substantially increased the discharge from this creek's small (34 km^2) catchment, resulting in substantial erosion and sediment transport into Lake Kununurra.

(4) Lake Kununurra

Water from Lake Argyle is released into the Ord River which then flows into the headwaters of Lake Kununurra which covers approximately 40 km of river channel downstream to the Kununurra diversion dam. The Kununurra diversion dam constructed at Bandicoot Bar was completed in 1963. A gravity-fed irrigation channel, with a design capacity of approximately 25 m^3 per second (cumecs) carries water from Lake Kununurra to the Ivanhoe Plains irrigation area. Prior to the construction of the Ord River dam, seasonal floods were allowed to pass through the diversion dam radial gates as there was no surplus storage capacity. Lake Argyle now stores much of the seasonal flood flows and provides water to Kununurra throughout the year through the Ord River dam irrigation valves and spillway flows.

The diversion dam gates are used to maintain levels in Lake Kununurra, with an average operating level maintained approximately 0.15 m below the top of the gates at 41.5 m AHD. Levels in Lake Kununurra are closely monitored and controlled to facilitate irrigation releases, with variations occurring between 41.0 m and 41.8 m AHD.

(5) Ord River Downstream of the Diversion Dam

The majority of the discharge from the Ord River dam flows into Lake Kununurra, through the diversion dam, and down the Ord River. A few irrigation operators pump water directly from the river below the diversion dam.

The Dunham River joins the Ord River 2 km downstream of the diversion dam and contributes substantial seasonal flows from its 4,000 km^2 catchment.

5.4.2 Vegetation

The only published vegetation map that covers all of the project area is Beard's 1:1,000,000 scale map of Kimberley vegetation (Beard 1979). This map is based upon interpretation of aerial photographs, traverses by motor vehicle and examination of earlier maps of geology and land systems. One of these earlier maps, by Stewart *et al.* (1970), shows project area land systems at a scale of 1:1,000,000.

On his 1:1,000,000 scale vegetation map, Beard (1979) shows the vegetation of the project area as being within, mostly, the Gardner Botanical District and, in the relatively short strip south of the Glen Hill area (Lat. 16°28'), the Hall Botanical District.

Vegetation in the Ord River valley now inundated by Lake Argyle is described by Kitchener (1978). Vegetation in transects on river banks downstream of the Ord River Dam and on the shores of Lake Argyle is described by Meagher & Le Provost (1980).

The vegetation of one part of the project area, the southern end, has been described as plant associations and vegetation complexes (Weston, 1980; Dames & Moore, 1982), and those vegetation complexes have been mapped at a scale of 1:100,000. A vegetation complex approach is also taken in this report, with the major vegetation types of the project area being described as components of vegetation complexes (Weston, 1991). The location of the vegetation complexes is shown in Figure 13.

The vegetation complex approach to the classification and description of vegetation is based on field survey and photo interpretation.

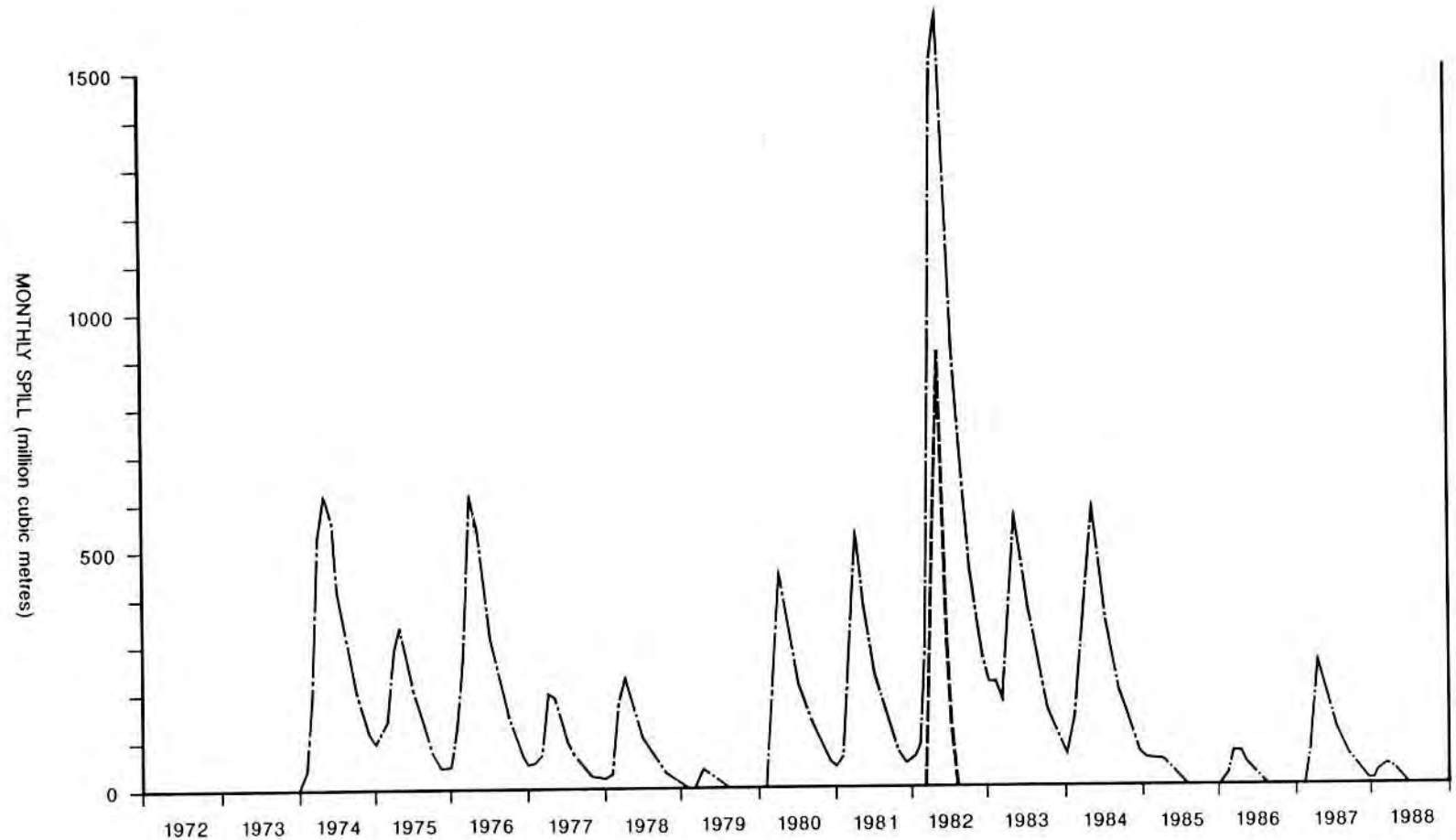
The vegetation is not, in terms of density and relative species importance, constant in any of the complexes, or even in the units that make up the complexes. There are, consequently, variations in each complex from the vegetation described below.

(1) Mountains Complex (M)

Savanna low woodlands, steppe low woodlands and sparse vegetation on skeletal soils and small pockets of alluvium on steep mountain slopes, ridges, plateaux and internal, minor drainage lines of the Carr Boyd Ranges.

The mountains complex low woodlands in the project area corridor and vicinity of Ord River and Ord River Dam typically are dominated by 5 m to 8 m tall *Eucalyptus coniophloia* trees, often with *Eucalyptus ? clavigera, Terminalia canescens, Erythrophleum chlorostachys, Owenia vernicosa, Cochlospermum fraseri*, two *Gardenia* species and understoreys of spinifex species, of both *Triodia* and *Plectrachne*, and *Sorghum. Eucalyptus brevifolia, E. confluens* and other eucalypts are common on rocky slopes and foothills and, especially, in valleys, with *Grevillea*

SOURCE : SMEC



Recorded spillway discharges without project

Simulated spillway discharges with spillway weir at 92.2m AHD and operation of Hydro - Electric Station (40 MW at 50-60% capacity)

ARGYLE DIAMONDS
ORD RIVER HYDRO - ELECTRIC PROJECT

COMPARISON OF
DISCHARGES DOWN SPILLWAY CREEK
WITH & WITHOUT PROJECT

FIGURE 12

D.C. BLANDFORD & ASSOCIATES PTY LTD

ORD RIVER DAM

HYDRO - ELECTRIC STATION

ARGYLE DIAMOND MINE

LEGEND

- EXTENT OF PROJECT AREA SURVEYED
- 21 VEGETATION SURVEY SITE REFERRED TO IN TEXT OR PLATES
- SENSITIVE LOCATION
- M MOUNTAIN COMPLEX
- Hb BLATCHFORD ESCARPMENT HILLS COMPLEX
- Hr RAGGED RANGE HILLS COMPLEX
- Pc CARR BOYD PLAINS COMPLEX
- Pe EROSIONAL PLAINS COMPLEX

SOURCE : A. WESTON

SCALE 1 : 250 000

0 10 kilometres

ARGYLE DIAMONDS
ORD RIVER HYDRO - ELECTRIC PROJECT

VEGETATION AND FLORA

FIGURE 13

D.C. BLANDFORD & ASSOCIATES PTY LTD

PROPOSED ROUTE

ORD RIVER DAM

HYDRO - ELECTRIC STATION

ARGYLE DIAMOND MINE

LEGEND

13□ INTENSIVE SAMPLING SITE REFERRED TO IN TEXT

● SUPPLEMENTARY SAMPLING SITE

▽ SENSITIVE LOCATION

SOURCE : NINOX WILDLIFE CONSULTING

SCALE 1 : 250 000

0 10 kilometres

ARGYLE DIAMONDS
ORD RIVER HYDRO - ELECTRIC PROJECT

VERTEBRATE FAUNA SITES

FIGURE 14

D.C. BLANDFORD & ASSOCIATES PTY LTD

EL QUESTRO

IVANHOE

MIRIMA NATIONAL PARK

CONSERVATION & ENVIRONMENTAL PROTECTION RESERVE

VACANT CROWN LAND

DOON DOON

PROPOSED ROUTE

PROPOSED LAKE ARGYLE AND CARR BOYD RANGES NATIONAL PARK

Coolamon Pocket

VACANT CROWN LAND

ORD RIVER DAM

HYDRO - ELECTRIC STATION

GLEN HILL

ARGYLE DIAMOND MINE LEASE AREA

VACANT CROWN LAND

ARGYLE DIAMOND MINE

LISSADELL

LAKE ARGYLE

SCALE 1 : 250 000

0 10 kilometres

ARGYLE DIAMONDS
ORD RIVER HYDRO - ELECTRIC PROJECT

PROPOSED ROUTE
IN RELATION TO
EXISTING AND PROPOSED
LAND USE

FIGURE 15

D.C. BLANDFORD & ASSOCIATES PTY LTD

pyramidalis, Buchanania obovata, Eucalyptus confertiflora and the above species. *Ficus platypoda* and *Pouteria sericea* grow on steep bare rock and bouldery slopes. There are also areas of rock pavement and bouldery slopes with almost no trees and with a sparse layer of ground vegetation. These are populations of *Cycas pruinosa* on slopes above the Ord River and west of it.

Eucalyptus collina and *E. aff. cupularis* dominate woodlands on Carr Boyd Ranges plateaux south of transmission line route alternative B, but none of the woodlands would be affected by the project or is close to the route. There are also springs, pools and creeks in the range which support small groves of trees having species which are found in rainforest patches in wetter parts of the Kimberley. None of these groves is close to the transmission line routes or would be affected by the project.

(2) Hills Complex (Hb, Hr)

Low-tree steppes, savannas and savanna woodlands on colluvial and in situ skeletal soils and, in some drainage lines, alluvial soils on footslopes of the Carr Boyd Ranges and Blatchford Escarpment and generally low-relief hilly terrain in the southern part of the project area.

There are two types of hills complexes in the project area, which differ geologically, topographically and vegetationally. These hill complexes are:

(i) Blatchford Escarpment Hills Complex (Hb)

Low-tree steppes and curly spinifex savannas, generally on basaltic soils, on the western foothills of the Blatchford Escarpment and Ragged Range.

The low-tree steppe and savanna vegetation of the basaltic hills west of the Blatchford Escarpment is dominated by various combinations of 3 m to 6 m tall trees that range in density from very sparse to, rarely, almost low woodland. The trees are *Eucalyptus confluens, E. coniophloia, E. grandifolia, E. pruinosa, Terminalia canescens, Erythrophleum chlorostachys, Grevillea pyramidalis, Lysiphyllum cunninghamii, Hakea arborescens, Cochlospermum fraseri* and *Dolichandrone heterophylla.* The four eucalypts are the most consistently dominant trees in the vegetation; *Eucalyptus brevifolia* is locally common. The grasses include *Triodia* and *Plectrachne* spinifexes, *Heteropogon contortus, Sorghum* sp. and smaller grasses.

Lower slopes and plains among the hills often have open stands of *Terminalia arostrata.* The watercourses have *Lophostemon grandiflorus* sub.sp. *riparius* trees and *Lysiphyllum cunninghamii*, often with *Adansonia gregorii, Terminalia platyphylla, Exocarpos latifolius* and *Vitex glabrata.*

(ii) Ragged Range Conglomerate Hills Complex (Hr)

Low-tree steppe and low-tree savanna on the eastern foothills of the Ragged Range at the southern end of the transmission line route; on stony hills of the Ragged Range Conglomerate Member.

The foothills north of the Argyle mine on the eastern side of the range are vegetated with a *Eucalyptus brevifolia* low-tree curly spinifex savanna on the gentler, lower slopes and a *Eucalyptus confluens* low-tree steppe on the higher, steeper slopes.

Other less common tree and shrub species in the low-tree steppe include *Eucalyptus coniophloia, Cochlospermum fraseri, Grevillea pyramidalis, Dolichandrone heterophylla, Acacia gonoclada* and *A. retivenia.* Typically the ground cover comprises *Plectrachne pungens* and, especially in lower areas, *Sehima nervosum* and *Eriachne obtusa.*

Four other less common trees in the low-tree steppe are *Eucalyptus brevifolia, E. coniophloia, E. pruinosa* and *Erythrophleum chlorostachys.* Although shrubs are generally sparse, open stands of species of *Grevillea* and *Acacia* are locally common lower on the slopes. The ground cover comprises hummocks of spinifex, both *Plectrachne pungens* and at least one species of *Triodia.*

(3) **Plains Complex (Pe, Pc)**

Grasslands, savannas, savanna woodlands and woodlands on flat to gently-undulating, erosional and fluvial plains in the high rainfall area, mainly flanking the Ord and Dunham Rivers, in the Dunham River invagination of the Carr Boyd Ranges (Coolamon Pocket) and west of the Carr Boyd Ranges south of the invagination.

In the project area there are two types of plains complexes, each distinguished by its soils and vegetation. The two types are:

(i) Erosional Plains Complex (Pe)

Woodlands, savanna woodlands, pindan and seasonally inundated vegetation on gently sloping, usually deep, mainly yellow to red sand soils, with sandstone outcroppings.

The dominant species of the extensive woodlands and savanna woodlands on the plains immediately west of the Carr Boyd Ranges escarpment are 6 m to 10 m tall eucalypts, mainly *Eucalyptus coniophloia, E. cf. coniophloia, E. tetrodonta and E. ? foelscheana,* plus *Erythrophleum chlorostachys*, which mainly occurs as low regeneration. Other, less common trees in the woodlands are *Eucalyptus grandifolia, E. bigalerita and E. ferruginea.* The ground layers are variable mixes of sedges, short bunch grasses, *Plectrachne pungens* and *Sorghum. Petalostigma quadriloculare* is a common shrub in the understorey of *E. cf. coniophloia*, which grows on stony lithosols. Seasonally waterlogged soils support groves of *Melaleuca minutifolia* and other paperbarks.

Further west, a pindan of *Acacia tumida*, with a variety of trees, is widespread. The trees include *Erythrophleum chlorostachys, Eucalyptus miniata, E. coniophloia, E. ferruginea, Gardenia* sp., *Owenia vernicosa, Persoonia falcata* and *Terminalia canescens*. The principal grass is *Sorghum*.

Cabbage Tree Creek vegetation is characterised by *Lophostemon grandiflorus* spp. *riparius* and *Adansonia gregorii*, along with a variety of sedges, grasses, wattles and other shrubs. *Syzygium eucalyptoides*, an uncommon species in the project area, grows in the bed of the creek.

(ii) Carr Boyd Plains Complex (Pc)

Woodlands, savanna woodlands and seasonally inundated vegetation on gently sloping, sandy loams and deep, yellowish sandy soils in Coolamon Pocket, the large invagination in the Carr Boyd Ranges drained by a Dunham River tributary.

The project area vegetation on the southern part of the Carr Boyd plains is a mosaic of eucalypt woodlands, eucalypt savanna woodlands and paperbark seasonal swamps. The dominant eucalypts are *Eucalyptus bigalerita, E. grandifolia, E. clavigera, E. ferruginea, E. coniophloia and E. miniata*. Trees associated with the eucalypts include *Terminalia canescens, Acacia tumida, Erythrophleum chlorostachys, Owenia vernicosa, Buchanania obovata* and *Gardenia* spp. Characteristic suites of grasses, sedges and other herbaceous plants are components of the major woodlands and savanna woodlands.

The groves of 4 m to 5 m tall *Melaleuca nervosa* trees in the seasonal swamps are dense enough on some sites to be described as low open forest, but are usually more open. Many swamps have peaked termite mounds and a ground vegetation layer of species of *Fimbristylis, Rhynchospora* and other sedges and small herbaceous plants.

(4) **Levees/Terraces Complex**

Fringing woodlands and open forests on banks, alluvial terraces and flood plains bordering rivers and major creeks, including Ord River, Dunham River, Stonewall Creek, Flying Fox Creek and Smoke Creek.

The mixed, dense, often narrow communities of tall trees which line river bank levees are best developed along the Ord River, in the warm springs area next to Flying Fox Creek, in the gap just east of the project area, and around pools in the Dunham River. These fringing forests are the richest in species of any vegetation in the project area. *Eucalyptus camaldulensis*, the most widespread and common tree in levee fringing forests, is joined in these communities by *Melaleuca leucadendra, Melaleuca argentea, Nauclea orientalis, Barringtonia acutangula, Ficus coronulata, Ficus racemosa, Sesbania formosa, Terminalia platyphylla, Ziziphus quadrilocularis, Atalaya hemiglauca, Pandanus spiralis, Pandanus integer* and, at Flying Fox Creek, the shrub

Ziziphus sp. (ASW 12227). There is dense leaf litter and little ground cover under these dense, broad bands of forest. Often at the edges of these forests and underneath bands that are narrower and more open, there are dense swards of tall grass, primarily *Eulalia fulva, Mnesithea rottboellioides* and *Arundinella nepalensis.*

On the terraces and flood plains the common trees include *Eucalyptus papuana, E. confertiflora, E. ? polycarpa, E. pruinosa, Terminalia platyphylla, Lysiphyllum cunninghamii, Adansonia gregorii, Gyrocarpus americanus* and *Mallotus nesophilus.* In some places these trees constitute open forests and woodlands, but commonly, especially in the south, they are a scattered overstorey in high-grass savannas and bunch-grass savannas of *Aristida* spp. *Chrysopogon pallidus, Eriachne obtusa, Enneapogon glaber, Heteropogon contortus, Schizachyrium fragile* and *Panicum* spp.

(5) Riverine Complex

Riverine vegetation in habitats that are periodically inundated by flows in creeks and rivers, long-lasting pools and the permanently-flowing Ord River. The aquatic vegetation of Lake Argyle is considered here as belonging to a long-lasting, but extremely large pool.

In the seasonal watercourses that are most common in hilly and mountainous terrain the principal trees are *Lophostemon grandiflorus* sub.sp. *riparius* and *Lysiphyllum cunninghamii*, often with *Adansonia gregorii, Vitex glabrata* and *Terminalia platyphylla.* Common grasses include *Themeda australis, Heteropogon contortus* and species of *Aristida* and *Sorghum*, often with spinifex or curly spinifex. In basaltic areas north of Glen Hill, *Celtis philippensis* is occasional on steep rocky slopes and on cliffs up to 4 m above creek beds.

When seasonal pools on sandy and finer-textured alluvium in watercourses dry out, communities of small herbaceous plants appear. Such communities may include *Monochorea cyanea, Eriocaulon cinereum, Elytrophorus spicatus, Limnophila fragrans, Ludwigia octovalvis* and other species. *Eucalyptus ptychocarpa*, commonly called swamp bloodwood or spring bloodwood, is a dominant species in two small, spring-fed, swampy sites in the project area: at the south edge of the Carr Boyd plains and a short distance south of Spillway Creek. In these communities *Eucalyptus ptychocarpa* shares dominance with *Melaleuca leucadendra.* Other species in one or both of the communities include *Planchonia careya, Eucalyptus miniata, E. bigalerita, Erythrophleum chlorostachys, Adansonia gregorii, Terminalia latipes, Buchanania obovata, Pandanus spiralis* and the grasses *Eulalia fulva, Mnesithea rottboellioides, Heteropogon contortus* and others.

Lake Argyle Aquatic Vegetation and Fringing Vegetation

The shallow waters of Lake Argyle around the margins of the lake and the islands, especially in the south and east, support dense growths of aquatic plants, particularly

Potamogeton tricarinatus, which grow in water shallower than 3 m (Sainty and Jacobs, 1988). *Hydrilla verticillata* and *Najas graminea* have also been found in the lake, and are abundant in some areas in the east and north-east, but generally they are in deeper water than the *Potamogeton* (Meagher & Le Provost, 1980).

Ord River Aquatic and Semi-aquatic Vegetation

Gowland (1981) lists 57 species of grasses, sedges and forbs that grow in the emergent edge vegetation of Lake Kununurra. A large number of species of grasses, sedges and forbs also grow along the edges of the Ord River between the lake and Ord River Dam. Many of these species and others (including *Eulalia fulva, Paspalum scrobiculatum, ?Arundinella nepalensis* and *Poa* sp.) were recorded along the edge of the river during the May 1991 survey. These species include *Typha domingensis* (Cumbungi), which forms dense, very extensive stands out into the river. The stands appear to still be expanding and are not restricted to still water, although they impede and channel the flow of water down the river, collect sediments and protect river banks from erosion. Many of these stands in the upper part of the river are covered in the pink-flowered vine *Sarcostemma esculentum*. The reed-grass, *Phragmites karka*, is locally common in some areas.

Gowland (1981) lists eight species of vascular plants that are submerged or surface aquatics, most of which are illustrated and described by Sainty and Jacobs (1988).

These species are: *Aponogeton elongatus, Hydrilla verticillata, Myriophyllum verrucosum, Najas graminea, Nymphaea gigantea, Nymphoides indica, Potamogeton tricarinatus* and *Vallisneria spiralis*. The last two species are very abundant in the river between the Ord River dam and Lake Kununurra, to the point where they impede water flow and interfere with traffic along the river.

Significant Vegetation

None of the vegetation units found in the project area is rare, particularly restricted or under threat.

The significant vegetation communities recorded in the project area are all dense tree vegetation stands associated with water. These are swamp bloodwood forests, and the levee forests that border on being rainforests.

Rainforests are poorly represented in Western Australia and, at least in the broader Kununurra-Halls Creek area, are restricted to a number of patches which are mostly very small and intergrade with riverine or riparian closed forests of the type found in the Osmond Range (Forbes and Kenneally, 1986). According to Kenneally (the authority on Western Australian rainforests), no rainforests have been recorded in the project area. Intergrading patches of closed forest which might be considered rainforest in a broad sense are known to be associated with springs in the vicinity of the Argyle mine

and to occur along the Ord River and in Carr Boyd Ranges' gorges. Some such patches occur along the Dunham River in the project area, and along the Ord River and Flying Fox Creek just outside the project area.

Swamp bloodwood paperbark forests and woodlands are reasonably common and widespread in the high rainfall zone and wetter parts of the Kimberley and the Northern Territory's Top End, but in the project area and further south they are relatively uncommon. Two swamp bloodwood communities occur in the project area, south of Spillway Creek and on the south side of the Carr Boyd plains (Coolamon Pocket).

5.4.3 Flora

Phytogeography

As noted previously, the project area is in the Gardner District, but with its southern part in the Hall District (Beard, 1980). The districts extend westward to 124°0'E longitude and eastward well into the Northern Territory. More recent work has been carried out in the north-west of Australia by Hnatiuk and Maslin (1988) who have divided Australia into eight major areas on the basis of geographical distribution patterns of species and sections

of *Acacia*. Under the Hnatiuk and Maslin system, the project lies within the North-west Tropical (NWTROPIC) *Acacia* District.

Kenneally (1989) notes that the Kimberley vascular flora contains 1,860 species, of which all but 90 are native. At the present time, botanical knowledge of the Kimberley region as a whole is inadequate.

Flora of the Project Area

It is estimated that the project area, being long and covering a large number and wide range of habitats, contains a large number of vascular plants, probably well in excess of 450, and possibly of the same order of magnitude as the Bungle Bungle flora. A recent CSIRO biological survey of Bungle Bungle National Park and nearby areas, approximately 50 km south of the project area, identified more than 600 species there, including 14 previously unrecorded in the Kimberley and four previously unrecorded in Western Australia (Daily News, May 31 1990, p.10; Woinarski in edit.).

There has been no systematic wet season botanical survey anywhere in the project area, although previous investigations have been carried out during the dry season. An annotated species list for the Argyle diamond mine project area contains 321 species of vascular plants, a large proportion of which are in the project area.

Significant Species of the Project Area

Definitions of the terms 'significant species', 'priority species' and 'Declared Rare Flora Species' are contained in Appendix 12.1.

Four species currently gazetted as Declared Rare Flora ("DRF"), 44 priority species, and a number of other significant species are recorded in the Kimberley Region. There are no DRF or priority species recorded in the project area, but all of the significant species, listed and discussed by Dames & Moore (1982) have been collected in or near the southern end of the project area. These species are:

Acacia pachyphloia

A few small trees of *Acacia pachyphloia* were found near Sites 16 and 21. The plant is distinguished by its straight trunk, corky bark, drooping willowy branches and dichotomising bipinnate phyllodes. Though widely distributed, the species is uncommon where it does occur, at least in Western Australia.

Acacia pachyphloia is listed by Dames & Moore (1982) because, at the time the report was prepared, the species was represented in the Western Australian Herbarium by only three collections. It is now represented by more than 10 samples, which have been collected over a relatively wide geographical range.

Eucalyptus confluens

Smooth-barked, shiny green-leafed *Eucalyptus confluens*, is widespread and common in the Kimberley (Chippendale and Wolf 1981). *Eucalyptus confluens* (Kimberley Gum) is the dominant species in hills complex vegetation at the southern end of the project area and elsewhere.

Eucalyptus confluens is listed by Leigh *et al.* (1981) as rare but is actually widespread and common.

Nauclea orientalis

Nauclea orientalis is a generally large, dense-crowned, large-leafed tree found on the banks of the lower Dunham River. It may also occur along the Ord River and is common along some rivers in western parts of the Kimberley and in the Northern Territory.

Nauclea orientalis is listed by Marchant and Keighery (1979) as a D1 species, but is now much better collected and known to be reasonably common and widespread.

Gardenia aff. pantoni

During earlier vegetation surveys, this *Gardenia* was found to be a common small tree in the southern Ragged Range, and has since been found as scattered plants in the Carr

Boyd Ranges, where it was also found during this survey. The species may be *Gardenia pyriformis*, the only species of *Gardenia* listed by Forbes and Kenneally (1986) in their Bungle Bungle survey.

Other

A spreading wattle shrub collected near Site 39 has been identified as *Acacia setulifera*. This collection is the first of this rare species in Western Australia and only the third known. The other collections are from parts of the Northern Territory neighbouring the Kimberley. *Acacia setulifera* is now a Priority One species.

5.4.4 Fauna

Introduction

The project area is situated in the Kimberley Division and as such is part of the Torresian, vertebrate fauna sub-region proposed for birds by Spencer (1896) and the Leichardtian fish fauna region developed by Iredale and Whitely (1983). The Torresian sub-region extends across the northern quarter of Australia from the Fitzroy River in Western Australia to the Clarence River in northern New South Wales while the Leichardtian region takes in the Kimberley Division, most of the Northern Territory and the Gulf of Carpentaria drainage zone of north-western Queensland.

Serventy and Whittell (1976) agreed that the Kimberley Division was correctly placed into the Torresian sub-region since it was apparent from bird distributions that the most strongly demarcated boundary in Western Australia was that between the Pilbara and the Kimberley Divisions. For the most part, the mammals, amphibians, reptiles and fish show a similar, strong differentiation from the vertebrate communities of the more southern portions of the State and the proportion of endemics is high. In the case of fish, nearly 30% of the total number of species in Western Australia are unique to the Kimberley Division.

Specific locations in the region such as the Prince Regent River and Drysdale River Reserves, the Mitchell Plateau and a number of offshore islands have been surveyed in detail for vertebrate fauna. However, the eastern Kimberley, in particular, the Ord Basin in which the proposed development is situated, is poorly known. Survey work for the Argyle diamond project has contributed greatly in a strictly local sense. More recently, a biological survey of the Purnululu National Park and adjacent areas (Woinarski 1990, in edit) has contributed greatly to an understanding of this part of the east Kimberley region.

Habitat Definition

The range of habitats occurring in the project area was assessed by aerial reconnaissance, boat traverses along the Ord River, and ground inspections on foot and using four-wheel-drive vehicles.

A series of sites, representing replicates of the five major habitats and their variants, were chosen for detailed investigation and to ensure coverage of potentially sensitive areas (see Figure 14). In keeping with the format of the vegetation and flora survey, five habitats have been identified for the project area. These are:

- Mountains Complex - Vegetation mainly on the steep slopes, ridges, plateaux and internal minor drainage lines of the Carr Boyd Ranges, with skeletal soils and small pockets of alluvium.

- Hills Complex - Vegetation on the lower, mostly gently-sloping hills. Variations on this unit are found in the Carr Boyd Ranges, Blatchford Escarpment and Ragged Range.

- Plains Complex - Vegetation on more or less flat plains with a variety of generally deep, sandy or fine-textured soils.

- Levee/terrace Complex - Vegetation on the sandy and rocky alluvial terraces and levees on either side of the major creeks and rivers.

- Riverine Complex - Vegetation that is inundated by water flowing down the major creeks and vegetation that stands near, and just above, the flow. Includes long-lasting riverine pools and the permanently-flowing Ord River.

Birds

The field assessment represented an appraisal of the vertebrate habitats in the project vicinity rather than an inventory survey. One hundred and nineteen species of birds were recorded indicating the high productivity of the area. The richest habitats for birds were the Riverine Complex and Levee/terrace Complex found in the vicinity of the dam, the Ord and Dunham Rivers and watercourses along the transmission route options.

To date, 237 species of birds have been recorded in the vicinity of Lake Argyle, Lake Kununurra, the Ord Irrigation Area and the Argyle diamond mine project area, and a further 17 species which have not been observed could be present, based on published distribution patterns and known habitat preference. Many species, particularly waterbirds, are recent arrivals to the area and have been advantaged by the creation of Lake Argyle (Storr, 1980; Jaensch and Vervest, 1989).

Fourteen species are listed under Schedules 1 and 2 of the Fauna Conservation Act (1950) as being rare or otherwise in need of special protection. Thirty species of migratory birds are covered by international treaties, namely the Japan/Australia and China/Australia Agreement for the Protection of Migratory Birds and their Environment.

Of the 254 species of birds recorded or expected to occur in the project area, 195 (77%) are migratory, nomadic or dispersive. The remaining 59 species (23%) are generally permanent or semi-permanent residents with specialised behaviour or specific habitat requirements.

Mammals

Museum records and previous studies show that 52 species of native mammals and nine introduced species are present or are expected to occur in the area. Thirty-two of the native mammals are highly mobile and therefore unlikely to be seriously affected by the project. Typical among these are the larger kangaroos, the dingo and the 22 species of bat. The remaining 20 species are mainly small marsupial carnivores and native rodents. Typical among this group are the rare Carpentarian Dunnart *Sminthopsis butleri* and the Long-tailed Planigale *Planigale ingrami* which was originally classified as rare until it was found to be common in certain areas.

Amphibians and Reptiles

Two amphibians and 18 reptiles were recorded during the field assessment. With the addition of museum specimens, published lists and geographic distribution patterns, a further 27 amphibians and 96 reptiles are expected to occur in the study area.

The project area is rich in amphibian and reptile species, many of which show strong, if not exclusive, associations with particular habitat elements such as deep sands, spinifex (*Triodia* spp.) riverine habitats or cracking-clay/grasslands. Some species are very uncommon, others have only been rarely collected in the Kimberley Division. Several species recorded during surveys carried out for the Argyle Diamonds' Environmental Review & Management Programme, and the more recent CSIRO survey of Purnululu National Park and adjacent areas had not previously been observed beyond the Northern Territory.

Fish

Specimens lodged in the Western Australian and Queensland Museums between 1944 and 1986 show that 30 species of native fish have been recorded in the vicinity of the project area. The State Energy Commission study (SECWA 1980) lists 22 species prior to construction of the Ord River Dam, but subsequent studies and taxonomic revisions have increased this total. No rare species are known to be present.

Before construction of the Ord River Dam, all fish and invertebrates were free to move up and down the system at will depending on seasonal flow. Most species would have had no need to take advantage of this freedom as they are totally dependent on a freshwater environment and are not obliged to move downstream to a brackish or saline environment. A few species, namely the Barramundi or Giant Perch *Lates calcarifer*,

Ord River Mullet *Liza diadema*, Long Tom *Strongylura krefftii* and Scat *Scatophagus argus* breed in marine or brackish waters and any upstream barrier which they are unable to cross restricts their movements.

The most recent brief survey of Spillway Creek, Lake Kununurra and below the Ord River Dam was carried out in 1986. This survey indicated that:

- the fish populations and relative species-mix of the Ord River prior to the construction of Lakes Argyle and Kununurra was poorly known; and

- the current status of the species which occur in the drastically altered environments above and below both dam walls was even less understood.

Rare or Endangered Species

Twelve species of vertebrates gazetted under Schedules 1 and 2 of the Wildlife Conservation Act (1950) have been recorded or could be present in the project area or its vicinity. These are listed in Table 5 with their current conservation status and the potential project impacts.

Uncommon or Geographically Restricted Species

Uncommon or geographically restricted species are those vertebrates not classified as rare and of which very few records exist, or whose distribution patterns and habitat specialisation clearly indicate that they occur in a limited area. In remote areas such as the Kimberley Division, insufficient field work using current trapping and sampling techniques has been conducted to clearly define such animals.

TABLE 5

Rare or Endangered Species which have been Recorded or could be Present in the Project Area

Name		Status	Potential Project Impact
Freckled Duck	*Strictonetta naevosa*	1	None
Radjah Shelduck	*Tadorna radjah*	1	Marginal
Pacific Baza	*Aviceda subcristata*	1	None
Red Goshawk	*Accipiter radiatus*	1	None
Peregrine Falcon	*Falco peregrinus*	2	None
Grey Falcon	*Falco hypoleucos*	1	None
Rufous Owl (1)	*Ninox rufa*	1	Minimal
Purple-crowned Fairy-wren	*Malurus coronatus*	1	Minimal
White-browed Robin (2)	*Poecilodryas superciliosa*	1	Minimal
Yellow-rumped Mannikin	*Lonchura flaviprymna*	1	None
Fresh-water Crocodile	*Crocodylus johnstoni*	2	None
Salt-water Crocodile	*Crocodylus porosus*	2	None

Source: Ninox Wildlife Consulting (1991)

Notes: (1) Not confirmed in project area.
(2) See Management section.

Status: (1) Likely to become extinct, or is rare.
(2) In need of special protection.

Some species are understandably uncommon in the area because they are at the extreme limits of a much wider range, others because their preferred habitat is poorly represented in the area but widespread elsewhere, and some are naturally uncommon being a predator at a high trophic level on the food chain. Many species, particularly rodents and some birds, may apparently be extremely uncommon and geographically restricted but appear in large numbers given a good season or changed conditions. A typical example is the Long-haired Rat *Rattus villosissimus*, which was presumed to be locally extinct until it reached plague proportions in the Ord River Irrigation Area in the early 1980's. Similarly, the Long-tailed Planigale *Planigale ingrami* which was on the rare and endangered list in 1978 was later removed when found to be abundant and quite widespread in suitable habitats of the Ord River Basin and elsewhere in the Kimberley Division.

5.5 SOCIO-CULTURAL ENVIRONMENT

5.5.1 Introduction

Both Aboriginal and non-Aboriginal Australians have well-established traditions and associations with the region. Non-Aboriginal Australians have initiated the establishment of a vast pastoral industry, irrigation farming, mining and commercial fishing.

The Shire of Wyndham-East Kimberley, in which the project is located, covers an area of approximately 121,000 km^2. The population in 1989 was estimated to be 6,329, of which approximately one third were Aborigines (Shire of Wyndham-East Kimberley, 1990).

Wyndham is the regional sea port handling the receival of fuel and general cargo and the export of bulk mineral products. From 1919 until 1985, the Wyndham meat works provided the industrial base for the town, with processed meat being the port's major export. The economy and population of Wyndham has declined since the closure of the meat works in 1985, with the population at the 1986 census being 1,113 (Shire of Wyndham-East Kimberley, 1987).

Kununurra was established in 1963 to service the ORIA, and is the centre of local government. It is a growing town with a population in 1986 of 3,127 including 607 visitors. The economy of Kununurra is essentially that of a regional service centre. The workforce is employed in tourism (16.7%), pastoral, agricultural, fishing and horticultural industries (7.3%), construction (11.7%), mining (7.4%) and transport, storage, public administration, recreation, entertainment and utilities (around 7% each) (Taylor and Burrell, in prep.).

There are three Aboriginal communities within 70 km of the Argyle diamond mine. The nearest to the mine site is the Glen Hill community which is 20 km north; the largest community (by population) is Warmun which is located on the Great Northern Highway approximately 55 km by road south; and the third community, Doon Doon, is located 60 km north.

The Glen Hill community, an incorporated body known as the Mandangala Aboriginal Corporation Inc., occupies a small pastoral lease of approximately 14,275 ha. The population of the community is currently 68. The facilities at Glen Hill are quite good by most small community standards which possibly reflects the close association of the community with Argyle Diamonds through its community relations personnel and the Good Neighbour Programme. The community is currently very active in improving both the village and pastoral enterprise and an agreement with the neighbouring Doon Doon community will allow the Glen Hill community to have operational control over a portion of the Doon Doon lease to expand its grazing capability.

The Doon Doon community, an incorporated body known as the Woolah Aboriginal Corporation Inc., occupies the Doon Doon pastoral lease of approximately

396,000 ha. The population of the community is about 70. Facilities at Doon Doon are very comprehensive and include a school, housing for teachers, a medical complex, and office and accommodation facilities. The community has established a management committee in an attempt to improve overall property management. Results are promising and turnoff of saleable cattle in 1990 exceeded the combined total of the previous four years. Improvements planned include water points, paddock fencing and stock yards.

The Warmun community, formerly known as Turkey Creek, has a population of 300 to 350 people. There is no established industry within the community although some employment is obtained internally from community development programmes and from the operation and maintenance of services. The community infrastructure is substantial and includes a school, teacher housing, a large workshop and a general store. ADM has made significant contributions to the asset base including assistance with construction of basketball courts, a sports oval and recreation centre.

5.5.2 Land Use

Pastoral

Land use of the project area is shown in Figure 15. Cattle grazing commenced in 1884 at Ord River Station. Abundant water and feed resulted in a rapid rise in the cattle population with the stocking of other stations across the Ord River catchment. Problems with over-stocking were experienced as early as 1905. As a consequence of over-stocking the Government began active regeneration of the Ord River Catchment area in 1960, with stock numbers in the Lake Argyle catchment being reduced since that time to a current level of around 84,000 head.

Agriculture and Horticulture

Intensive irrigation farming is pursued in the ORIA incorporating Packsaddle and Ivanhoe Plains. The ORIA has an indicated potential to expand to 75,000 ha (Department of Agriculture 1987). Irrigation farming in the area has met with mixed success, with early attempts at broadacre farming, including cotton and rice, proving unsuccessful. Recent years have seen a resurgence in horticulture with the production of high-value crops for both domestic and export consumption. Although 13,000 hectares have been developed for irrigation, much of this land is currently not actively farmed and a large proportion is only cropped by dry season irrigation. The value of the 1989 dry season crop production from 3,900 ha of land is estimated to have been in the order of $17.8 million.

Mining

The East Kimberley region has supported prospecting and small mining ventures since the late 1800's, commencing with gold mining. Diamonds now dominate in terms of economic production and workforce. The Argyle mine is based on open cut mining of a lamproite pipe and a smaller alluvial mining operation on Smoke Creek. Export income generated by the Argyle mine exceeds $400 million per year. A workforce of over 600 is employed, most of whom commute from Perth fortnightly. Seventy employees live in Kununurra and commute by air daily. Alluvial diamonds are also mined on a much smaller scale at Bow River by the Normandy Poseidon Group. Other companies have mining leases but have not commenced mining operations at this time.

Several small leases are held or are being sought for prospecting and extraction of the sedimentary deposits of Zebra Rock . One operator has been extracting material from Lake Argyle during periods when low water level exposes the deposit.

Tourism

Tourist arrivals in the East Kimberley for 1988/89 were 69,000 (WA Tourism Commission, 1990). For Kununurra, annual site occupancy rates vary from around 33% in caravan parks to 44% for hotels, motels and guest houses. The cooler dry season of May to September attracts by far the larger number of tourists, with arrivals to the region's caravan parks being over 10,000 in July compared with 1,000 or less for each of the months from November to March.

What is now the Lake Argyle Tourist Village was originally the construction camp for the Ord River dam project. It is located within a kilometre of the dam, has a permanent population of 15-20 persons and includes a general store and the Lake Argyle Inn. The village also contains 24 motel rooms with 54 beds, 50 powered caravan sites and grassed camping areas with a capacity for 150 persons. The facilities are normally completely booked through July and August, the core of a five-month tourist season.

Tourists visit the area because of its many natural attractions and as part of more extensive trips across northern Australia. Features of particular interest in the region include the Purnululu (Bungle Bungle) National Park, the Ord River dam and Lake Argyle, the ORIA, the relocated Durack 'Argyle Homestead' and Hidden Valley in the Mirima National Park.

Commercial tour operators based in Kununurra run bus tours to the Ord River dam and hinterland, boat tours on Lakes Kununurra and Argyle, down the Ord River below Ivanhoe Crossing, and up the Ord River to the Ord dam. Several groups run backpacking trips to the Carr Boyd Ranges and the more distant Bungle Bungle Ranges. Aircraft flights over the area are also very popular, some of which include landing at the Argyle mine for a tour of the mine operations and lunch at the accommodation village.

Recreation

The area around Kununurra comprises pastoral leased lands, vacant Crown Land, and conservation and recreation reserves used for four-wheel-drive recreation, picnic and camping trips, bush-walking and back-packing. The Carr Boyd Ranges are used for pursuing these interests, with Lakes Argyle and Kununurra being used for boating and fishing.

A range of locally organised clubs also use the area for recreational purposes. The East Kimberley Fishing Club concentrates on Barramundi fishing below the Diversion Dam and in other unregulated river systems of the region. The Kununurra Rowing and Water Ski Clubs utilise Lake Kununurra on the outskirts of the town. The East Kimberley Scuba Diving Club pursues mainly ocean dives, but occasionally dives in Lake Argyle. The Ord River Sailing Club utilises both Lake Kununurra and Lake Argyle and is currently establishing a boat storage yard and clubhouse near the spillway of Lake Argyle.

5.5.3 Conservation Areas

Existing Conservation Areas

Lakes Argyle and Kununurra and the part of the Ord River which joins them, were accepted for listing on the Ramsar Convention List of Wetlands of International Importance in June 1990. This area of approximately 150,000 ha was one of nine Western Australian wetlands submitted for listing. The submission recognised that Lake Argyle is man made with an annual fluctuation in water level of approximately 3 m and that, in conjunction with Lake Kununurra, its level is managed for the purpose of providing water for the ORIA. "The existing type of management of water levels has proven highly beneficial to water birds and should continue" [Department of Conservation and Land Management (CALM) 1990].

The Lake Kununurra Foreshore Draft Management Plan makes recommendations regarding Packsaddle Sanctuary, on the southern bank of Lake Kununurra, cited as vested in CALM for the protection of wildlife. CALM's reserve records indicate that Packsaddle Swamp, Reserve No. 40143, is an unvested drainage reserve. This reserve will not be affected by the project, as proposed.

Mirima (Hidden Valley) National Park borders the east side of Kununurra, north of the Victoria Highway road reserve, but will not be affected by any project activities.

Similarly, the Ord River Nature Reserve over tidal land at the mouth of the Ord River is well beyond the extent of any impact of this proposal and has therefore not been considered further.

Proposed Conservation Areas

The islands in Lake Argyle and land west and north west of the lake and the Ord River, including a large part of the Carr Boyd Ranges which is currently Vacant Crown Land, have been recommended as a national park [CTRC 1977; EPA 1980; (see Figure 15)]. The Conservation Through Reserves Committee reporting on System 7 (CTRC 1977) stated that the 'grandeur of the ranges, rising steeply from a large body of navigable water give them an obvious recreational value, particularly within a few kilometres of the waters edge'. The 1987 CALM submission to the Kimberley Region Planning Study lists other key features of abundant wetland fauna and islands in Lake Argyle. The CALM submission endorses the EPA recommendation that the area shown in the EPA's Figure 7.10 'be declared a Class C reserve for National Park' and that the reserve 'extend to high water mark'.

The CTRC report (1977) included the Carr Boyd Ranges on the premise that 'there is at present no major conservation reserve in this part of the Kimberley'. However, since the CTRC made its recommendation, the Purnululu (Bungle Bungle) National Park (Reserve No. 39897) has been created south of the project area (Gazetted 6/3/87) .

Wyndham-East Kimberley Shire's Town Planning Scheme No. 4, Amendment No. 14, adopted by Council in March 1990, extends the Town Planning Scheme Boundary south to the northern Carr Boyd Ranges, fringing Packsaddle Plain, and amends the scheme to include land for Conservation/Environmental Protection Reserve (see Figure 14). One of four such areas set aside in the amended scheme is referred to as 'Carr Boyd Ranges' and 'includes the ridges and foothills systems of the far northern parts of the Carr Boyd Ranges where they intrude into the study area on the Packsaddle Plains'. A second area, east of the Ord River south of Kununurra, is referred to as 'Elephant Rock' monolith. This area contains lesser ridges and outcrops and intervening lagoons. Neither of these areas would be affected by the project.

The Lake Kununurra Foreshore Draft Management Plan recognises the importance of Lake Kununurra and its foreshore for conservation and recreational uses by the residents of Kununurra and tourists.

5.5.4 Archaeology

Introduction

An archaeological survey of the proposed Ord River hydro-electric project was commissioned by SMEC, and the fieldwork was conducted in October 1990.

The objectives of the archaeological survey were:

- To assemble data from previous work in the region including information from the Western Australian Museum Aboriginal Site files, previous survey reports, site maps and environmental data.

- To conduct a sample survey of the project area.

- To locate and record archaeological sites within the project area which includes:

  . the Ord River hydro-electric facility site;
  . Site office area;
  . Contractors' allocated works area;
  . Disposal areas;
  . Water tank site;
  . Construction camp site;
  . Alternative camp site;
  . Spillway Creek; and
  . the Powerline routes between the Ord River dam and the Argyle diamond mine.

Previous Archaeological Research

There have been no Aboriginal sites recorded within the proposed project site areas. However previous surveys and independent research have identified some sites in the vicinity of the proposed project areas (Dortch, 1977; Troilett, 1982; Humbree, 1983; O'Connor and Quartermaine, 1989). The range of artefact types recorded at both open campsites and rockshelters includes bifacial and unifacial points, blades, scrapers, adzes, cores and flakes. These are made from a variety of materials which include quartz, quartzite, chert, chalcedony and various types of silicified sediment.

Excavations in the Ord River valley have provided dated sequences for archaeological assemblages in the region. Dortch (1977) recognised two possible stone industrial phases from these excavations. The earlier phase which is characterised by thick flake tools, notched flakes, and retouched flakes has been dated at 17,980 years B.P. The later phase contains blades and points and is dated at 3,000 years B.P.

Results of Survey

For the purpose of the survey a site was defined as any material evidence of pre-historic Aboriginal activity. This manifested in a number of different site components, the most common being surface artefact scatters, quarries, art sites, stone arrangements, rock shelters with evidence of occupation, grinding patches, burcals and marked trees. An artefact scatter was recorded as a site if it contained three or more artefacts in association. Solitary artefacts were recorded as isolated finds.

As a result of the field survey, no archaeological sites were located at the proposed hydro-electric facility, nor at the areas proposed for associated facilities. The results of the survey together with ethnographic information and prior disturbance to the environment indicate that these areas are unlikely to contain any archaeological sites.

During the survey of the proposed transmission line route five archaeological sites and two isolated finds were recorded. None of these sites is on the proposed route. The sites are all surface artefact scatters and were found in the process of gaining access to the route. None of the sites will be affected by construction of the power line.

5.5.5 Anthropology

Historical Perspective

The early contact history of the survey area is not well documented, and is overshadowed by European-Aboriginal confrontations at Halls Creek and Wyndham.

Settlement of the region by pastoralists was relatively recent. Forrest's exploration through the East Kimberley occurred in 1879 and the Duracks completed their historic overland journey to the area in 1885 settling at Lissadell and Argyle Downs on the Ord River (Durack, 1959). Expansion of grazing activities resulted in confrontation and conflict with local tribes resulting in a protracted guerilla war being carried out (Gill, 1979). By the end of the 19th century, the pastoral industry had developed throughout the region and Aboriginal people tended to settle on stations on, or close to, their tribal land.

This pattern lasted until the development of the ORIA, when the pastoral industry competed with the farming industry for Aboriginal labour. Higher wages for farm labour resulted in a drift to Kununurra (Willis, 1980). The extension of the Pastoral Award to Aboriginal workers in 1968 led to the streamlining of the station industry, and in it being more selective in its workforce. From 1980, government-sponsored purchases of cattle stations for Aboriginal groups have resulted in a gradual return to the land by Aborigines as is occurring at Doon Doon and Glen Hill stations.

Background

The aim of the anthropology survey commissioned by ADM and carried out between April and October 1990,was to locate Aboriginal people who retain cultural links with the country surrounding the Ord River Dam and along the proposed transmission line corridor, and to consult with them to ensure that the project did not impact on areas of significance to Aboriginal people. Both the consultation and field research involved Aboriginal people from Kununurra, Wyndham, Doon Doon Station, the Mandangala Community (Glen Hill), the Warmun Community and the Balangarri Resource Agency. The survey was conducted in conjunction with the archaeological survey mentioned previously.

Detail

The formal consultative process commenced in February 1990 with letters of intent to all organisations and individuals identified by the Social Impact Unit as having an interest in the project area.

This was followed by a field visit to Kununurra in April 1990, where meetings were held with:

- the Waringarri Aboriginal Corporation;
- the Miriuwunga Gajerronga Ninguwung Yawurrung Inc.;
- the Joorookngarni Aboriginal Corporation;
- the Chairman of the Kimberley Land Council;
- the Doon Doon Station Community;
- the Mandangala Aboriginal Corporation;
- the Warmun Aboriginal Community; and
- the Balangarri Resource Agency.

The project was discussed in detail, traditional land title in the region was delineated and invitations to participate in scouting operations were issued.

Ongoing communication with the above groups continued until October 1990 when the scouting operation was finally arranged and executed. The proposed transmission line route was realigned in one area for heritage reasons.

Finally consultative meetings were held with the public officer of Miriuwunga Gajerronga Ninguwung Yawarrung Inc. and later the Chairman of the Waringarri Aboriginal Corporation.

Results

Field inspections and site scouting operations adopted a procedure of site avoidance rather than site recording. The relevant Aboriginal people accompanied the consultant and/or the design engineer on an inspection of those sections of the route that traversed tribal territories. In areas where the planned route appeared to approach too close to areas of significance, a re-alignment was arranged and agreed to during the inspection.

Following consultation with, and inspection by, Aboriginal people, and following a number of minor realignments agreed to by the Aboriginal people, the proposed development at the Ord River dam and the location of the proposed transmission line have been approved by the Aboriginal people concerned.

6.0 ENVIRONMENTAL IMPACT ASSESSMENT

6.1 INTRODUCTION

Before proceeding, some of the terms used in the assessment of environmental impacts will be defined. Specifically it is necessary to differentiate between the term 'effect' and 'impact'. Shirley *et al.* (1985) suggest that an 'effect' is a change produced by some agency or cause, but its magnitude is not evaluated using a set of formal definitions. An 'impact' is an effect whose magnitude is evaluated using a set of formal definitions. Both impacts and effects may be direct or indirect.

In addition to the differences between 'effects' and 'impacts' it is appropriate to define the term 'significance' in relation to environmental impacts. In this document, an impact is regarded as significant if it breaks laws or regulations; if it affects the functioning of ecosystems; or if it has effects that are outside established social norms.

While this approach may seem to be straightforward, there are difficulties with interpretation of the term 'significance' from an ecological perspective. A key factor in the impact assessment is the high level of disturbance to ecosystems that has already occurred as a result of the construction of the Ord River dam, and the extensive overgrazing that has occurred on rangelands through which the transmission line will pass. The prior changes to ecosystem structure and function have not been documented. This makes the formal evaluation of the magnitude of changes difficult.

This section on environmental impact assessment therefore identifies changes and effects on a broad scale. The term 'impact' is used here to describe the effects and changes resulting from project implementation.

During the scoping process for impact assessment as part of project development, potential effects are identified and ranked according to perceived importance or significance. These effects then become integrated with conceptual engineering design and then final design for the project. By this means, potential significant impacts are reduced to impacts. However, there is still a level of ecological uncertainty, the fundamental cause of which is the complexity of ecosystems. This is compounded by a lack of understanding and by a lack of documented evidence on ecosystem response to changes induced by development.

6.2 EXISTING ENVIRONMENTAL IMPACTS

The project area lies within an environment that has been highly modified.

At the regional scale, the introduction of cattle, and cattle grazing as a preferred land use, has altered the characteristics of rangeland in terms of both vegetation and hydrologic response. The development of the beef cattle industry has in turn resulted in development of a socio-economic support regime.

The construction of the diversion dam on the Ord River, the introduction and development of irrigation agriculture, and the construction of the main Ord River dam and subsequent formation of Lake Argyle, have all resulted in dramatic changes to existing ecosystem components, structure, and complexity (see Plates 11 and 12).

The proposed hydro-electric project is being superimposed onto systems that have developed as a response to the artificial manipulation of key components. The two major project elements, the hydro-electric station and the transmission line, are both in areas that have been highly altered. The aquatic ecosystems are no longer representative of natural systems in the Kimberley. The transmission line passes through rangeland that is suffering from various stages of deterioration within the overall land degradation process.

However, despite the prior changes and existing impacts on the regional and local environment, it is possible to identify and define impacts that will result from project implementation. These impacts though, must be put in context, not only within the existing highly-altered state of the environment, but also within the individual project phases, i.e. construction and operation.

As noted above, implementation of the project will result in short-term effects, particularly those associated with construction of the hydro-electric station, and longer-term changes, particularly those associated with the transmission line.

6.3 IMPACT ASSESSMENT

6.3.1 Construction of the Hydro-electric Station

The initial requirement in developing the hydro-electric station site is to construct a coffer dam around the proposed site. During establishment of the coffer dam, water will not be discharged from the irrigation valves for a period of up to three weeks. During this period, the section of the Ord River between the coffer dam and Lake Kununurra 15 km downstream, will have reduced water levels and may become a series of large pools.

This temporary reduction in flow in this section of the river will not result in a long-term impact on fringing vegetation. Any impacts associated with this reduction will be insignificant as the flows fall within the range already experienced.

The impact on fish and other aquatic species resulting from this temporary cessation of flow is impossible to predict. No data are available on the river ecosystem structure and function prior to construction of the Ord River dam, and no studies have been carried out since the dam was completed. Temporary cessation of flow has occurred regularly in the past when Lake Kununurra was drained as a method of weed control. Resulting adverse impacts have never been documented and any potential effects resulting from this project will be short term.

PLATE 11

Water levels in Lake Argyle fluctuate according to natural flood/drought sequences, and the inundation/drawdown cycle associated with the project will be within the range that already occurs. These photos show characteristic beach and strandline development associated with a fall in lake water level.

PLATE 12

Despite fluctuating water levels, regrowth on areas previously inundated is rapid. These photos illustrate the extent of natural regeneration following a fall in water level.

On completion of the coffer dam and during construction of the hydro-electric station, water will be released from the irrigation valves, but at a reduced rate of 25 m^3/sec, subject to agreement with WAWA. This reduced rate of flow may affect local fish population and accordingly may also affect the number of fish-eating birds present in the area. Potential impacts will not be significant. Past variations have exceeded the disturbances which will result from this project and, in addition, these species are present elsewhere in the Kimberley.

The decrease in flow rate during construction may result in an increase in congestion levels of floating weeds. Some species of birds use these floating weed beds, e.g. the Comb-crested Jacana (*Irediparra gallinacea*), the Black-fronted Plover (*Charadrius melanops*) and species of terns and ducks. As a result, the local population of these species may increase during the construction period. The impact of this increase in certain bird species on ecosystem functioning is unknown, but any long-term effects will be insignificant because of the short-term nature of the construction period.

Potential impacts on mammals as a result of reduced downstream flow rates during construction will be restricted to a possible reduction in the number of water rats (*Hydromys chrysogaster*) in the fast-flowing sections of the river near the irrigation discharge valves. Any reduction in numbers will result from a reduced food supply. This impact will not be significant as flows will return to normal when construction of the hydro-electric station is completed.

During construction of the coffer dam and of the hydro-electric station, the reduced water levels in the river between the dam and Lake Kununurra may restrict boat excursions by tourists. Impacts on commercial operations such as this are unavoidable.

During construction of the hydro-electric station, there will be periods of time when access to the dam and picnic viewing area below the dam will be restricted. While the general public may be inconvenienced during these periods of restricted access, the duration of restriction will be very short term, and impacts on public use will not be significant.

There will be an increase in local ambient noise levels as a result of construction activities. However, the impacts resulting from noise will not be significant.

6.3.2 Construction of the Spillway Weir

Construction of the weir in the existing spillway will require aggregate materials for concrete. This material will be taken from Spillway Creek, downstream from Spillway Creek bridge, or from an existing stockpile near the spillway cut.

Potential impacts will not be significant as the area has been subject to prior disturbance and erosion, and is in the bed of Spillway Creek.

Equipment and material laydown areas proposed for use during construction are pre-existing quarry or hardstand areas created during construction of the Ord dam. Any impacts associated with use of these areas will not be significant.

6.3.3 Construction Camp and Workforce

The preferred location for the construction camp is an area of land previously used for this purpose during construction of the Ord dam. Water supply available at the Argyle Tourist Village will be sufficient. However ADM will be required to install separate sewerage facilities for the camp.

The workforce required for construction will be within the range of population variations experienced in both Kununurra and at the dam as part of normal tourist activities in the area. As a result, it is considered that there will be no significant impacts associated with the workforce.

6.3.4 Construction of the Power Transmission Line

The transmission line route, its placement within the landscape and the type of structures used, have been chosen to minimise environmental impacts. However, despite scoping and engineering design, construction of the transmission line will result in a number of impacts.

Tall vegetation will be cleared from a three metre wide strip along the centreline of the easement. In addition, any vegetation that compromises the performance of the conductors will be cleared. This loss of vegetation will not be a significant impact as there are no rare and endangered species of vegetation threatened by the line, and the species to be cleared are representative of vegetation throughout the Kimberley region generally.

The Priority 1 species *Acacia setulifera* occurs adjacent to the transmission line corridor but this species will not be disturbed during the construction of the line.

Poles will be delivered to their locations on trollies towed by a rubber-tyred tractor. This operation will result in highly localised compaction of surface soil. The impacts associated with pole location and erection are not significant. Management of these kinds of impacts is addressed in Section 7. A potential impact associated with construction of the transmission line is the increased risk of fire.

In a few restricted locations, the transmission line has the potential to have some impact on waterbirds. These locations are associated with cross-over points on the Ord River and on other creek crossings close to permanent or semi-permanent waterholes. Waterbirds flying along the watercourse at night may collide with the power line. As many of the waterbirds are nocturnally active, some reduction in numbers may result.

As a result of transmission line construction, a range of habitats of terrestrial birds will be partitioned by either a continuously-cleared service easement or by temporary clearing and disturbance. Impacts will be on small territorial species that form cohesive groups and defend large areas for feeding and breeding. Because of the wide distribution of habitats throughout the regional and project areas and because of the wide distribution of species associated with these habitats, impacts will not be significant.

6.3.5 Landscape Impacts

The level of visual intrusion of any development on a landscape is dependent on a number of factors, but in general relates to the degree of consistency in form and colour between the development and the landscape.

The power line and its supporting poles will not be consistent in form with the landscape through which it passes and there is a potential impact for visual intrusion.

The transmission line will be visible from the dam wall and from the picnic and recreation area located immediately downstream. The crossing point on the Ord River is not accessible to the public by road. However, the transmission line will be visible from a small section of the river at the crossing point.

Although visible from the ground, the transmission line will be difficult to see from an aircraft. For most of its length, the transmission line will be at mustering heights. However its design will comply with all relevant civil aviation regulations.

6.3.6 Impacts Associated with Project Operation

When the hydro-electric facility is in operation, the way in which water is discharged into the stilling pond will be different. Instead of water being discharged via the irrigation valves, it will be discharged through the turbines, below the surface. The water now being released is partially de-oxygenated, resulting in a change in the overall oxygen level of the water. However due to the significant turbulence occurring as a result of the turbine releases, re-oxygenation of the water below the outfall will occur. The dynamics of Lake Argyle also mean that the typical thermal stratification may be disturbed around May/June of each year. In fact there is a complete overturn (holomixis) and the lake is expected to be well mixed in July. Water temperatures are approximately 20°C throughout the lake and oxygen concentration ranges between 80-110% saturation. In this case fully oxygenated water will be discharged through the turbines. The combination of all these factors means that the extent of de-oxygenated water discharged through the turbines, and its exact effect on the overall oxygen levels in the stilling pond is unclear.

Although some specialised mammals may undergo population reductions, changes in water levels will not have significant impacts on project area fauna.

As a result of conversion to hydro-electric power at the Argyle mine site, the requirement for fossil fuel will be substantially reduced.

The transmission line route will pass through rangelands for the greater part of its length. Aerial mustering of cattle is carried out throughout this area. The transmission line could be a hazard to low flying aircraft and needs to be considered during mustering.

6.3.7 Impact of Raising the Spillway Level

The expected behaviour of the lake level after construction of the spillway weir is fully described in Section 3.3 of this document. There are no potential impacts from raising the spillway level. The proposed spillway discharge level of 92.2 m AHD is 4.2 m lower than the maximum water level recorded for the lake.

This means that the new spillway level will lie within the range of water levels that have already occurred.

7.0 ENVIRONMENTAL MANAGEMENT

The environmental management programme proposed for the Ord River hydro-electric project is designed to minimise or alleviate the effects of changes occurring as a result of project implementation.

The concept of environmental management is first introduced at the scoping stage of the impact assessment process. As planning and design progress, management strategies are introduced so that they become an integral part of project development.

The following management programme addresses impacts associated with construction of the hydro-electric station and associated facilities.

7.1 CONSTRUCTION OF THE HYDRO-ELECTRIC STATION

(1) If possible, construction of the coffer dam will be undertaken early in the dry season to minimise potential effects on fringing vegetation and aquatic fauna.

(2) The low water levels between the Ord River dam and Lake Kununurra that result from construction of the coffer dam have been discussed with the local tour operator. ADM will endeavour to minimise disruption.

(3) Prior to the construction, and removal of the coffer dam, WAWA will raise the level of Lake Kununurra to partially compensate for the three-week cessation of water release from the irrigation valves.

(4) Blasting, when necessary, will be restricted to daylight hours.

(5) During periods of heavy traffic use on the road below the dam, for example when pouring concrete at the hydro-electric station site, traffic management and control will be undertaken by the project managers to ensure the safety of the general public.

(6) The construction site will be cleaned up by the contractor prior to leaving the site. All construction and industrial waste will be removed to a waste disposal site that will be selected, designed, and operated in accordance with standard waste disposal practices.

(7) Because much of the tourist interest at the Ord River dam is in viewing the dam and irrigation discharge valves, it is believed that the construction activity will provide an added interest. Accordingly, ADM will examine the possibility of establishing new viewing areas or upgrading existing viewing areas to facilitate public interest.

(8) The hydro-electric station will be an extension to an existing man-made structure and attention will be given to architectural design and materials used to ensure that they are in harmony with the surrounding environment.

(9) A Code of Practice for noise control in the work place has been established for use in designated work places under the Occupational Health, Safety and Welfare Act 1984-1987. ADM will include specifications for noise emission levels in tender documents for the construction of the hydro-electric station and construction of the spillway weir. At the present time, 90 dB(A) is the action level for exposure in an eight-hour period. Monitoring will be carried out at periodic intervals to ensure compliance with State regulations.

7.2 CONSTRUCTION OF THE SPILLWAY WEIR

(1) Signposting currently directs tourists to the spillway viewing area. Construction activities may enhance interest and during periods of heavy road use by construction vehicles, traffic management and control will be undertaken by the project manager to ensure the safety of the general public.

(2) Following completion of construction, the site will be cleaned up by the contractor and all waste materials removed to the project waste disposal site.

7.3 ASSOCIATED WORKS AREAS

(1) It is proposed to use aggregate from Spillway Creek for concrete. When excavation of this material has been completed, the disturbed area will be re-shaped, where possible, to minimise scour.

(2) If excavation of aggregate results in creek bank instability, control works will be designed and put in place. These works would normally involve control of drainage into the area and stabilising that section of the bank by a combination of vegetal and rock mulch techniques.

(3) Laydown sites and hardstand areas will be subjected to a set of rehabilitation procedures where development of such areas is required outside areas suffering from prior disturbance.

7.4 CONSTRUCTION CAMP AND WORKFORCE

(1) The construction camp will be located adjacent to the Argyle Tourist Village and will require new and separate power services, sewerage facilities and domestic waste disposal services. The construction of these facilities will comply with the appropriate regulations and construction industry standards.

(2) The management of the camp and its workforce will be ADM's responsibility. Induction programmes will be conducted during construction to promote environmental awareness amongst contractors' employees. The ADM appointed camp manger will perform the necessary monitoring role to ensure satisfactory on-site behaviour and compliance with environmental commitments.

(3) ADM and the Tourism Commission are investigating the possibility of the construction camp being of a standard suitable for use as tourist accommodation on completion of project construction.

7.5 TRANSMISSION LINE

The transmission line route, its placement within the landscape, and the type of structures have been chosen to minimise environmental impacts during both construction and operation.

(1) Route selection was based on knowledge and location of significant flora, vegetation and fauna habitats, and accordingly no species are under direct threat from construction, operation or maintenance activities.

(2) Route selection was also made in consultation with Aboriginal people in order to avoid areas of cultural significance.

(3) Whenever possible, access for construction will utilise existing tracks. Where suitable tracks do not exist, new access routes will be selected with the aim of minimising disturbance to vegetation. Where possible, tracks will be located in areas of low erosion potential. The location of all new access tracks to the transmission line will involve consultation with the landholder.

(4) All vehicles used in construction of the transmission line will be equipped with fire extinguishers and knap-sack sprays in case of accidental fire.

(5) Explosives will only be used for foundation preparation where ground conditions do not permit drilling or augering. The use of explosives will be in accordance with statutory regulations and lease holders will be notified of blasting in advance.

(6) All foundation holes will be kept covered prior to pole erection to prevent injury to stock or native fauna.

(7) A number of temporary laydown areas will be required along the transmission line route. Whenever practicable, areas of prior disturbance will be selected for laydown areas.

(8) Where it is not possible to select previously disturbed sites for laydown areas, sites will be selected that minimise disturbance to the environment.

(9) A workforce of approximately 30 people will be involved in construction of the transmission line. It is proposed that up to three temporary construction camp sites be used during construction. Each site will be selected according to construction requirements. ADM will control the movements of the workforce on the pastoral leases.

The use of off-road vehicles by project personnel for recreational purposes will not be permitted during construction of the transmission line.

(10) Each construction camp site will have a vehicle parking area, a waste disposal site, a suitable septic system, mobile power generators and fuel supply. Engineering design and careful attention to siting the waste disposal/septic systems will ensure that there will be no impacts on ground or surface water from nutrient pollution or leach-drain effluent.

(11) A potential impact of the transmission line will be its visual intrusion on the landscape as noted in Section 6. Commitment to sound construction management principles, together with design, will minimise visual impacts.

The proposed route follows valley forms where possible, and the line will therefore not be visible from outside the valley. In addition, from within the valley, the line will be seen against a solid background of hills and mountains. The Kimberley landscape has a great capacity to absorb visual intrusion and it is proposed to minimise intrusion by careful management of any construction activities that could result in developing a permanent scar on the landscape.

(12) As a general rule for environmental management, all areas disturbed as a result of project development will be subjected to a specified programme of rehabilitation. The level of rehabilitation imposed will be site specific, but will generally include measures to prevent soil erosion, minimise surface runoff, enhance rainfall infiltration, enhance vegetation regrowth, and, where appropriate, promote habitat restoration.

(13) The visibility of the transmission line will be discussed with station managers in relation to aerial mustering. It may be appropriate to use standard transmission line markers along some sections of the route to enhance line visibility.

(14) The environmental management programme will commence at the start of construction and will continue through construction and operation.

Rehabilitation will be carried out as soon as practicable in each area of operation and along the transmission line route, rehabilitation will be progressive.

Earthworks for erosion control, and control of surface runoff will be designed and constructed so that they are in place prior to the wet season.

7.6 ABORIGINAL HERITAGE

No specialised environmental management practices are required because there are no archaeological sites near the proposed hydro-electric station, transmission line or contruction camp.

Following consultation and inspection of the Ord River dam project and the transmission line route by Aboriginal people, it has been established that no ethnohistorical sites will be impacted by the project, and accordingly there are no special management requirements relating to Aboriginal anthropology.

ADM is well aware of its responsibilities in project development. This will be made clear to contractors who will be advised of their obligations under the Western Australian Aboriginal Heritage Act 1972-1980.

7.7 RESPONSIBILITY

ADM will carry out the proposed Ord River hydro-electric project using reputable engineering and construction contractors. Conditions relating to environmental protection will be developed by ADM and will form part of all contracts for the project.

ADM will supervise all aspects of the operation that relate to environmental management including review of contractor performance. Detailed design work will be carried out by ADM who will also supervise construction and be accountable for the implementation and completion of rehabilitation programmes.

The environmental management programme and associated works will be carried out to the satisfaction of the EPA on advice from WAWA and SECWA, and in accordance with practices relevant at the time.

7.8 DECOMMISSIONING

A decommissioning programme for the Ord River hydro-electric project cannot be developed with certainty at this time. However, a number of options are possible for utilising the infrastructure when mining ceases at Argyle.

Power generated at the dam may be utilised by SECWA for use in Kununurra or Wyndham or dedicated to other mining ventures in the region. Further development of the agricultural sector, and specifically the ORIA, may result in a greater demand for power in the future.

At an appropriate time, prior to the cessation of mining, ADM will liaise with SECWA and WAWA on relative alternative uses for the power and associated infrastructure.

8.0 CONCLUSION

8.1 OVERALL ENVIRONMENTAL IMPACTS

The overall environmental impacts of the project are not significant.

The scoping process in environmental impact assessment allows identification of potential impacts in the planning stages of the project. As a result, potential impacts are alleviated by engineering design or environmental management strategies.

Direct environmental impacts resulting from project implementation are the loss of small areas of vegetation and wildlife habitat and a loss of less mobile fauna as a result of construction activities. Habitat and species so affected are widely distributed throughout the Kimberley region. Because of this and the restricted zone of influence of the project, none of the impacts identified is classed as significant.

In assessing the direct impacts, it is important that the existing state of ecosystem disturbance is taken into account. The aquatic ecosystems of the project area are dynamic and operate within boundaries which are dictated by climatic controls. These controls dictate a range of conditions that far exceed those generated by the project.

The resilience of ecosystems in the Kimberley is indicated by the ability of foreshore areas to regenerate as water levels in Lake Argyle fall during periods of prolonged low runoff, and for rangelands to regenerate following periods of prolonged grazing or wildfires.

8.2 PROJECT ENVIRONMENTAL ACCEPTABILITY

The environmental acceptability of the Ord River hydro-electric project is high as there are no significant impacts resulting from project implementation. It is acknowledged that there are a number of secondary impacts associated with project development, and management strategies will be implemented to minimise adverse effects.

8.3 MANAGEMENT COMMITMENTS

ADM is committed to a programme of environmental management and protection. This is detailed in Section 7 and is summarised as follows:

(1) Areas disturbed during project construction will be stabilised as soon as practicable and soil erosion control works will be undertaken where necessary. Stabilisation and rehabilitation methods will be determined on a site-specific basis following assessment of each disturbed area.

(2) A continual programme of liaison and consultation will be carried out with the Doon Doon, Glen Hill and other relevant local communities during the construction phase of the project.

(3) Camp areas associated with construction of the transmission line will be located in areas of prior disturbance wherever practicable. Each camp site will be subject to environmental management guidelines which will be designed to control recreational activities, minimise disturbance to the land, provide for site rehabilitation, and control waste management and effluent disposal.

(4) An induction programme will be conducted during construction and operation to promote environmental awareness amongst employees and contractors.

9.0 BIBLIOGRAPHY

Australia's Mining Monthly, December/January 1989/90. 'Major upgrade for Argyle Diamond Mine', pages 17-31.

Beard, J. S. (1979) - The Vegetation of the Kimberley Area. (Explanatory Notes to Sheet 1, 1:1,000 Vegetation Series). Univ. West. Aust. Press, Nedlands (and Sheet 1, 1978).

Beard, J. S. (1980) - A New Phytogeographic Map of Western Australia West. Aust. Herb. Res. Notes 3: 37-58.

Bureau of Meteorology (1981) - Tropical cyclones in the Australian Region July 1909 to June 1980, Aust. Govt. Publ., Canberra.

Chase, V. D. (1978) - Coming : Super Windmills for Super Power. Pop Mech. May pp 114-287

Chippendale, G. M., and Wolf, L. (1981) - The Natural Distribution of *Eucalyptus* in Australia. Aust. Natl. Parks & Wildlife Serv.Spec. Pub. No. 6.

Conservation Through Reserves Committee (1977) - Conservation Reserves in Western Australia. A Report on System 7 to the Environmental Protection Authority, 1977.

Dames & Moore (1982) - Environmental Review and Management Programme. Ashton Joint Venture Argyle Diamond Project.

Department of Agriculture (1987) - Ord River Irrigation Area, Kununurra, Western Australia. Miscellaneous Publication No. 1/87, Second edition-1987.

Department of Conservation and Land Management (1987) - Nature Conservation Reserves in the Kimberley, Western Australia. A submission to the Kimberley Region Planning Study 1987 (unpublished).

Department of Conservation and Land Management (1990) - Wetlands nominated by the Government of Western Australia for inclusion on the 'List of Wetlands of International Importance' - Ramsar Convention. Prepared by the Department of Conservation and Land Management, February 1990.

Dortch, C. E., (1977) - Early and Late Stone Industrial Phases in Western Australia, in Stone Tools as Culture Markers. R.V. S. Wright (ed) A.I.A.S., Canberra, Pp 104-132.

Durack, M. (1959) - Kings in Grass Castles. London. Constable and Co.

Environmental Protection Authority (1980) - Conservation Reserves for Western Australia; System 7. As recommended by the Environmental Protection Authority 1980.

Forbes, S. J. and Kenneally, K. F. (1986) - A Botanical Survey of Bungle Bungle and Osmond Range, South-eastern Kimberley, Western Australia. West. Aust. Natural 16(5-7) : 93-169.

Gentilli, J. (1972) - Australian Climate Patterns, Thomas Nelson Aust. Limited.

Gill, A. (1979) - Aborigines, settlers and police in the Kimberleys, 1887-1905, In: Studies in Western Australian History. 1.

Gowland, P. N. (1981) - Lake Kununurra Wetlands. West. Aust. Dept. Agric. Kununurra.

Griffin, T. J. and Grey, R. (1990) - King Leopold and Halls Creek Orogens. In : Geology and Mineral Resources of Western Australia. Memoir 3. Geol. Surv. of Western Australia. Dept. of Mines, W.A.

Hayes, D. (1977) - Rays of Hope: The Transition to a Post-Petroleum World. New York: Norton.

Hnatiuk, R. J. and Maslin, B. R. (1988) - Phytogeography of *Acacia* in relation to climate and species richness. Aust. J. Bot. 36.

Humbree, D. (1983) - Aboriginal Sites in the East Kimberley. Unpublished Report. W.A. Museum.

Imberger, J. & Patterson, J. C. (1979) - Report on Dynamics of Lake Argyle: for Meagher & Le Provost.

Iredale, T. & Whitely, G. P. (1983) - The fluvifaunulae of Australia. S. Aust. Nat. 18.

Jaensch, R. P. & Vervest, R. M. (1989) - Waterbirds at remote wetlands in Western Australia, 1986-8. Part One: Lake Argyle and Lake Gregory. RAOU Report No. 32 (in press).

Kenneally, K. F. (1989) - Checklist of Vascular Plants of the Kimberley, Western Australia. West. Aust. Naturalists Club Handbook No. 14.

Kitchener, D. J. (1978) - Mammals of the Ord River Area, Kimberley, Western Australia. Rec. West. Aust. Museum 6(2): 189-219.

Leigh, J., Briggs, J. and Hartley, W. (1981) - Rare or Threatened Australian Plants. Aust. Natl. Parks Wildl. Serv. Special Publ. No. 7

Marchant, N. G. & Keighery, G. J. (1979) - Poorly Collected and Presumably Rare Vascular Plants in Western Australia. Kings Park Res. Notes No.5.

Meagher & Le Provost (1980) - Ord Hydro Power Development Environmental Review and Management Programme (2 Vols) SECWA, Perth. Rep. No. 106.

Northcote, K. H. (1971) - A Factual Key for the Recognition of Australian Soils. Rellim Techn. Publs. Glenside, S.A.

O'Connor, R.E and Quartermaine, G. (1989) - Addendum to Report on a Survey for Aboriginal Sites at the Proposed Realignment on a Section of the Halls Creek-Kununurra Road, East Kimberley. Report to MRD, Derby.

Sainty, G. R. & Jacobs, S. W. L. (1988) - Water plants in Australia. Sainty & Associates, Darlinghurst.

Serventy, D. L. and Whittell, H. M. (1976) - Birds of Western Australia. Univ. West. Aust. Press, Western Australia.

Shire of Wyndham-East Kimberley (1987) - Lake Kununurra Foreshore Draft Management Plan.

Shire of Wyndham-East Kimberley (1990) - 1990 Community Information Directory.

Shirley, A. M., Conover, K. T., Strong, T., Hickey, E. and Sander, F. (1985) - An Evolving Framework for Environmental Impact Analysis. 1. Methods. Jour. Env. Mngt. 21. 343-358.

Spencer, W. B. (1896) - Summary of the zoological, botanical and geological results of the expedition. In: Report of the Horn Expedition to Central Australia.

State Energy Commission of Western Australia (1980) - Ord Hydro Power Development Environmental Review and Management Program: Volumes 1 and 2. Prepared by Meagher & Le Provost in association with W. H. & M. A. Butler. January, 1980.

Stephens, C. G. (1962) - A manual of Australian Soils. Third Edition. CSIRO Melbourne, Australia.

Stewart, G. A., Perry, R. A., Patterson, S. J., Traves, D. M., Slatyer, R., Dunn, P. R., Jones, P. J. and Sleeman, J. R. (1970) - Lands of the Ord-Victoria Area, Western Australia and Northern Territory. Land Research Series No. 28. CSIRO, Melbourne. (Text and maps).

Storr, G. M. (1980) - Birds of the Kimberley Division, Western Australia. West. Aust. Mus. Spec. Publ. No. 11.

Taylor, R. & Burrell, W. (in prep). Shire of Wyndham-East Kimberley Town Planning Scheme No. 4, Amendment No. 14; Kununurra Rural Planning Strategy. Prepared by Russell Taylor and William Burrell, Consultants in Town Planning and Civil Design.

Troilett, G. (1982) - Report of the Archaeological Survey, Argyle Diamond Project. Unpublished Report. W.A. Museum.

Western Australian Tourism Commission (1990) - Wyndham/East Kimberley Tourism Research Overview 1988/89. Research and Planning Division.

Weston, A. S. (1980) - Report. Flora Study, Argyle Diamond Project. C.R.A. Exploration-Ashton Joint Venture, Belmont (Unpublished).

Weston, A. S. (1991) - Vegetation and Flora of The Ord River Hydro-electric Project Area. Unpub. report to D. C. Blandford & Associates Pty Ltd.

Willis, P. (1980) - Patrons and Riders. Unpublished M.A. Thesis. Australian National University, Canberra, A.C.T.

Woinarski, J. C. Z. (ed) (1990 in edit.) - A survey of the wildlife and vegetation of Purnululu (Bungle Bungle) National Park and adjacent area. (Ed. J. C. Z. Woinarski). Report to the W.A. Department of Conservation and Land Management.

10.0 PUBLIC PARTICIPATION AND CONSULTATION

The proposal to establish a hydro-electric power project on the Ord River is not new. The Ord River dam was designed and built with the capacity to incorporate hydro-electric power generation. Various alternative hydro-electric development schemes have subsequently been investigated in an attempt to establish a financially viable project.

In 1980 SECWA produced an ERMP for a 60 MW hydro-electric facility at the Ord River dam. That proposal was assessed by the EPA and found to be environmentally acceptable. A smaller power station on the diversion dam was also investigated by SECWA in 1985. The current proposal, with ADM as proponent, is for a 40 MW hydro-electric facility at the Ord River dam, supplying power to the Argyle mine site only.

Based on this background and community group discussions to date, CRA concluded that the local residents were familiar with the concept of hydro-electric power generation on the Ord, but that it remained appropriate to:

- disseminate information on the nature of the proposal to the public; and

- liaise effectively with those sections of the public which have legitimate interests and can identify issues which require addressing in the evaluation and planning for the project.

Formal referral of CRA's proposal, and the EPA's decision to assess it at the level of PER were advertised in The West Australian Newspaper of 14 April 1990. Information about the project has also reached the general public through several articles in regional and state newspapers.

Public consultation inviting feedback was initiated by disseminating information through various community groups. The groups to be consulted were identified in discussions with the Shire of Wyndham-East Kimberley, the EPA, the State Government's Social Impact Unit, the Aboriginal Affairs Planning Authority, the Argyle Social Impact Group and Dr. G. Syme, social impact assessment specialist with the CSIRO Division of Water Resources. Table 6 lists the groups and the methods by which each was consulted.

Meetings in Kununurra were held in December 1989 with the Wyndham-East Kimberley Shire Council, officers of the Departments of Agriculture, Regional Development and the North West, CALM, WAWA, the Tourism Commission and the Argyle Social Impact Group to brief these organisations on the project and receive their comment.

These were followed by letters to State and Federal Government departments and agencies advising of the feasibility study and seeking comments.

TABLE 6

GOVERNMENT AGENCIES AND COMMUNITY GROUPS INVOLVED IN THE PUBLIC CONSULTATION PROCESS

	Method of Consultation				
Government Agencies	A	B	C	D	E
Aboriginal Sites, Department of		x	x	x	
Agriculture, Department of	x	x	x	x	
Agriculture Protection Board of Western Australia	x				
Civil Aviation Authority		x	x		
Conservation and Land Management, Department of	x	x	x	x	
CSIRO, Division of Water Resources		x	x	x	
Employment, Education and Training, Department of		x	x		
Fisheries Department	x	x	x	x	
Heritage Commission, Australian		x	x		
Health Department of Western Australia	x	x	x		
Land Administration, Department of	x	x	x	x	
Main Roads Department	x	x	x		
Marine & Harbours, Department of	x				
Mines Department	x	x	x	x	
Museum, Western Australian	x	x	x	x	
National Trust		x	x		
Planning & Urban Development, Department of	x				
Regional Development and the North West, Dept. of	x		x	x	
Resources Development, Department of	x	x	x	x	
Shire of Wyndham-East Kimberley	x	x	x	x	x
Social Impact Unit		x	x	x	
Sport & Recreation, Ministry of	x		x		
State Energy Commission of Western Australia	x	x	x	x	
Telecom	x		x		
Tourism Commission, Western Australia	x	x	x	x	
Water Authority of Western Australia	x	x	x	x	

* The Methods of Consultation are listed on the next page.

TABLE 6 (continued)

GOVERNMENT AGENCIES AND COMMUNITY GROUPS INVOLVED IN THE PUBLIC CONSULTATION PROCESS

	Method of Consultation				
Communty Groups and Organisations	A	B	C	D	E
Argyle Social Impact Group			x	x	
Balangarri Aboriginal Corporation	x	x	x	x	
Doon Doon Station Community	x	x	x	x	x
East Kimberley Scuba Diving Club	x		x		
East Kimberley Sports Fishing Club	x		x		
Horticultural Producers' Association	x				
Joorook Ngarni Aboriginal Corporation	x	x	x	x	
Kimberley Land Council	x	x	x	x	
Kununurra Agricultural Society	x				
Kununurra Progress Association	x				
Kununurra Rowing Club	x		x		
Kununurra Ski Club	x				
Mandangala Aboriginal Corporation (Glen Hill)	x	x	x	x	x
Miriuwunga Gajerronga Ninguwung Yawurrung Inc.	x	x	x	x	
Ord River Sailing Club	x		x		
Warmun Community (Turkey Creek)	x	x	x	x	x
Waringarri Aboriginal Corporation	x	x	x	x	x
Wilderness Society - Kununurra		x	x	x	x
Wilderness Society - Western Australia			x	x	

Type of Consultation

A General letter of advice regarding proposed project and seeking comments
B Detailed or extended correspondence
C Telephone discussion(s) with representative(s)
D Meeting(s) with representative(s)
E Meeting with full group/agency

Community groups representing cultural, commercial, recreational and environmental interests in the project area were contacted. Discussions were held with representatives of ten groups. CRA or its consultants addressed meetings of six groups, while telephone discussions were held with the remaining four.

Aboriginal resource agencies, community groups and individuals with direct land title interests or cultural association with the project area were consulted in a staged process appropriate to their level of interest in the project. The process commenced with letters to the participants requesting meetings to introduce and provide a briefing on the project being considered. At the first meeting the project was described, questions answered and the participants invited to consider potential impacts. At the second meeting a briefing outlined the project investigations since the first meeting, and questions were answered and issues identified. A commitment was given to take the appropriate custodians to inspect the land on which the project would be established. This has been done. The process of consultation with Aboriginal community groups and representatives is continuning.

The project was discussed with members of the local business community. These included Mr Jeff Hayley of Triple J Tours, the operator of tour boats on Lakes Kununurra and Argyle, and the Ord River; and Mr Steve Sharpe, a commercial fisherman on Lake Argyle.

CRA in its capacity as proponent actively communicated with all relevant bodies. ADM intends to resume all previous links with the relevant communities and local bodies, who will be consulted following the release of this PER document.

The consultants engaged in the consultation process to date, and in providing information for this PER were:

D. C. Blandford & Associates Pty Ltd	Principal Environmental Consultant
Snowy Mountains Engineering Corporation	Engineering and Hydrology
Arthur S. Weston, Ph.D	Vegetation and Flora
Ninox Wildlife Consulting	Fauna
Rory O'Connor & Associates Pty Ltd	Aboriginal Ethnohistory
Quartermaine Consultants	Archaeology
Centre for Water Research, U.W.A.	Lake Argyle Water Quality
CSIRO Division of Water Resources	Social Impact Assessment/Community Involvement

11.0 GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS

ADM	Argyle Diamond Mines Pty. Limited
AHD	Australian Height Datum
A2	The A2 horizon in a soil is a master horizon that is paler in colour than both the overlying horizon and the underlying B or any other horizon material. The A2 horizon therefore is defined by colour differences.
B.P.	Before Present
CALM	Department of Conservation and Land Management
coherent	Two-thirds or more of the soil material, whether composed of individual natural soil aggregates or not, will remain united at the given moisture stage unless force is applied.
cumecs	cubic metres per second
dB(A)	The most common unit for sound measurement. dB= decibels, (A) = Weighted sound pressure levels. 90dB(A) is the current action level under the Occupational Health, Safety and Welfare Act 1984-1987
duplex	A primary soil profile form dominated by the mineral fraction with a texture contrast of 1.5 texture groups or greater between the A and B horizons. The characteristic feature of these soils is the high clay content of the B horizon relative to the overlying A horizon.
EPA	Environmental Protection Authority of W.A.
epilimnion	the warmer uppermost layer of water lying above the thermocline in a lake
ERMP	Environmental Review and Management Programme
FSL	Full Supply Level
gradational	A primary soil profile form dominated by the mineral fraction and showing increasingly finer (more clayey) texture grades with an increase with depth such that the texture of each successive horizon passes gradually from the one above into the one below.
ha	hectares

hypolimnion	the colder, non-circulating layer of water in a lake, lying beneath the thermocline
km	kilometres
km^2	square kilometres
kV	kilovolts
lithosol	A young soil which has not been subjected to the soil-forming processes, agencies and influences for a sufficient period of time for the soil to develop mature characteristics.
m	metres
m^3	cubic metres
mm	millimetres
m/s	metres per second
Mt	million tonnes
MW	Megawatts
ORIA	Ord River Irrigation Area
profile	The soil profile is the face of soil exposed in a vertical section.
SECWA	State Energy Commission of Western Australia
t	tonnes
thermocline	the plane at which temperature drops most rapidly in the zone between the epilimnion and hypolimnion.
WAWA	Water Authority of Western Australia

12.0 APPENDICES

12.1 Definition of the Term 'Significant Species'

12.2 Public Environmental Review Guidelines

Appendix 12.1 DEFINITION OF THE TERM 'SIGNIFICANT SPECIES'

The term 'significant species' is used to refer to species which are, or appear to be: rare; geographically restricted; on the boundaries of, or outside, their normal ranges of habitats; diminishing in abundance or geographical range; particularly vulnerable to environmental changes; or poorly represented in secure conservation reserves. This informal, unofficial category, 'significant species', contains Priority Species, and Declared Rare Flora species, as well as species which have not been assigned any formal conservation or protection status such as 'Priority' species or 'Declared Rare' species.

Significant species other than priority species and Declared Rare Flora have no legal protection and no formal or official conservation designation. Declared Rare Flora species have been officially gazetted and are legally protected. Priority species are not gazetted and have no legal protection but are considered, at least provisionally, to be uncommon, rare or restricted: many are being considered for gazetting pending the results of field surveys to assess how abundant and widespread they are.

Species are added to the priority lists and are gazetted as Declared Rare Flora when CALM believes it has sufficient information about the species' abundance, distribution and conservation. Less commonly, species are taken off the lists, when they are found to be more common, widely distributed, or better protected in secure conservation reserves, than previously thought.

For example, none of the species found during the vegetation and flora survey of the Ord River hydro-electric project area was a priority species in 1990 when the surveys were carried out, but one of the significant species found then, *Acacia setulifera,* has since been elevated to the rank of Priority 1 species. The population of this wattle is unlikely to be affected by the project. No other priority species was found in the project area.

No gazetted, legally protected species [of Declared Rare Flora] was found in the project area, and it is highly unlikely that any occurs there. No Declared Rare Flora species have been recorded there in the past, and there are no habitats in the project area similar to the ones in which any of the four Kimberley species of Declared Rare Flora have been found.

APPENDIX 12.2

Public Environmental Review Guidelines

PROPOSED HYDRO-ELECTRIC POWER GENERATION - ORD RIVER

PUBLIC ENVIRONMENTAL REVIEW GUIDELINES

These guidelines provide a list of topics that should be included within the Public Environmental Review (PER).

They are not intended to be exhaustive and the proponent may consider that other topics should also be included in the document. The purpose of the PER should be explained and the contents should be concise and accurate as well as being readily understood. Specialist information and technical description should be included where it assists in the understanding of the proposal. It may be appropriate to include ancillary or lengthy information in technical appendices.

The guidelines are as follows:

1 SUMMARY

The PER should contain a brief summary of:

- salient features of the proposal;
- alternatives considered;
- description of environment both physical and social and analysis of potential impacts and their significance;
- environmental and social monitoring and management programmes, safeguards and commitments; and
- conclusions.

2 INTRODUCTION

The PER should include an explanation of the following:

- identification of proponents and responsible authorities;
- background and objectives of the proposal;
- brief details of, and timing of, the proposal;
- relevant statutory requirements and approvals, including Commonwealth involvement; and
- the scope, purpose and structure of the PER.

3 NEED FOR THE PROPOSAL

The PER should examine the justification for the proposal. Broad costs and benefits of the proposal at local, regional, State and National levels should be discussed. Consequences of not implementing the proposal should be outlined.

4 EVALUATION OF ALTERNATIVES

A discussion of possible alternatives to the use of hydro-electric energy for providing electricity supply to Kununurra and Argyle Diamond Mine should be provided.

A discussion of alternative transmission line corridors should be provided. This discussion should clearly explain the rationale for choosing the preferred option.

5 DESCRIPTION OF THE EXISTING ENVIRONMENT

This chapter should provide an appraisal of all environmental and social systems likely to be affected by the power station, the spillway modifications and transmission line options.

5.1 Study Area

5.2 Geomorphology, Soils and Geology

5.3 Hydrology

- description of surface water systems, wetlands, natural drainage patterns, flow capacity, water quality, storage capacity, man-made drainage and lakes, catchment areas (existing and potential).

5.4 Aquatic

- description of aquatic systems;
- incidence of flooding, storm activity, etc, which could affect development site;
- water quality;
- circulation; and
- stratification.

5.5 Biota and Ecosystems

5.5.1 Vegetation

- major associations;
- areas of particular value (eg due to high species richness);
- rare and endangered, uncommon or geographically restricted species;
- conservation areas (eg National Parks, Reserves);
- aquatic vegetation.

5.5.2 Wildlife

- species occurring or likely to occur;
- areas of particular value (eg important habitat areas, areas with a high species richness);
- rare and endangered, uncommon or geographically restricted species;
- important habitat areas;
- movement paths/corridors;
- conservation areas (eg National Parks, Reserves);
- fish; endemic, endangered, commercially or recreationally important species.

5.5.3 System 7 Red Book Recommendations (where applicable)

5.6 Social Environment

5.6.1 Land Use Pattern (Existing and Future), including tourism, recreational opportunities

5.6.2 Significant Sites (Aboriginal, Ethnographic; Archaeological, Historic, Scientific, Educational)

5.6.3 Existing Infrastructure, Powerlines, Roads, etc

5.6.4 Landscape Amenity/Quality

5.6.5 Characteristics of Surrounding Communities

5.7 Conclusions (synthesis of the existing environmental and social conditions and of the resilience of the environment)

6 DESCRIPTION OF PROPOSED DEVELOPMENT

Adequate information and technical data, including maps, diagrams, photographs, etc, should be presented to allow a careful evaluation and review of the proposed development.

This should include all aspects of the project including the power station, power transmission, spillway modifications, reservoir and power station operation components. The social, technical and broad economic characteristics of the project and associated facilities, both public and private should be discussed.

Important principles which the Authority feels could be incorporated into this section include:

- forecast demand for electricity including implications and intentions for electricity supply and ownership when Argyle Diamond Mine ceases operations;
- time-scale of implementation and project life;
- transmission line alignment and construction techniques;
- access tracks, and infrastructure for all aspects;
- project elements, eg survey traces, construction camp sites, water supply resource consumption expected (energy, water, etc), options available for supply of resources; and
- the management structure of the completed development should be described so it is clear how the development will be managed and by whom.
- decommissioning and rehabilitation of power station and/or transmission line.

7 DESCRIPTION OF THE ENVIRONMENTAL IMPACTS

This should present an assessment of the environmental impact of all facets of the proposal, based upon the description of the existing environment. Both construction and operational phases should be considered. Impacts should be quantified where possible and uncertainties highlighted. Criteria employed when making impact assessments should be quite clear.

An overview or synthesis should be attempted to show how the power station and transmission lines will interact with the total ecosystem and its elements, including people.

Potential environmental and social impacts that need to be addressed include:

7.1 Impact of Raising the Spillway Level on Lake Argyle

- aquatic ecology
- aquatic weeds
- vegetation, flora and fauna around the lake shore and islands
- catchment erosion
- commercial and recreational fishing
- tourism

7.2 Impact of Altering Downstream Regimes

- tourist operations, including access and safety
- changes in river morphology
- potential for bank scour
- effect on lower reaches of the Ord beyond the diversion dam
- impact on irrigation use in the Ord River Irrigation Area
- impact on fringing vegetation and aquatic fauna
- possible effect of changes in water quality, eg, temperature and oxygen levels
- possible effect of changes in the timing and amount of water flows down Spillway Creek on boat owners and other users

7.3 Biota and Ecosystems

7.3.1 Disturbance of Vegetation (With particular reference to any rare or endangered, uncommon or geographically restricted species)

- direct loss as a result of power station and transmission line construction
- other losses (eg as a result of machinery compounds, access tracks, construction camps etc)
- weed invasion

7.3.2 Disturbance of Wildlife (With particular reference to any rare or endangered, uncommon or geographically restricted species)

- disruption of habitats (terrestrial and aquatic)
- severance of movement corridors

7.3.3 Intrusion Upon Conservation Areas and Reserved Lands (eg direct severance and spillover effects)

- System 7 recommendations and areas
- other areas identified as having conservation value
- implications for the Ramsar Convention areas

7.3.4 Hydrological Implications

- disruption of water systems (watercourse/drainage line crossings; maintenance of natural drainage patterns; drainage from access tracks)
- use of water supply for construction purposes

7.3.5 Maintenance of Soil and Landform Stability

- erosion hazards
- cuttings and filling
- drainage

7.3.6 Other Impacts

- mosquito breeding
- impact of switching station
- waste emissions
- noise
- fire
- weed invasion
- impact of increased access for Carr Boyd Ranges

7.4 Social Environment

7.4.1 Intrusion upon Significant Sites (Direct and indirect)

- aboriginal/ethnographic
- historic
- scientific
- educational

7.4.2 Alteration of Landscape Amenity/quality

- impact of overhead line which will span the river from the power station
- extent of vegetation loss
- visibility of transmission line from external viewpoints (especially with regard to Aboriginal communities)
- rehabilitation of roads, tracks and cleared areas
- Impact of switching station location

7.4.3 Other Impacts

- Impact on tourism
- noise
- demand for additional services
- fishing and recreation uses
- impact on existing land uses, eg, small mineral operations (Zebra Rock and Alluvial diamonds)

7.5 Synthesis

Should include an assessment of the significance and timing of the various potential impacts identified.

8 ENVIRONMENTAL MANAGEMENT

Based on the detailed synthesis of environmental and social impacts presented in the previous chapter, the intended programme for the management of impacts (including monitoring) needs to be described.

The purpose of the overall management programme is to demonstrate the manner in which the potential environmental and social impacts can be avoided or ameliorated.

Major issues requiring attention would include:

- management of unavoidable impacts during construction and operation
- amelioration of lesser impacts
- staging and construction
- landscaping and rehabilitation - issues capable of being managed
- monitoring and reporting
- authorities responsible for management should be clearly identified

9 CONCLUSION

Conclusions on the overall impacts of the respective project options and the associated management requirements, need to be presented. On this basis, an assessment of the environmental and social acceptability of the respective options needs to be made and the environmentally preferred strategy identified.

10 GUIDELINES

A copy of the guidelines should be included in the document.

11 REFERENCES

All references should be listed.

12 APPENDICES

Where detailed technical or supporting documentation is required, this should be placed in appendices.

13 COMMITMENTS

A numbered list of all environmental and social management commitments should be given. A commitment should include:

- who makes the commitment
- the nature of the commitment
- when the commitment will be carried out and to whose satisfaction.

14 PUBLIC PARTICIPATION AND CONSULTATION

A description should be provided of the public participation and consultation activities undertaken by the proponent in preparing the PER. This section should describe the activities undertaken, the dates, the groups and individuals involved and the objectives of the activities. A summary of the concerns raised should be documented. This section should be cross referenced with the 'Environmental Management' section which should clearly indicate how these concerns have been addressed.