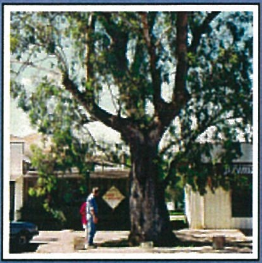



HYDER ENVIRONMENTAL

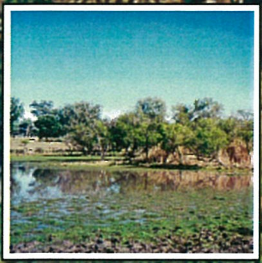
A DIVISION OF HYDER CONSULTING (AUSTRALIA) PTY LTD

Hyder Consulting



IMPACT ASSESSMENT STUDY FOR PROPOSED DAWSON DAM






FEBRUARY 1998

SUPPLEMENTRY REPORT

TABLE OF CONTENTS

Maps

Hyder Environmental			
Report preparation:	R. Thistlethwaite	**Verified by:**	S Macnish
Position:	Project Manager	**Position:**	Qld Manager - Env
Date:	27 Feb 1998	**Date:**	27 Feb 1998
Signed:		**Signed:**	

I. INTRODUCTION

A. IAS PROCESS

It is apparent from the submissions that there is a very wide range of expectations for an IAS and just what an IAS is required to deliver to the Responsible Authority (in this instance DNR- Resource Management Group).

An IAS is required under the State Development and Public Works Organisation Act 1971-1981 for an analysis of the environmental effects of development proposals and public works in Queensland. Major water resource developments are specified in Schedule IV of *Impact Assessment in Queensland: Policies and Administrative Arrangements* as the type of development which may require an IAS. Environmental effects are defined as '... the beneficial as well as the detrimental effects of any development on the physical, biological, or social systems within which the development occurs.' The Act does not contain a specific definition of an Impact Assessment Study (IAS) but does set out procedures to be taken as part of any study. This commences with preparation of an Initial Advice Statement followed by development of appropriate Terms of Reference for the IAS using input from relevant Advisory Bodies.

The Act goes on to say ...

Where applicable, the impact assessment study should be required to provide:

a) Description of relevant aspects of the existing environment;
b) Description of the development proposal and any optional means of achieving the development objectives;
c) Definition and analysis of the likely impacts of the development on the environment;
d) Definition of all significant impacts and measures proposed to mitigate against those effects; and
e) Presentation of an environmental management programme to monitor actual impacts of the development, and mitigate adverse impacts.

To meet these requirements '...*the Terms of Reference for each development proposal should be prepared on a case by case basis based upon Advisory Body comment on initial advice for the development.*'

The Draft Terms of Reference (ToR) were prepared for this study and were subject to open tender for the project. At this stage the ToR were distributed to a range of Advisory Bodies for comment and consultants were required to modify their proposal approach in response to any changes in these draft ToR should this be necessary. Hyder Environmental (at that time trading as Axis Environmental Consultants) was the successful tenderer. In preparing its submission, Hyder Environmental sought clarification on the limits of the study area, as these had not been specified in the Draft ToR. Advice was provided by DNR at this stage that an appropriate limit was the junction of the Dawson River with the Mackenzie River. This advice was based on Hyder Environmental's contention that there are no credible baseline data available on system inputs from other sub-basins in the Fitzroy catchment (i.e. Mackenzie, Nogoa, Comet, Callide), or point and non-point sources to the Fitzroy River from the lower reaches. Therefore, only incremental inputs from the Dawson River could reasonably be considered. A further major consideration was the concurrent conduct of the WAMP for the entire Fitzroy River basin, data from which were expected early in the study.

Hyder Environmental's proposal, thus, set out what work would be undertaken within the specified time frame and the available budget. This approach was accepted by the review panel which assessed all proposals and was consulted in relation to the final selection. This panel included the Chairman of the Local Management Group. The approach was ratified when Hyder Environmental was selected following the interview process. Members of the Local Management Group were advised of this approach at the initial meeting attended by the Consultant on 14 October 1996 and this verbal advice was subsequently confirmed in a letter to LMG members from the Secretary of the LMG on 6 December 1996. This letter advised that, "*... DNR and Hyder had considered carefully all comments made by Advisory Bodies and others, and have concluded that the majority of issues raised were either clearly covered or were formal subsets of aspects covered by the draft document. An acknowledged exception to this is the impact of the dam proposal on the Fitzroy River and downstream to the reef.*" The letter went on to advise *that "... the*

Draft ToR will now be considered the final ToR for the IAS/EMP." The IAS was conducted according to these ToR.

Work program and budget were set by both the Principal and the Consultant according to the ToR and not according to what may be considered the most desirable level of investigation in the absence of restrictions on time or budget. The time frame for the original study allowed a maximum of 14 weeks for the conduct of all field work, community consultation and the preparation of a draft IAS and EMP for review. This was met for all studies except for the land use, hydrology and economic studies which were dependent on the outcomes of the WAMP and yield calculations. Draft reports were available for all other studies by the original due date. At that time additional work was proposed on the fauna and flora of the study area, and on the conduct of further social impact studies (which were all subsequently presented in the Main Report).

The initial time frame enabled an acceptable rather than a maximum level of investigation to proceed, resulting in study outcomes which would permit an effective assessment of the scope and nature of the adverse and beneficial impacts of the proposal. The IAS process by being interactive in setting the ToR, thus, acknowledges a realistic investment in the acquisition of appropriate levels of data to assist further planning. It is the role of the IAS to identify where major deficiencies in knowledge exist and to recommend appropriate measures to obtain such information, or to apply conditional evaluations until such time as the knowledge becomes available.

The Consultant believes that an appropriate amount of work was undertaken within the original time frame in line with the ToR. Though the final documents were delayed somewhat pending availability of hydrological data and completion of the WAMP, it should be noted, that with the exception of the approved additional studies, no further substantial work was undertaken during much of the intervening period. It is unrealistic to expect that the studies could have acquired the level of data that is apparently expected by the authors of some of the submissions within the permissible time frame.

It is not economically feasible nor is it necessary for the purposes of an IAS to study every facet of the environment or pursue baseline studies until every detail of all aspects of the natural system is known. Where data may be limited, there is often little alternative, given practical time and financial constraints, but to call on professional specialists to apply their experience to the evaluation and resolution of identified impacts. The ultimate safeguard lies in the inclusion of sound management guidelines in the final detailed EMP which governs the construction and operation phases of the project.

It should be noted that while the ToR referred to study requirements for boggomosses and for Aboriginal Cultural Heritage, these were expressly excluded from the ToR by DNR which commissioned separate studies for these aspects. The role of the Consultant was only to incorporate relevant major findings of these studies in the IAS Report. Copies of the reports of these separate studies had been made publicly available prior to the finalisation of the IAS Main Report. Nevertheless, these documents, together with the IAS Main Report, the Draft EMP and the 8 Supporting Documents constitute part of the information base for the decision making process on the Dawson Dam proposed project. Additionally a series of engineering studies related to dam site selection and design, hydrology, and geotechnical aspects have been undertaken since 1995. Preliminary fauna, flora and land suitability surveys were also commissioned by DNR prior before the commencement of the IAS. These have all been referred to in the Main Report.

The IAS involved the input of a series of specialist sub-consultants. The sub-consultants have validated that their work has been treated fairly in both letter and spirit in the reports prepared by the Consultant, and these letters of validation are attached at Appendix 1.

B. THE SUPPLEMENTARY REPORT

The purpose of the Supplementary Report process is to review public submissions received in response to the IAS, and incorporate relevant issues raised in those submissions. Where necessary, more detailed explanations may be provided of concepts less familiar to non-scientists, explain apparent ambiguities, and correct errors of fact or inference.

The IAS report was presented by DNR to the Local Management Group (LMG) in Taroom on Monday 3 November 1997 and placed on public display the same date. Each member of the LMG and the Project Reference Group (PRG) received a personal copy of the IAS Main Report and Appendices, and a number of sets of the Supporting Documents were also made available to both advisory bodies. The Public Review period was originally set for 4 weeks with a deadline for submission of 1 December 1997, but this was extended by 3 weeks to 19 December 1997.

The Consultant presented an overview of their report to a joint LMG/PRG meeting in Taroom on 25 November 1997, and again that night to a public meeting which was very well attended by over 200 people from throughout the Dawson Valley from Wandoan to Duaringa, with some persons from outside the Valley.

At the combined PRG/LMG meeting, a participant requested an assurance that certain maps contained in the IA report would not be used for land management or compensation purposes at the property level. The DNR subsequently wrote to affected landholders providing that assurance, and attaching Hyder Environmental's comments on map scale and presentation of soils and land use data, and the appropriate use of the maps for different purposes at the broad planning level.

II. SUBMISSIONS

Fifty-six submissions were registered by the Resource Management Group of the Department of Natural Resources. Although the cut-off date for submissions had been extended by 3 weeks to 19 December 1997, 4 late submissions were accepted, one dated as late as 30 December 1997. These submissions are listed in Table 1 below. The addresses given in the Table for the respondents are those provided on the submissions. All submissions are referred to in discussions in the Report by their number (Column 1). The name/s given are those of signatories to the submission, or in unsigned submissions, to the name of the secretary (in the case of an Organisation) over whose name the document was despatched.

The 56 submissions involve several hundred pages of input (some 8 cm thick), a substantial amount of it repetitious in nature. As a large number of Supplementary Reports are to be printed and circulated, it was not considered cost-effective to reproduce and include all these submissions in the Supplementary Report. These submissions will be accessible to the public for viewing by arrangement with DNR - Resource Management.

Table 2 categorises the 56 submissions into three broad groups of Government, Organisations and Individuals. The numbers in brackets within Table 2 refer to the registered number of each submission. The Government category is then sub-divided into Commonwealth (3 submissions), State (8 submissions) and Local Government (4 submissions). Organisations are split into Conservation Groups (8 submissions), Land-based Groups (4 submissions), Water-based Groups (6 submissions), Political Groups (1 submission), Academic Institutions (1 submission), and Consultants (3 submissions). The Individuals Category is split into Most Affected Landowners (those who stand to lose property if the dam is constructed) (4 submissions), Dawson Valley people (who have a direct stake in the outcome of the development proposal) (9 submissions), and Others (individuals from other areas who are concerned about the proposed development) (5 submissions).

The submissions were then passed to the Consultant for review. DNR Resource Management undertook its own review as well and sought independent opinions on some matters raised. Those issues relevant to the IAS were then listed for each submission, and from this listing a framework was developed for responding to the submission issues. Submissions ranged from one page letters of support for the IAS to 40 pages of detailed critique.

Some excellent, constructive criticism was received and where relevant to the IAS this has been addressed in the Supplementary Report, or issues have been flagged for future attention and management. In some instances, such as downstream social impacts, an attempt has been made to flag outstanding or unresolved issues.

There is a striking similarity in the content of many submissions, with many examples of word-for-word paragraphs which are common to submissions from the conservation groups and from some government departments and individuals.

It was, however, a disappointment to note that comments in a surprising number of submissions displayed a very superficial reading of the IAS, misconstruing meaning and taking information completely out of context, or indeed a superficial understanding of the topic being discussed. Where the Consultant inferred that the comment may have arisen from unclear or ambiguous text, an attempt has been made to clarify the meaning, while retaining the original sense. Such changes are included, along with more important errors of fact or inference, in an Errata section which is appended to the Supplementary Report.

In many instances the Consultant was criticised for the use of 'motherhood' or non-definitive approaches to the treatment of issues of a scientific import. It was difficult, or quite impossible, to respond to many of these because the submissions themselves used a mix of conjecture, unsubstantiated data, and non-specific assertions of a pseudo-scientific nature in an attempt to call into question the credibility of the Consultant and the IAS Report.

There were also a considerable number of issues raised which were not pertinent to a review of the IAS as framed by the Terms of Reference, or were at best tenuously connected . Fundamentally, some of these comments can be addressed only by the DNR, or indeed on a whole of government basis. The latter include a number of social issues and compensation matters, policy issues such as the full cost recovery principle for water supply, and some equity issues.

The broad issues of wider concern, referred to in 10 or more of the submissions, were:

- Economics
- Water Allocation and Management Planning (WAMP)
- Environmental flows
- Fitzroy to Reef: downstream impacts
- Buffer zone
- Whole property management planning
- Groundwater/Watertable/Salinity
- Chemicals/agri-chemicals
- Blue-green algae
- Fishways
- Boggomosses
- EMP issues

Of these, economics and WAMP issues were the two main areas of comment. Many of those commenting on the economic analysis had obviously not been written by persons with economics training, some clearly confusing an economic analysis with a financial analysis. Others had not read the text carefully and asked questions which had been addressed. Notwithstanding, there were a set of substantive submissions which raised pertinent questions on aspects of the economic analysis and these have been addressed in a revised economics report (Attachment 1). The main WAMP concern was that the IAS was being undertaken before the completion of the WAMP. Many considered that a decision on the IAS could not be reached in the absence of the WAMP output, especially with respect to 'water allocations' for environmental flows.

Questions on the buffer zone and proposed easement loomed large in the minds of many of the rural submissions, especially those from the Taroom area, as would reasonably be expected. These concerns were also raised by the conservation movement affiliated with Taroom groups. There was obvious confusion about what constitutes a buffer zone, and an obvious misconception that the area chosen for the upstream land use studies constituted a 'buffer'. Consequently this has been addressed in some detail in an attempt to clarify the matter.

The concern for water quality and human health aspects was evident in the comment on possible impacts from agri-chemicals (fertilisers and pesticides). A common concern (especially from the Rockhampton end of the Fitzroy basin) was that fertilisers might enter the river from the irrigation areas, causing eutrophication of the waters, with a risk of increased blue-green algae outbreaks. Similarly there was concern with the possible impact of agricultural pesticides on health for downstream water users. A further health concern related to potential insect-borne diseases due to increased occurrence and populations of mosquitoes and sandflies/midges near Taroom.

In the biology area, the main expressed concern was for loss of habitat in various forms, but particularly the loss of riparian habitat. The prospect of inundation of up to 50% of the existing mapped boggomosses was of concern to conservation submissions, and also to those government departments charged with environmental responsibilities.

A concern emerged from a range of submissions that the IAS focused too much on the main area of impact from Taroom to the Nathan Gorge to the detriment of the 'receiving area' downstream of the dam. Some considered that insufficient weight had been given to beneficial downstream impacts, including social impacts, while others were concerned for negative biological and social impacts. Some criticisms of the Consultant were made by those unaware of the original 14 week's time frame allotted for the IAS.

The overarching social concern was for equity, especially for what might be described as inter-shire or inter-regional equity, stemming from the perception that those downstream of the proposed dam are profiting at the expense of those upstream by virtue of being in the right place at the right time.

The comment on the draft EMP generally offered constructive advice for improving or expanding the suggested plan strategies and elements. Many of these will need to be taken into account in the preparation of the detailed EMP following any decision by Government to proceed with the dam development.

Of course other issues were raised which, though not receiving the level of comment afforded the issues above, are important issues, nevertheless, and the Supplementary Report has attempted to treat them as such, within the imposed limitations of time and resources.

It should also be obvious that with the volume of paper involved in the 56 submissions (8 cm thick), it is simply impossible to answer each submission individually. So there may well be points of specific detail which loom large in the mind of an individual respondent which have escaped attention, despite the best efforts of the Consultant in addressing the issues. For example, one submission raised the potential for development of a coal deposit some distance south-west of Taroom. As the mine does not yet exist and there are no known location or design details available, it is difficult to assess any impacts due to the construction of the dam. The assessment of impacts of the mine on the dam would, however, in due course be subject to a future IAS associated with the mine's development. Other examples included letters of support for the IAS which did not require comment, while some letters simply made observations.

To those persons or organisations not specifically identified by submission number in the main body of the Supplementary Report, the Consultant apologises for any perceived shortfall. Nevertheless, the Consultant believes that these issues have been addressed sufficiently in the overall responses. There are also many comments both praising or damning the whole IAS or parts of it. To these generalisations we have not responded. The same is true of statements of opinion or assertions proffered as fact.

There was also a small number of submissions, notably one dealing with fish issues, which were full of excellent information and advice. These were a pleasure to read and the information will be conveyed to those who can make best use of it, in consultation with the authors. But again, for such submissions, no direct response was feasible in this Supplementary Report.

The Consultant would like to thank those respondents who have taken the time to closely study the Main Report, and the 9 supporting documents provided by the Consultant, together with the 4 separate reports on boggomoss and aboriginal cultural heritage elements of the IAS, and provided constructive criticism. Such criticism is most welcome and serves to improve the IAS and the IA process.

TABLE 1: SUBMISSIONS: IAS DAWSON DAM PROPOSAL

No.	Title	First Name	Surname	Position	Organisation	IAS Process Linkage	Address	City	State	Post-code	Date on Submission
1	Mr	Rob	Hoare		Rob Hoare & Associates		15 Munro Street	INDOOROOPILLY	QLD	4068	21-Nov-97
2	Mr	D.L.	Stower	Chief Executive Officer	Duaringa Shire Council		PO Box 2	DUARINGA	QLD	4702	24-Nov-97
3	Mrs	Jill	Chamberlain	Hon. Secretary	The Wildlife Preservation Society of Qld: Caloundra Area		PO Box 275	CALOUNDRA	QLD	4551	25-Nov-97
4	Dr	Russell	D'Arcy	Senior Geologist	Department of Mines and Energy: Resource Development Division		GPO Box 194	BRISBANE	QLD	4001	28-Nov-97
5	Emeritus Professor	John	Holmes			CCC Rep. on NPRG	73 Ironside St	ST LUCIA	QLD	4067	28-Nov-97
6	Mr	Scot	Stewart		Department of Local Government & Planning: Western & Central Qld Planning Division		PO Box 113	ROCKHAMPTON	QLD	4700	03-Dec-97
7	Mr	Terry	Hill	District Director	Main Roads: Rockhampton		PO Box 5096	CENTRAL QLD MAIL CENTRE	QLD	4702	05-Dec-97
8.	Mr	Mark	Morrison	Ph.D. student			C/- ADFA University College	CANBERRA	ACT	2600	05-Dec-97
9	Mr	Doug	Adam	President	Taroom District Development Association	TDDA Rep. on LMG	PO Box 374	TAROOM	QLD	4420	10-Dec-97
10	Mr	G.J.	Merry	Acting Chief Executive Officer	Rockhampton City Council		PO Box 243	ROCKHAMPTON	QLD	4700	12-Dec-97
11	Mrs	J.	Simpson		Ecological Water Alliance of Queensland		9 Meher Road, Keil Mountain	WOOMBYE	QLD	4559	12-Dec-97
12	Mr	Sandy	McCubbin				PO Box 32	THEODORE	QLD	4719	13-Dec-97
13	Mr	Dale	Stiller	The three signatories are: D. Poole, M. Mayes, Dale Stiller	Taroom Shire Landcare Group		PO Box 255	WANDOAN	QLD	4419	13-Dec-97
14	Mr	Jack	Baxter				PO Box 226	TAROOM	QLD	4420	15-Dec-97
15	Mr & Mrs	G. & M.	Becker			M. Becker LAND Rep. on LMG; LMG Rep. on NPRG	"Spring Creek"	TAROOM	QLD	4420	15-Dec-97
16	Mr & Mrs	J. & C.	Gall				"The Glebe"	TAROOM	QLD	4420	15-Dec-97
17	Ms	G. R.	Griffith		Ecological Water Alliance of Queensland		6 Peppertree Close	MARCUS BEACH	QLD	4573	15-Dec-97
18	Mr	Gerry	Morvell	Assistant Secretary	Environment Australia: Environment Assessment Branch		40 Blackall Street	BARTON	ACT	2600	15-Dec-97
19	Mrs	Anna	Doneley	President	Wildlife Preservation Society of Queensland: Dalby Branch		PO Box 338	DALBY	QLD	4405	16-Dec-97
20	Mr	Donald	Joyce			LAND Rep. on LMG	"Balcarris"	TAROOM	QLD	4420	16-Dec-97
21	Mrs	R.S.	Moffat	The 8 signatories to the submission are: C. Green, S. Coutts, P. Sparkes, R. Moffat, L. Moffat, D. Rodger, J. Wearing, R. Phelps	Taroom Coalition of UGA, CU, QGGA, Riparian Landowners, WPSQ, LAND	R. Moffatt RL Rep. on LMG; D. Rodger Landcare Rep. on LMG; J. Wearing WPSQ Rep. on LMG; and R. Phelps CU Rep. on	"Eurombah"	TAROOM	QLD	4420	16-Dec-97

TABLE 1: SUBMISSIONS: IAS DAWSON DAM PROPOSAL

						LMG					
22	Mr	Simon	Baltais	Secretary	The Wildlife Preservation Society of Queensland: Bayside Branch		PO Box 427	CAPALABA	QLD	4157	17-Dec-97
23	Mr	David	Bateman	Executive Officer	Sunfish Queensland (07) 3284 5977 Chris Ryan		10 Dalloon Street	BOONDALL	QLD	4034	17-Dec-97
24	Mr	Adam	Clark				PO Box 348	TAROOM	QLD	4420	17-Dec-97
25	Mrs	Anne	Clarke	Hon. Secretary	Australian Marine Conservation Society		PO Box 3139	YERONGA	QLD	4104	17-Dec-97
26	Mr	Mark	Elmer	Senior Resource Manager	Queensland Fisheries Management Authority Andrew Thwaites (07) 3225 1896		PO Box 344	FORTITUDE VALLEY	QLD	4006	17-Dec-97
27	Mr	Peter	Hale	Executive Director	Centre for Conservation Biology		University of Queensland	BRISBANE	QLD	4072	17-Dec-97
28	Mr	John	Hooper	Chief Executive Officer	Banana Shire Council		PO Box 412	BILOELA	QLD	4715	17-Dec-97
29	Mrs	Deirdre	Llewellyn		The Five Mile		PO Box 248	TAROOM	QLD	4420	17-Dec-97
30	Mr	Jim	Llewellyn				PO Box 248	TAROOM	QLD	4420	17-Dec-97
31	Dr	R. L.	Miles	Rural Services Co-ordinator: Central Region	Department of Primary Industries		PO Box6014	ROCKHAMPTON MAIL CENTRE	QLD	4702	17-Dec-97
32	Dr	Peter	Nimmo	A/Executive Director (Environment)	Department of Environment		PO Box 155	BRISBANE ALBERT STREET	QLD	4002	17-Dec-97
33	Mrs	Veryan	Collyer				Yeramba	THE GUMS	QLD	4406	18-Dec-97
34	Ms	Susan	Cunningham	Co-ordinator	Capricorn Conservation Council Inc. (07) 4927 8644		PO Box 795	ROCKHAMPTON	QLD	4700	18-Dec-97
35	Mr	Graeme	Gall	President	Landholders Affected by Nathan Dam	LAND Rep. on NPRG	"Cockatoo Station"	WANDOAN	QLD	4419	18-Dec-97
36	Dr	Kris	Plowman	Submission from C. Greenway, Dr E. Stock, Dr K. Plowman			PO Box 363	RED HILL	QLD	4059	18-Dec-97
37	Ms	Julie	Kirkwood	Water Project Officer	Queensland Conservation Council		PO Box 12046	ELIZABETH STREET BRISBANE	QLD	4002	18-Dec-97
38	Ms Mr	Jo Jim	Wearing Llewellyn	President Secretary	Wildlife Preservation Society of Queensland: Upper Dawson Branch		PO Box 262	TAROOM	QLD	4420	18-Dec-97
39	Mr	Steve	Mercer		Environment Australia		40 Blackall Street	BARTON	ACT	2600	18-Dec-97
40	Dr	Jon	Brodie	Director Water Quality Program	Great Barrier Reef Marine Park Authority		PO Box 1379	TOWNSVILLE	QLD	4810	19-Dec-97
41	Mr	Pat	Comben	Director	Wildlife Preservation Society of Queensland		1st Floor - 133 George Street	BRISBANE	QLD	4000	19-Dec-97
42	Ms	Robin	Healy		Wildlife Preservation Society of Queensland: Capricorn Branch Inc.		PO Box 263	YEPPOON	QLD	4703	19-Dec-97
43	Mr	R. J.	Heywood				PO Box 196	THEODORE	QLD	4719	19-Dec-97
44	Mr	Drew	Hutton		The Queensland Greens		PO Box 5763	WEST END	QLD	4101	19-Dec-97
45	Mr	Ray	Phelps			CU Rep. on LMG	PO Box 167	TAROOM	QLD	4420	19-Dec-97
46	Dr	Ngaire	Phillips				57 Seventh Avenue	WINDSOR	QLD	4030	19-Dec-97
47	Mr & Mrs	B.H. & J.M.	Smith				"The Brae"	TAROOM	QLD	4420	19-Dec-97
48	Dr	Roscoe	Taylor	Director Health	Queensland Health		PO Box 946	ROCKHAMPTON	QLD	4700	19-Dec-97

TABLE 1: **SUBMISSIONS: IAS DAWSON DAM PROPOSAL**

				Surveillance & Disease Control						
49	Ms	Jo	Wearing			WPSQ Rep. on LMG	North Dalziel	TAROOM	QLD	4420	19-Dec-97
50	Ms	Jo	Wearing			WPSQ Rep. on LMG	North Dalziel	TAROOM	QLD	4220	19-Dec-97
51	Mr	N. J.	Weldon	Chief Executive Officer	Taroom Shire Council		PO Box 21	TAROOM	QLD	4420	19-Dec-97
52	Mr	Shane	Ryan	Manager, Service Development & Planning: SW Queensland Region	Department of Families, Youth and Community Care		PO Box 876	IPSWICH	QLD	4305	22-Dec-97
53	Ms	Anne	John					ROCKHAMPTON	QLD	4700	23-Dec-97
54	Mr	Daryle	McPhee	Senior Project Officer	Queensland Commercial Fishermen's Organisation		PO Box 392	CLAYFIELD	QLD	4011	23-Dec-97
55	Mr	G.T.	Houen		Landholder Services Pty Ltd		13 Cottesloe Street	TOOWOOMBA	QLD	4350	30-Dec-97
56	Mr	Scott	Spencer	Executive Director, Resource Management	Department of Natural Resources		GPO Box 2454	BRISBANE	QLD	4001	

CU Cattleman's Union
CCC Capricorn Conservation Council
LAND Landholders Affected by Nathan Dam
LMG Local Management Group (for the IAS process)
NPRG Nathan Project Reference Group
RL Riparian Landholders
TDDA Taroom District Development Association
WPSQ Wildlife Preservation Society of Queensland

TABLE 2: CATEGORIES OF RESPONDENTS IN THE PUBLIC REVIEW PROCESS TO THE DAWSON DAM IAS

GOVERNMENT

Commonwealth	Queensland State	Local
Environment Australia (18/39*)	**Department of Mines and Energy (4)**	**Duaringa Shire Council (2)**
Great Barrier Reef Marine Park Authority (40)	**Department of Local Government and Planning (6)**	**Rockhampton City Council (10)**
	Main Roads Department: Rockhampton (7)	**Banana Shire Council (28)**
	Department of Primary Industries: Central Region (31)	**Taroom Shire Council (51)**
	Department of Environment (32)	
	Queensland Health: Public Health Unit, Rockhampton (48)	
	Department of Families, Youth and Community Care (52)	
	Department of Natural Resources: Resource Management Group (56)	

* *The numbers in brackets are the registered number for each submission as listed in Table 1*

Notes:
1. The Commonwealth Government submission (S18) from Environment Australia included comment from the Environmental Assessment Branch, the Great Barrier Reef Marine Park Authority, the Environmental Economics Unit, the Australian Heritage Commission, the Threatened Species and Communities Section, and the Wetlands, Waterways and Waterbeds Section. Submission 39 was provided by the Water Policy Section of the Sustainable Water Branch of Environment Australia, and was indicated as being complementary to those comments provided by the Environment Assessment Branch on behalf of Environment Australia dated 12 December 1997 (S18).
2. The separate GBRMPA submission (40) was also included in the Environment Australia submission

Thus, these three apparently separate Commonwealth Government submissions are considered as one for response purposes.

ORGANISATIONS

Conservation Groups	Land-based Groups	Water-based Groups	Political Groups	Academic Institutions	Consultants
Wildlife Preservation Society of Queensland (3, 19, 22, 38, 41, 42)	**Taroom District Development Association (9)**	**Ecological Water Alliance of Queensland (11, 17)**	**The Queensland Greens (44)**	**Centre for Conservation Biology, University of Qld (27)**	**Rob Hoare & Associates (1)**
Queensland Conservation Council (37)	**Taroom Shire Landcare (13)**	**Sunfish (23)**			**Landholder Services Pty Ltd (55)**
Capricorn Conservation Council (34)	**Taroom Coalition (21)**	**Aust. Marine Conservation Society (25)**			**Dr Ngaire Phillips, Brisbane (46)**

	Landholders Affected by Nathan Dam (35)	**Queensland Fisheries Management Authority (26)**			
		Queensland Commercial Fishermen's Organisation (54)			

INDIVIDUALS

Most Affected Landholders	Dawson Valley People	Others
GJ & GM Becker, "Spring Creek" (15)	**Sandy McCubbin, Theodore (12)**	**Emeritus Prof. John Holmes, Brisbane (5)**
John Gall, "Glebe" (16)	**Jack Baxter, Taroom (14)**	**Mark Morrison, Canberra (8)**
Donald Joyce, "Balcarris" (20)	**Adam Clark, Taroom (24)**	**Veryan Collyer, The Gums (33)**
BJ & JM Smith, "The Brae" (47)	**Deirdre Llewellyn, Taroom (29)**	**C. Greenaway, Dr E. Stock, Dr K Plowman, Red Hill (36)**
	Jim Llewellyn, Taroom (30)	**Anne John, Rockhampton (53)**
	Ray Phelps, Taroom (45)	
	RJ Heywood, Theodore (43)	
	Jo Wearing, Taroom (49, 50)	

III. RESPONSE TO SUBMISSION ISSUES

A. ECONOMICS

(S1, 3, 5, 8, 11, 13, 17, 18, 21, 22, 23, 26, 27, 28, 30, 31, 32, 34, 35, 36, 37, 38, 42, 43, 45, 47, 50, 52, 53, 55, 56)

There was extensive comment in the submissions on the economic analysis undertaken for the proposed dam development. Several aspects of the economic analysis were identified by reviewers as requiring more detail. The major concerns were reliability of the irrigation water and sensitivity of the performance criteria to movements in key input/output variables. Owing to the range of comment and the unfortunate occurrence of a mathematical error in the benefit:cost analysis which gave an inflated but still strongly positive benefit:cost ratio, the economic report has been revised and is made available with this Supplementary Report as Attachment 1.

Considerable capital was made of the mathematical error, but submissions failed to point out that the corrected benefit:cost ratio, cited in submissions from conservation organisations and associated interests at 2.28, remained an exceptionally high ratio which continued to indicate in some measure the economic attractiveness of the development proposal. However, far more attention should be paid to NPV values rather than to simple benefit:cost ratios. These errors have now been corrected in the attached revised Economic Report now designated as the Final Report, February 1998.

The issues raised in the submissions fall generally into the following categories:

- Methodology;
- Costs or benefits not considered;
- Assumptions used in the models; and
- The report and its presentation.

1. Methodology

The methodology adopted for the economic evaluation of the proposal was conventional benefit:cost analysis with sensitivity testing of key variables. This is the universally accepted methodology for this type of project and is consistent with the requirements of the Queensland Treasury Project Evaluation Guidelines (PEG). Furthermore, in response to an approach from the Resource Management Group, Department of Natural Resources for assistance in the review of the economic report, Queensland Treasury stated that. "*Overall, the methodology of the Dawson economic impact assessment is sound. The project demonstrates a net positive economic benefit, even after the inclusion of different externalities and assumptions cited by different public responses.*" (Queensland Treasury facsimile dated 12 February 1998.) The Treasury advice is given at Appendix 2.

Several reviewers considered that the economic analysis should have included some consideration of the distributional effects which relate to the differing levels of impact on different sections of the community. While such an analysis would certainly provide additional information to decision makers, it is not part of a benefit:cost analysis and is not required in economic analyses conducted in accordance with PEG.

Multipliers which measure the secondary or indirect effects of a project are not included in an economic analysis. This is because any construction project will generate activity, however this could also be generated by alternative uses of funds. Nevertheless, Government will consider regional economic impacts in its decision on the future of this project.

2. Costs and Benefits Not Considered

The PEG clearly sets out the manner in which project evaluations of capital project proposals should be conducted. The evaluation of the Dawson Dam proposal closely follows the prescribed process below:

Definition of objectives and scope: the services to be provided by the project are assessed and identified to clarify the purpose of the project. For the Dawson Dam proposal, a preliminary demand study had indicated that there was a very great need for additional water supplies in the Dawson Valley to meet the current and future needs of agriculture and industry which underpin the economic development and social sustainability of the Valley.

Identification and selection of suitable options: all realistic options, including the 'do nothing' option, should be identified early in the process.

For the Dawson Dam proposal an Appraisal Study had established that the most promising option for the provision of additional water supplies was a dam on the Dawson River upstream of Nathan Gorge. The storage created by the dam was to have a maximum full supply level of 185 m EL so that the town of Taroom, upstream of the dam, was not affected by flooding.

In reaching this conclusion, the economic, social and environmental implications of a large number of other options for water provision including dams, weirs and off-stream storages had been considered.

Having established that only a large dam was worthy of further consideration, detailed studies of the economic, financial, social, cultural and environmental aspects of a range of development levels for the dam were commissioned.

Economic analysis: this provides the initial default ranking for projects which may then be modified by analysis of the social and environmental issues associated with the projects. The PE Guidelines focus primarily on the economic analysis because it is usually the major element of a project evaluation in that it provides a means to rank projects in terms of the efficient allocation of resources.

Only direct primary benefits and costs which can be valued in monetary terms are included in the economic analysis. Often some notional financial measures will be available but the PE Guidelines recognise that the valuation of these may be excessively expensive and the results produced may be uncertain.

Environmental and social analysis: this analysis should identify whether there are any significant environmental and social impacts resulting from the project and if anything can, or should, be done in relation to those issues.

In general terms, the IAS will identify two types of inputs - those which can be managed and those which cannot. The final decision regarding whether or not Government will proceed with a project involves the consideration of a full range of impacts and information. In arriving at the final decision, Government will take into consideration the results from the economic analysis, environmental and social analysis, budget implications and regional economic impacts.

It may be seen from the above that, while the cost of intangible impacts, both positive and negative, have not been considered in the economic analysis, government in making its decision on the future of the proposal will certainly consider them. It should be noted that Queensland Treasury, in its response to DNR Resource Management (see Appendix 2) advised that costings provided by conservation groups for some environmental factors are unsubstantiated and that caution should be exercised when interpreting them. Treasury have also concurred that the inclusion of these factors would not make the scheme uneconomic.

3. Assumptions Used in the Model

Several submissions criticised some of the assumptions made in the analysis. Further justification of all major assumptions e.g. choice of cotton as the principal crop, establishment costs, key variables, has been included in the final (February 1998) Economics Report presented as an Attachment to this Supplementary Report. The analyst stands by the values adopted for key variables in the base case. These figures were based upon the best available information at the time of the study and were verified by the Department of Primary Industries, industry and growers. Furthermore, with several minor reservations, Queensland Treasury supports the assumptions made in the analysis.

The cost of $1,900 per hectare adopted for the cost of developing and establishing land for irrigation does not include the capital cost of plant and equipment. This cost has been amortised and included in the fixed costs of production. It is suspected that the cost of $4,000 per hectare suggested by some reviewers includes the cost of plant and equipment. To adopt $4,000 rather than $1,900 in the analysis would be double counting.

Concerns about the sustainability of the cotton industry, particularly in relation to the high resistance of *Heliothis* to insecticides assumes, perhaps rather short-sightedly, that advances in science will not proceed at the rate at which they have in the past. In any account, the break-even point for this project is well within the economic life assumed in the analysis. Anything after that could be considered a bonus.

4. The Report and Its Presentation

Some reviewers generally criticised the report and its presentation. Comments ranged from a lack of transparency through to arithmetical errors in one of the tables presented in the report. The author has responded to these criticisms by undertaking a redraft of the report which is included as an Attachment.

The comments below are highlights drawn from the redrafted Final Report (Attachment 1).

a) Reliability of the irrigation water

In order to increase the yield of irrigation water from a large dam, it is accepted that the reliability of delivery should be partially compromised. The optimal yield will mean supply failures in some years but not so many as to undermine the comparative advantages of irrigation. The reliability factor adopted for the Dawson analysis was 85%. This reliability is considered a practical ideal for agriculture as it effectively increases dam yield (compared to 100% supply reliability) while not overly diminishing the production advantages of irrigation. Reducing delivery reliability beyond a critical point however will force the economics of irrigation to fall and eventually equate with that of dryland agriculture.

A monthly reliability level of 85% means that the nominal monthly allocations for irrigation will not be fully met in 15% of months. The analysis accounts for this by using a weighted average approach. It is assumed that in two years out of three years, the full nominal allocation will be supplied and thus a full crop will be produced. In the remaining one-third of years, it is assumed that only half of the crop will be produced. Obviously operating costs will be reduced in years of lower or no production. Later in the analysis, the adoption of 85% water reliability is explicitly accounted for by factoring net farm income and benefits by 95%.

The tables below in the section dealing with 'sensitivity to variations in key variables' explicitly account for the use of 85% reliability.

b) *Sensitivity to variation in key variables*

This subject was addressed at length in the Economics Report, but further explanation and calculations are provided in the revised Final Report. Additional tables showing the sensitivity of net present value and benefit:cost ratios to three discount rates are provided as shown below.

The tables show the net present values and benefit:cost ratios for three discount rates and the likely combinations (defined by an environmental allowance of 10-30% of total yield). The results also reflect the fact that agricultural returns will be reduced in some years because of the 85% monthly reliability. As previously explained, this level of reliability has been incorporated by reducing the net present value of total net farm income and net benefits by 5%.

Net Present Values and Benefit:Cost Ratios at Three Discount Rates for Likely Combinations when all Commercial Water is Allocated to Agriculture and Explicit Allowance is made for 85% Supply Reliability

'Likely' Combinations	Net Present Values ($m)			Benefit Cost Ratios		
	Discount Rates			Discount Rates		
	4%	6%	8%	4%	6%	8%
6	249	171	113	2.73	2.30	1.96
7	226	157	106	2.84	2.41	2.05
8	190	130	85	2.30	2.27	1.92
9	168	116	79	2.41	2.04	1.74
11	182	121	76	2.13	1.79	1.51
12	136	103	52	1.93	1.62	1.37
13	136	89	54	2.02	1.70	1.43
14	125	84	54	2.20	1.84	1.56

Net Present Values and Benefit:Cost Ratios at Three Discount Rates for Likely Combinations when 35,000ML/year allocated to Urban and Power and Explicit Allowance is made for 85% Supply Reliability

'Likely' Combinations	Net Present Values ($m)			Benefit Cost Ratios		
	Discount Rates			Discount Rates		
	4%	6%	8%	4%	6%	8%
26	320	228	160	3.00	2.51	2.11
27	282	201	141	3.10	2.58	2.16
28	256	182	127	2.97	2.48	2.08
29	224	160	112	3.24	2.69	2.45
31	242	168	113	2.64	2.20	1.84
32	208	144	96	2.68	2.21	1.84
33	188	129	90	2.56	2.12	1.76
34	179	127	87	2.96	2.45	2.04

Note:
The 'likely' combinations in the above tables are drawn from the 40 possible combinations of water use, dam size and environmental flow (refer Attachment 1).

1-20	**All commercial water allocated to agriculture**	
	1-5	No allowance for environmental flow for 5 dam sizes
	6-10	10% of total yield allowed for environmental flow for 5 dam sizes
	11-15	30% of total yield allowed for environmental flow for 5 dam sizes
	16-20	50% of total yield allowed for environmental flow for 5 dam sizes
21-40	**Power generation included as the priority user of commercial water**	
	21-25	No allowance for environmental flow for 5 dam sizes
	26-30	10% of total yield allowed for environmental flow for 5 dam sizes
	31-35	30% of total yield allowed for environmental flow for 5 dam sizes
	36-40	50% of total yield allowed for environmental flow for 5 dam sizes

These results indicate that the Dawson Dam proposal has strong economic prospects, even after factoring in 85% monthly reliability of supply, using a discount rate of 8%, and relatively unfavourable combinations of environmental flow allowance and dam size (i.e., the bottom right hand corner of each table). Even at the maximum 50% environmental flow considered in the scenario, the economics of the proposal were viable. What were they?

The economic analysis was undertaken using a project life of 20 years. For long-lived assets such as dams, a longer period of analysis is acceptable under P. E. Guidelines. Using a 30 year life significantly increases performance assessment, e.g., the NPV of Case 1 would increase the net present value of the project by $112 million (Appendix 2, page 4).

Additional comments in the Final Report regarding the sensitivity of the results are as follows.

It is assumed the main crop grown will be cotton. This crop has a strong track record in irrigation schemes throughout Australia. Moreover cotton is already successfully established in the Dawson Valley, albeit on a relatively small scale. These background considerations mean there is little risk about cotton fulfilling expectations as prescribed by the project assumptions. As the project matures, it is likely other crops will be rotated. Net income figures (refer to Table 9 in the Final Report) suggest that crops such as cotton, peanuts, soybeans, mungbeans, sunflower and perhaps others, will readily substitute for one another as cost and price relationships change at the margin. Ultimately, the viability of the project will stem from the competitive advantage of irrigation over dryland farming rather the sustainability of one particular crop.

Will EMP cater for this? recycle of water + pesticides

In practice, for within-farm agronomic and economic diversification purposes, it is more likely that a whole range of annual crops will be grown. Tree crops such as grapes and citrus and even irrigated wood trees can utilise lighter soils and are desirable from the standpoint of regional diversification.

c) Development Costs

Several submissions commented on the figures used for 'cost of land development'. The figure used for 1st class flood irrigation land in the analysis was $2,000/ha. This estimate was developed in consultation with practising irrigation farmers of the *area and takes into account the existing state of the land likely to be irrigated.* A break-down of the $2,000 is shown below.

Land clearing	$200/ha
Survey and design	$20/ha
Levee construction	$100/ha
Land levelling	$450/ha
Tail drains and water return	$100/ha
Supply channels and head ditches	$130/ha
Water storage	$300/ha
Pump station	$580/ha
Pipes and control gates	$120/ha
TOTAL	**$2,000/ha**

Though the actual development costs could be refined further, Queensland Treasury, in its analysis of the economic methodology used by the consultant, endorsed the assumptions with only minor concerns. Their review pointed out that some assumptions stated in various submissions on environmental costs could not be substantiated. However, Treasury found that the project showed a net benefit even when these assumptions were used.

d) Resumption costs

Several submissions commented that there should be a detailed breakdown or disaggregation of the project capital costs used as input to the economic analysis. Public capital costs comprise the following components:

- the cost of construction of the dam;
- relocation, diversion, reinstatement of roads, power, bores, fences, yards etc;
- the cost of land resumptions (compensation for loss of land); and
- possible heritage (Aboriginal and European) consideration.

Of the above, only the first two may be estimated using established Civil Engineering estimating principles. The others are subject to negotiation and then only at such time as the project proposal becomes an officially approved project.

This being the case, the analyst must adopt some notional figure for use in the economic analysis. In the case of resumption costs, there are several ways in which some estimate rather than a guess may be made of the order of magnitude of the figures involved. This is because the basis of valuations for resumption purposes is known. The cost of heritage, in particular Aboriginal cultural heritage considerations, are, however, purely notional.

In any event, estimates of costs in this regard for use in the economic analysis are intended to be indicative only of allowances made for such purposes in the initial costings. Until the final design parameters have been decided more accurately, definition of structural and operating costs and other factors such as compensation cannot be assigned.

e) Equity

Submissions, and feedback during the extensive public consultation process which was an integral part of the IAS, indicated that there are many interpretations of equity. There are temporal considerations (i.e. intergenerational - related to the perception that the construction of the Dawson Dam will preclude the implementation of future storages upstream), and spatial considerations.

The latter may be intra-generational, inter-regional or inter-shire. These are related to the perception that those downstream of the proposed dam are profiting at the expense of those upstream by virtue of being in the right place at the right time. Other issues connected to this equity include the potential for Taroom Shire to lose part of its rates base owing to the loss of land. This is dealt with by negotiation at the time of a decision being made to proceed with the project.

Those who lose land directly under the impoundment or because of the construction are compensated directly. In this instance, compensation is intended to allow for the purchase of additional land adjoining, nearby or elsewhere, or to re-establish a new lifestyle depending on the individual's desires. Compensation cannot ever replace the severance of emotional attachments to the land but it has long been the only means available to deal with resumptions where greater public good is involved.

Downstream landholders may also benefit by an increase in land values to the extent that they may have access to water. This is to some degree offset by the need to purchase that water (payment of head charges) and annual fees for its use. Those who are not riparian to the impoundment or stream are not losing just because they perceive that others are gaining. Though they may not benefit directly, they do participate in the benefits of an improved regional economy which may be reflected in better infrastructure and services and improved access to markets.

The idea that the debts of current generations will be a burden for future generations is basically flawed at least in economic terms. This is simply because the recipients of any payments of future generations will, of course, be members of the same generation. The economics report thus spells out the upstream storage situation as being a trade-off between economic efficiency and social equity which is a decision for our elected representatives.

f) Full cost recovery principle

A few submissions purported that with a very generous benefit:cost ratio, there is a strong case for adopting the principle of full cost-recovery in the sale of water rights derived from the proposed dam. The full cost-recovery principle has nothing to do with the economic analysis required of an IAS to assess development options. This is a policy issue which is the province of the Government and the DNR.

B. UPSTREAM AREA

1. Buffer zone

(S6, 13, 15, 18, 21, 24, 25, 29, 32, 34, 35, 38, 45, 47, 49, 50, 55, 56)

The Terms of Reference clearly stated the need for the Consultant to assess the impacts of a buffer zone under social aspects of the environment by specifying an '*..assessment of the need for and extent of buffer zones around the proposed reservoir and an assessment of the impacts of the provision of such buffer zones (e.g. land resumption, fencing, stock access, water quality management)*' (see Main Report Appendices, Appendix 1, p 15, second dot point).

In preparing the initial project proposal and subsequently after being awarded the contract, the Consultant held discussions with the Principal to determine limits to the study area and the width of the buffer zone to be investigated. It was up to the Consultant to decide on both the need for and an appropriate width for any buffer zone around the impoundment. The study, therefore, set out to investigate the need for, an appropriate width and any management requirements which would be necessary should it be recommended. The **study area** was, therefore, defined for the purposes of the IAS as three components, namely:

- the ***impoundment area*** - which was the area to be inundated by the dam at the specified maximum FSL of 185 m EL for the original dam site at 313.9 km AMTD;
- the ***upstream area*** - an area within a radius of 10 km out from the 185 m EL contour including sub-catchments of all streams draining directly into the impoundment; and
- the ***downstream area*** - these are the riparian lands below the dam to the confluence of the Dawson River with the Mackenzie River north of Duaringa, which is the main potential irrigation area. (Main Report p 50).

As the IAS was limited by practical considerations, it was necessary to circumscribe an appropriate area to be investigated both as a buffer around the impoundment and the potential benefit area for downstream irrigation. With no guidelines established, the area investigated could have been as little as a few hundred metres or as much as the total catchment area above the dam wall, and it was simply a matter of selecting an area which would capture most data relevant to a rational evaluation of impacts. This accords with the general requirements of an IAS in looking at the broader issues and areas of likely impact. Accordingly, a 10 km zone out from the maximum FSL was selected based primarily on the understanding that 10 km is a sufficient distance for natural dissipation of the impacts of most potentially adverse land uses which may lead to unmanageable consequences for the storage. As stated in the main report (p 63) '*...The selection of a 10 km radius implies no intent for resumption, imposition of land use controls or other restrictions on current land use activities.*' Thus, most effort was applied to assessing soils and land use within this area to assist in evaluating the need for a buffer zone and in developing any subsequent EMP.

Where used as a management tool for water storages, buffer zones provide a mechanism for the water managing authority to control land use activities within the area which could adversely affect water quality or the operation of the storage in some manner. These activities could include urban, industrial, recreational or rural pursuits which may cause serious erosion or the generation of waste streams which could enter the storage and impact on water quality. The buffer zone concept, where the DNR, under the Water Resources Act 1989 can gazette a Declared Catchment Area, is most frequently (but not exclusively) applied to storages used for domestic water supplies. Declared Catchment Areas may also be instituted in major irrigation scheme areas or in catchments of particular environmental sensitivity. This enables the DNR to apply land use controls and renders the DNR responsible for managing land use in the contributory catchment. Such a course of action is high cost and only warranted in special circumstances.

A preferable mechanism is to use land use controls which already exist in Shire planning schemes which cover the area under consideration, and through the Environmental Protection Act (EPA) which applies strict Licence conditions for Environmentally Relevant Activities (ERAs) for those pursuits which could adversely impact on the environment. In future, co-ordination of such approvals will lie with the Integrated Planning Act due to be promulgated in March 1998. At the time of undertaking the IAS, the Taroom Shire Plan was in the process of being prepared. The Town Plan, through its zoning provisions for both As of Right and Consent Uses, provides an adequate level of protection for controlling land use when supported by provisions of the EPA. No additional formal land use controls were, therefore, considered necessary provided land use complied with these relevant measures. These Town Plan provisions apply across the whole of the Shire and all landholders are obliged to operate under them unless they are amended or conditional use is allowed for specific applications. It is not proposed that any additional controls be placed on the fringing properties that differ from those applicable across the Shire unless future events prove this approach to be unsatisfactory.

WQ [illegible]

From an agricultural land use perspective, current forms of land use were not regarded as of particular concern. The majority of the catchment above the dam is used for grazing with some irrigated and dryland cropping. Dryland cropping is greatly limited by the reliability of rainfall and fertiliser use is limited. However, the introduction of large scale irrigation has elsewhere led to the increased runoff of nutrient-rich waters and the dispersal of agricultural chemicals into storages through both spray drift and runoff. With the likely introduction to the district of cotton, a crop which has in the past been particularly associated with such problems, it was considered that some controls might be necessary to prevent adverse environmental impacts. A strategy was recommended which required all applications for new water allocations to demonstrate that (i) the area proposed for irrigation on the property actually comprised a sufficient area of soils suited for sustainable irrigated production, (ii) that zero discharge systems would be implemented to prevent runoff and tailwaters entering the stream and (iii) that a whole property management plan would be prepared as part of the application. These steps, supported by the general trend in agriculture towards best management practice were considered sufficient to prevent adverse land use impacts. The draft EMP went on to recommend that a program of water quality monitoring, both in-stream and groundwater, be implemented to detect the early onset of change so that steps can be taken to reduce and manage the impacts.

The combined strategy of using the existing provisions of the Town Plan, the EPA and the property management plan which controlled the supply and use of water for irrigation was considered to be an effective means of preventing environmental impacts and protecting the impoundment. Given the significant concerns expressed by those above the dam in Taroom Shire regarding social equity, it is not considered feasible to introduce any system which would limit present land use or constrain future land use for irrigation by imposing conditions which are more stringent than those which apply to downstream beneficiaries. Continued grazing and irrigated/dryland cropping using best practice farming techniques, zero discharge irrigation layouts and sustainable stocking rates matched to land types were considered sufficient protection for water quality maintenance in the impoundment (S56). Therefore, there was no need for a buffer zone around the storage. This was unequivocally stated in both the Conclusions (p 276) and the Executive Summary (p A).

Nevertheless, should this approach be found over time to be ineffective, the potential remains for DNR to declare a Gazetted Catchment Area. This requirement was considered as only a last resort and not a first stage need. Should it be required, however, the report proposes that it need concentrate only on gazettal of an area some 10 km out from the maximum FSL to achieve desired outcomes. This was the intent of the discussion in *Section 6 Strategic Planning* on p 204 and *Section b) Gazetted Catchment Area* on p 218 of the Main Report.

Compensation

Width?

Mention was also made in the text (i.e. p 203, 203) to the use of an appropriate 'buffer' zone between the "*... top of the Dawson River levee and the adjacent irrigated area within which no cultivation will be permitted.*' These references should in no way be interpreted as related to the above discussion. Here, the 'buffer zone' refers to a margin of uncultivated land which is intended to act as a soil conservation measure to prevent erosion of the cultivated land and the levee/streambanks. It would perhaps be better to consider this as a grassed or timbered strip to avoid confusion with the term 'buffer'. It would also serve the purpose of catching and filtering any runoff and entrained nutrients from the paddock should the tailwater drainage system designed as part of the zero discharge requirement be breached. It would also prevent such tailwater drains being located along the top of the levee as in flood zones, levee systems are dynamic and could be affected by streambank erosion and thus fail.

2. Management of impoundment

(S3, 11, 13, 18, 21, 22, 24, 25, 32, 34, 35, 37, 38, 47, 50, 51, 56)

a) Easement

Though no buffer zone is considered necessary, the acquisition of an easement of up to 200 m in width by DNR was a recommendation of the report (p 217, p 276 and p A). This easement would surround the perimeter of the inundated area and allow access by the storage managing authority to all parts of the storage for the purposes of weed, fire, feral animal and regrowth control as well as for monitoring of the water levels and the implementation of the EMP.

As the investigations found no reasons to prevent the continuation of the existing land use practices on properties fringing the impoundment, it was considered that grazing could continue to occur up to the storage margin. As the margin will fluctuate depending on the level of water in the dam, this will result in a significant area of land which will periodically become available for grazing. The strategic use of temporary electric fencing, or more permanent fencing such as is used at Lake George in NSW, could effectively extend the area available for grazing. Because of this moving margin, the actual easement area is really only needed at periods of maximum storage and as a formalised area to be included in resumptions during the compensation process to ensure that access for DNR can be obtained at full storage.

Grazed wildlife corridors?

The actual width of the margin can only be defined at specific sites once the FSL has been determined and the final margin survey been conducted. The width is expected to be highly variable depending on landform, the nature of the land use fringing the impoundment at a particular site, the presence of impediments to movement (i.e. deep, steep-sided creek crossings etc) and a range of other features. In places, where revegetation is required to re-establish wildlife corridors, it is probable that this will occur within the easement so as not to impact further on adjacent landholders.

Factors such as use of the margin for grazing, access for fire and pest control, corridor re-establishment and general management of the storage are the basis of recommending the acquisition of an easement up to 200 m wide around the impoundment and for permitting the continued use of this area for grazing.

Extending cultivation into the easement area or the retreat zone of the storage, however, is not recommended owing to the probability of loss of crop should the dam fill prior to harvest. There would also be an increased potential for erosion on fallow land and loss of infrastructure if the area was set up for irrigation. Cropping in this margin would likely increase the direct movement of nutrients to the storage and contribute to blue-green algal risks. Cultivation of this area is, therefore, not recommended. This is in line with DNR policy not to use such areas for cropping around other storages in Queensland. Silt deposited in this storage margin area during periods of maximum inundation is not expected to differ in any way from that which normally occurs under natural floods at present.

Mandatory?

There will be no need for a wide (or perhaps any) easement where the impoundment lies near the residential area of Taroom. At this point, the majority of the storage is within banks and in any event full storage in this area will occur for only a short time owing to retreat under drawdown and evaporation losses. Nevertheless, the margins around the impoundment and within the FSL near the town will still be subject to the same management inputs for weeds, fire and feral animal control.

b) Weed, fire, feral animal issues

Within the easement, DNR will be responsible for management of all issues such as weed, fire, feral animal and other forms of control. This responsibility may be contracted out or other arrangements made under the terms of the EMP. The easement, which lies above FSL, and the zone of fluctuating margins of the storage are obvious sites for potential weed infestation. The means of control will be specified in the final EMP and this will include defined monitoring and preventative programs, as well as action plans for outbreaks. Similarly, the management of feral animals and fires will be specified in the final EMPs..

In flood prone areas, regrowth of Coolibah can often be a farm management problem in both grazing and cultivation lands. Coolibah regrowth in the easement and along the fringes of the impoundment, if managed properly however, could assist in re-establishment of riparian vegetation and wildlife corridors, though its survival may be dependent on the frequency with which the FSL is attained and maintained.

c) Fencing

It is not anticipated that the easement will be fenced (except perhaps at critical sites for, say, the purposes of preventing stock access to the storage on steep banks or highly erodible places). Fencing would only impede the use of the easement and the impoundment margins for grazing and would be extremely expensive both to install and maintain.

Concerns raised by landholders regarding stock bogging in the clay soils as the waters retreat can be allayed by the strategic placement of watering points and the progressive training of stock to their use. This approach has been used successfully elsewhere such as along parts of the Mary River catchment.

It is highly unlikely that fluctuations in the dam will be of short duration (i.e. up and down over short time frames) so that in most instances, the storage will replicate the current natural flooding sequences of rising and falling waters with an extended period of inundation. If cattle are accustomed to accessing water at permanent troughs above the maximum FSL it is unlikely they will walk into boggy conditions for water any more than they currently do. Establishment of such watering points if necessary is rightly a matter for compensation negotiations with affected landholders.

It is neither feasible nor economic to fence the whole perimeter of the impoundment and there are no precedents for this. It should be noted that the existing properties do not fence off all frontage land as such areas are currently viewed as valuable grazing land as well as providing cattle with access to water. Normal stock management practices, the fencing of critical areas including property boundaries, and the judicious and strategic location of new watering points are seen as sufficient means to control this zone of the impoundment.

d) Rehabilitation

Following any clearing and construction activities associated with the dam construction including sand and gravel stockpiling, timber salvage and habitat reinstatement, there will be a need for rehabilitation in the easement and around the impoundment margins.

This will constitute part of the contractor's contract established with DNR and the requirements will be clearly specified in the EMP relating to the construction and operation phases. The means by which this work will be undertaken will be largely dependent on the contractor but it would be logical to offer such work to local residents as there will be an ongoing need for maintenance into the establishment phase of the revegetation program.

e) . Riverine corridor

The riverine corridor is important for both movement and habitat of fauna. The construction of the dam will flood some riparian vegetation and create further breaks in the riverine corridor. It should be nóted, however, that this corridor is in no way intact at present and that significant parts of the riparian vegetation comprise regrowth communities which may differ in composition from the original communities at that site.

The IAS recommends the re-establishment of this riverine corridor associated with the impoundment area. The report does not deal with the need for this issue to be addressed along the whole river as this is not a function of the dam but rather the province of individual landholders and community interests. It is worth noting that although the Tree Clearing Guidelines recommend that 150-200 m wide corridors are left alongside major streams, there is much of the Dawson River at present which does not meet this criterion. The conditions of the WAMP will also ensure that no flow regimes are established that will adversely impact on the existing downstream riverine corridor.

The Consultant believes there is sufficient evidence to demonstrate that given time and appropriate effort and funding that re-establishment of vegetated corridors can be achieved. Of course, this would not be a riverine corridor as the river is effectively covered by the impounded water. Nevertheless, the riparian vegetation around the margins of the storage, once established by both natural means and human intervention, will perform the same function as the riparian vegetation to be removed by the construction of the dam. The earlier it is started the better the chances of relocation of fauna and the greater the reduction of adverse impacts. Recolonisation may occur naturally but this is likely to be a much slower process than where facilitated by replanting and the shifting of hollow trees for habitat to replace the loss of old growth trees. The Consultant has proposed that appropriate funding be provided by DNR through the contract and that local community groups be given the opportunity to participate in the design, implementation and maintenance aspects of this program. This would be one way of providing local employment opportunities as discussed under the social issues in the IAS report. It is noted from some submissions that some local environment groups have stated that they would not assist in such programs.

In most cases the corridor would be established within the easement and thus be the responsibility of DNR, though contracts could be let for its maintenance. Wherever possible, the corridor would connect up any remnant vegetation communities though as shown in Map 18 there are significant areas where no timber cover exists at present owing to past clearing and development for pastures and cropping. Adjacent landholders would have the opportunity to complement this revegetation process and improvement in habitat by extending the timbered area onto their properties if they so chose.

Decisions on the most suitable approach depend on the final FSL should the dam proceed and planning could only commence once such a decision was taken. The IAS report recommended that the most appropriate area for revegetation was along the northern side of the impoundment as this would connect up the Lake Murphy wetlands with the Nathan Gorge while utilising Palm Tree Creek which still retains much of its riparian vegetation. The Consultant acknowledges that there is no reason why a similar revegetation program should not apply to the southern margins of the impoundment. An access track would be required along the whole length of the corridor to allow its continued use by DNR for maintenance activities. Gaps would also be necessary on properties to permit the use of the impoundment margins for grazing as the water levels retreat.

f) Noxious weed management

(S 13, 21, 24, 47, 50, 56)

Concern has been raised about weed management in the impoundment area, particularly with respect to Parthenium. This report has already discussed issues relating to management of the easement around the storage. Responsibility for this lies with DNR and a formal strategy will be established in the final EMP for the operational phase should the dam proceed. Actual management of weed control may be contracted out to the Taroom Shire Council or to a private operator but liability vests with DNR.

It should be noted that Taroom Shire is a Parthenium-free zone and protocols exist to ensure that this remains so. The Shire has implemented a plan for regular patrols and spraying to manage any roadside outbreaks caused by passing traffic.

EMPs for the construction phase will specify vehicle washdown requirements and the need for other protocols to ensure that Parthenium is not brought into the area on equipment or materials, or that any outbreak attributable to the construction will be remediated immediately. The responsibility for this would lie with the Site Environmental Officer.

It was recently announced that Taroom was to receive funding to construct a washdown facility, and this, together with any facilities established as part of the construction camp, will constitute the basis of the quarantine facilities against seed introductions.

Other noxious weeds may also be translocated downstream during floods and establish in the impoundment margins as the storage retreats. These will also be dealt with as part of the weed management EMP. Comments in the IAS regarding the potential for Coolibah to attain 'weed' status were dismissed as nonsense in some submissions. Nevertheless, it has been the experience elsewhere on floodplains that after floods retreat, Coolibah can establish prolifically and invade cultivation/grazing areas in sufficient densities to impede flood flows, cause significant erosion problems and impact adversely on farm management. Any increase in Coolibah establishment within the impoundment at periods of low storage will also need to be managed.

3. Salvage of timber and gravels

(S56)

The IAS referred to the salvage of useful timber prior to inundation, but omitted to comment on the salvage of sand and gravels for future use in the Shire. Stockpiles of sand and gravels sourced from within the impoundment area would be created in a designated area for future use for local infrastructure development and maintenance.

C. LAND USE

1. Concerns about incorrect mapping

(S15, 16, 20, 21, 35, 45, 47, 56)

The landscape units mapped during the study are based on land systems identified by CSIRO as part of a large regional mapping study (CSIRO 1968) where land systems were identified and mapped at 1:500,000 scale approximately. Land Systems are defined as '... areas of similar soils, geology, landform and vegetation...' These provide a conceptual mechanism for describing extensive areas of land with quite complex characteristics in a simple way that conveys a high degree of meaning to the user. For example, many people would feel quite comfortable talking about the 'Brigalow Lands' but individual perceptions about just exactly what these would include would vary from place to place and individual to individual. The Land Systems approach attempts to bring a higher level of order to such general usage by defining areas in more detail in terms of landform, vegetation, soils, geology and other easily recognisable features.

Land Systems, thus, are used in a regional sense to describe extensive and often non-contiguous parcels of land with more similarities than differences. Land Systems comprise a series of Land Units which allows the surveyor to describe the soils, vegetation and other features for distinctive segments of the landform, i.e. a typical slope from crest to valley floor would comprise valley floor; lower, mid and upper slopes; and crest units which may have different soils and other attributes though they are all related and always occur in association. For any given Land System it is possible to estimate the approximate proportions of each Land Unit which occurs in the Land System. These proportions are based on the total occurrence of the Land System across the region and may not reflect the proportional distribution of the Land Units in every particular site.

For example, a *Land Unit x - Lower slopes* may occupy 20% of the whole Land System for the whole region where the mapping was undertaken but on an individual property could have a greatly different percentage occurrence of a specific land unit. It may, therefore, appear to those not accustomed to using the Land System approach to describing land that there is a mapping error when in fact there is not. It is this type of problem which has occurred in relation to the above submissions. The details are described below.

There are two main Land Systems involved, Narran and Woleebee, but for the purposes of this discussion, examples will be drawn only from Narran. There are ten Land Units within Narran as set out in the following Table (these are summarised from the original table in Speck *et al.* 1968).

Land Unit	Area %	Landform	Soils	Vegetation
1	15	Gentler crest slopes on weathered rock	Moderately deep to deep cracking clays	Softwood scrub
2	10	Steeper crest slopes on weathered rock	Shallow texture contrast soils	Softwood scrub with brigalow
3	35	Crest slopes on sandstone; up to 10% but mainly less than 5% and 1 mile) in extent; sandy surface with pebble-cobble patches and local rock outcrops	Shallow to moderately deep texture contrast soils with a fine sandy surface over sandy or silty clay	Tall eucalypt forest with variable amounts of Cypress, moderate shrub layer and moderately dense forest grass
4	5	Stony mid slopes	Very shallow sandy clay loams and clays	Brigalow scrub with blackbutt
5	5	Hill slopes; up to 80% and less than 0.25 mile long with vertical faces locally; boulder covered outcrop surfaces	Outcrop with pockets of shallow sand	Semi-evergreen vine thickets with emergent bottle tree and eucalypts
6	5	Erosional lower slopes	Shallow to moderately deep texture contrast soils	Silver leaved ironbark grassy woodland
7	15	Colluvial slopes in upper sectors	Deep to very deep cracking clays	Brigalow scrub with wilga, sandalwood and locally belah
8	5	Colluvial slopes in lower sectors	Deep texture contrast soils	Poplar box grassy woodland with sandalwood
9	<5	Drainage floors	Deep texture contrast soils	Poplar box grassy woodland
10	<5	Channels; mainly up to 50 ft wide and 10 ft deep	Bed loads silt and sand	Fringing vegetation

From this table it can be seen that the largest unit (35%) is dominated by eucalypts and on this basis it has been referred to as Eucalypt Highlands. In fact, some 50% of the Land System can have various units of brigalow and softwood scrub occurring in association with each of these units occupying a smaller proportion of the Land System (5 - 15%). Nevertheless, the Land System has been characterised as a Eucalypt unit and for the purposes of evaluation, land use properties have been assigned on this basis. This may introduce errors on an individual property but at the larger regional scale, the Land System is an appropriate means of dealing with spatial information. It is appreciated that these apparent errors have caused some concern for the individual landholders. But owing to the limitations of time available for field survey, it was not possible to investigate every part of each property and as a result, the earlier Land System mapping of Speck *et al.* (1968) was used as the basis of all maps.

Similarly, as in the case on *Spring Creek*, Land Systems referred to as Softwood Scrub Uplands are dominated by softwood scrub but also include components of brigalow scrub. Another consideration is that at the scale of mapping, boundaries between Land Systems on the maps may be displaced from the actual boundary on the ground by several hundred metres.

This level of mapping, which is appropriate to an overview study as was required for the IAS, may lead to slight errors in individual instances at a property scale where land use recommendations such as stocking rates or cropping suitability are applied to the Land System as a whole. Stocking rates for the units were obtained from discussions with landholders during the field work. While the recommendations are true for the regional extent of the Land system, they are not strictly accurate for individual properties where perhaps only one of the component Land Units with a higher land use potential dominates. This situation will be identified and rectified during a more detailed property survey which would necessarily be undertaken as part of any final compensation negotiations. This detailed acquisition of data at a property scale would be supported by DNR should a decision be taken to build the dam.

Land use attributes attach to soils and landform though, and in the particular cases referred to in the submissions listed above, the land use and productivity would appear to belong to the brigalow clay soils in at least some proportion.. One of the problems faced in the field survey and aerial photography interpretation for the IAS . was the extent of clearing in the area which had removed vegetation communities as evidence of soil changes. Detailed field investigations would be necessary to ascertain the exact boundaries and time was not available for this level of mapping. In these instances, reliance was placed on boundaries delineated in the CSIRO report as they were based on earlier photography and detailed field survey. Some corrections were made where obvious errors were identified in the original mapping. For example, a significant area of Eucalypt Floodplains not previously mapped was delineated. In the case of Balcarris and Spring Creek, the area considered to be incorrectly mapped is a brigalow unit within a Land System characterised as predominantly Eucalypt by the classification.

As detailed in a response by DNR to all landholders following the LMG and public meetings in November 1997, the maps contained in the IAS will never be used as a basis for compensation negotiations as they are at inappropriate scale for such determinations. At this stage, detailed property mapping at scales of approximately 1:25,000 will be undertaken and a more exact delineation of all soils and their productivity/land suitability will be documented.

From this, the Consultant suggests that there are no significant errors in the mapping at the scale at which the data are presented. Apparent errors relate to the occurrence of component Land Units which exist in the Land systems but in particular instances may dominate at a specific site. Such anomalies would be identified during subsequent detailed surveys undertaken as part of the compensation process.

Concern was also raised regarding the incorrect delineation of part of a sub-catchment upstream of Taroom (S45). The Consultant acknowledges this error but as it has no impact on the overall IAS outcomes, no changes will be made to the maps. It should be noted that again this has resulted from problems with the mapping scale of data available for use during the IAS. The sub-catchments were generated using contour information from published 1:100,000 scale Topographic Maps. The contour interval is insufficient to allow accurate definition in alluvial parts of the landscape where only minor elevation differences can form divides between catchments.

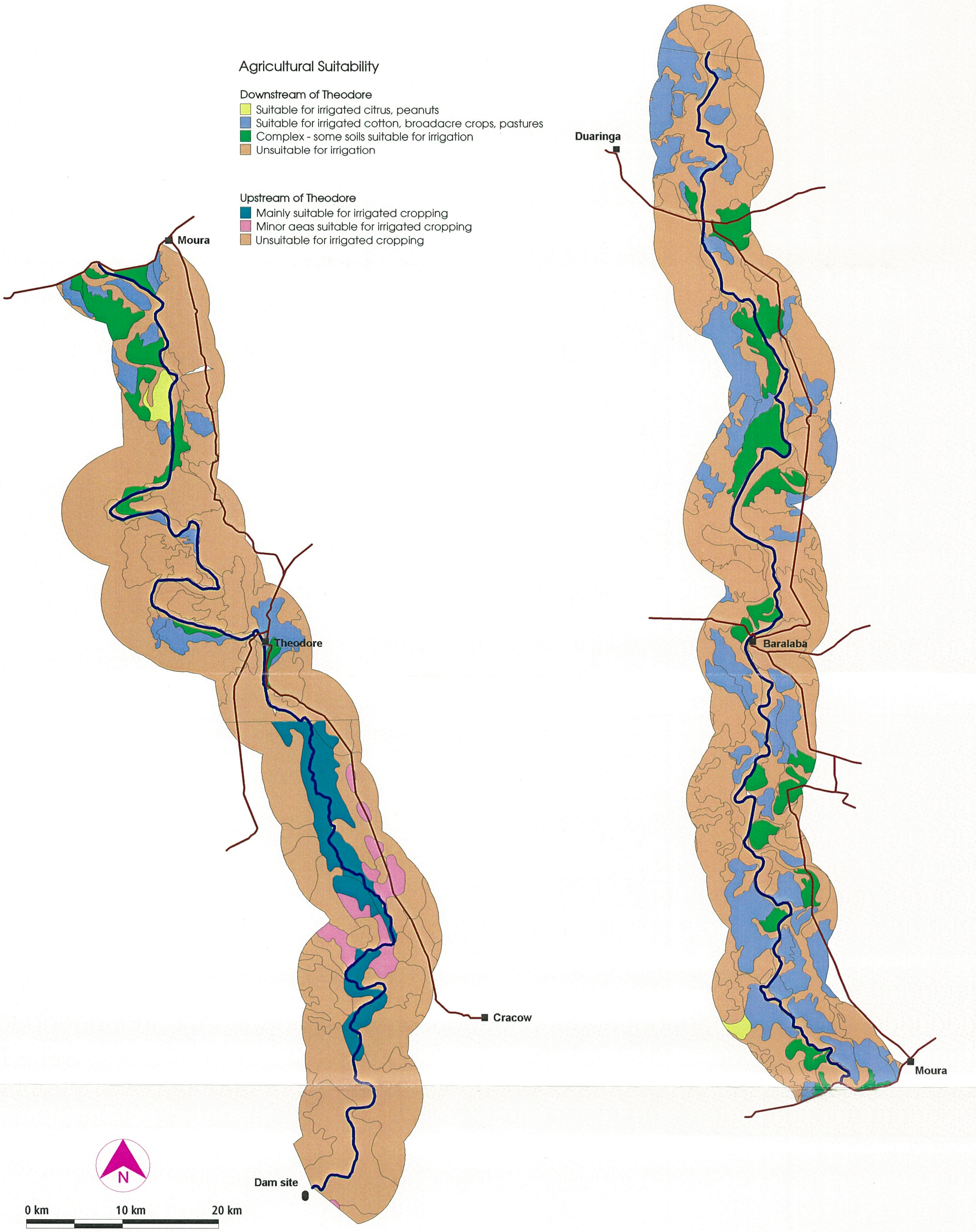
One submission questioned the missing section of agricultural suitability data between the dam and Theodore. The attached Map replaces Map 14 in the main report.

2. Land degradation

(S 13, 20, 22, 25, 35, 36, 37, 38)

The Main Report, page 74, Section D3a states that pasture growth (in the upstream area) may mask significant land degradation and consequently indicated caution should be used in interpreting land data in the area. One submission considered this statement indicated the Consultant's bias. The section refers to the degree of land degradation being directly related to the landscape units. On landscape units with light vegetation cover, the degradation is clearly visible. Some degradation on such units does occur in the upstream area (and downstream) and is clearly evident in aerial photography and the Landsat imagery. On other landscape units where there is a dense pasture cover, degradation might occur but would be masked by the pasture and not readily seen (from aerial photography). Such degradation could be assessed only by a detailed ground inspection, something which was physically impossible to do over such a large area in the allotted time. The section states for example that "There was no evidence of land degradation on the Eucalypt Floodplains..." but in view of the denser vegetation on such landscape units, it is entirely appropriate and scientifically responsible to insert a caution that such findings "...must be interpreted with caution in the light of those circumstances."

One submission expressed concern that statements regarding the extent of gully and stream erosion in the eastern portion of the study area as derived from Map 10 were incorrect. This information was determined from an assessment of the digital data on screen and not from the map at the scale at which it was presented in the report. It would be inappropriate and professionally negligent to evaluate data on such a reproduction given the quality of colour photocopying. Band separation on the imagery is sufficiently definitive to permit accurate determination by a competent resource specialist accustomed to evaluating Landsat TM imagery. Reflectance patterns observed in this band could only be derived from bare land and this was ground-truthed across the survey area.



MAP PREPARED FOR HYDER BY
Land Resource Assessment and Management Pty Ltd

LR A&M

REPLACEMENT MAP FOR ORIGINAL MAP 14

DAWSON DAM IMPACT ASSESSMENT STUDY

DOWNSTREAM

AGRICULTURAL SUITABILITY

27/02/98

A3-502278/A RSC MR14

Hyder Consulting

REPLACEMENT MAP 14

The independent soil conservation expert quoted in S 35 could not reasonably draw his conclusion without viewing the original data and without a commensurate level of experience as the land resource specialist used in the IAS.

There is a long history of land degradation in grazing and cropping lands throughout Australia and this part of Queensland is no exception. Over the years, a significant implementation of soil conservation measures has been achieved in the district but this has not noticeably reduced the amount of soil loss as reflected by the continued high turbidity in the river. It is also worth noting that historically, the river has carried high levels of sediment as evidenced by the extensive alluvial plains which fringe the river for much of its length. Indeed, the large areas of alluvial clay plains which will be flooded by the impoundment have been deposited above the gorge over a long period during flood events which have moved large volumes of sediment caused by erosion in the upper catchment. This process is continuing though in places it may be less obvious where gully infilling has occurred owing to the entrapment of sediments in dense pasture. Nevertheless, there is still a net movement of soil from sheet and gully erosion in the catchment and this was reported in the IAS accordingly.

3. Soil suitability

(S31, 35, 42, 56)

It was necessary to establish limits for the downstream area to be assessed for irrigation potential. Based on the preliminary figures for likely yield, only some 30,000 ha could be irrigated in addition to that currently under irrigation. This was estimated using an average irrigation requirement of 6ML/ha for the range of crops considered and the maximum 85% reliability yield supplied by DNR. This figure is an accepted usage rate for irrigation based on supplementary irrigation and has been widely used in Queensland studies. It is acknowledged that there are yield losses associated with on-farm distribution which would reduce this irrigable area but such losses are difficult to estimate at this point given the different soil types and differing levels of management efficiencies involved for individual properties (S56).

As no irrigation scheme involving channel or pipeline distribution systems was being considered by DNR, water would only be made available for riparian users or perhaps for small private group schemes. It was considered highly unlikely that water would be taken more than five kilometres from the Dawson River under such circumstances given the high costs of pumping and distribution systems. Therefore, a distance of 5 km either side of the centre line of the Dawson River was selected as an envelope within which detailed investigations into soil suitability and land use constraints would be confined.

Within this envelope downstream of Theodore, some 56,920 ha were identified as suitable for sustainable irrigation land use. Further work (see Replacement Map 14), based on an interpretation of Land System data for the area between Theodore and the dam site, an additional 9,370 ha have been identified as suitable for long-term irrigation use. A further 4, 105 ha are mainly unsuitable or marginal for cropping but within these units, some areas of suitable soils will occur which cannot be delineated at the scale of mapping. This gives a total area of 66,290 ha deemed suitable for sustainable irrigated production.

This envelope, therefore, contains considerably more than the 30,000 ha approximately which could be irrigated and was, therefore, regarded as an adequate base for assessing impacts for the study. Estimates of the area of suitable soils within this envelope greatly exceeded the area which could ever be irrigated by the water available should the dam be built. Thus, though the Consultant acknowledges that more detailed individual property surveys would significantly refine the actual area irrigable (S56), this was not considered important given the continuing uncertainty regarding the amount of water available until completion of the WAMP. It should be noted that detailed survey could even further increase the area deemed suitable but that any reduction in area determined suitable would have to represent a mapping error greater than 50% to reduce the suitable area below the 30,000 ha required.

It is inappropriate to interpret this 5 km envelope as indicating a recommendation on the part of the Consultant that a continuous 10 km wide irrigated cultivation zone would fringe the Dawson River downstream of the dam. Significant areas are unsuitable for either irrigated or dryland cropping and large areas are used for pastoral purposes. Additionally much of this zone is already developed for both irrigated and dryland cropping and in many instances, marks the extent of the more favoured alluvial soils. On both soil suitability and economic grounds, this zone was considered an appropriate area to define the investigation.

All references in the IAS to the potential area of land suitable for irrigation in the downstream area are estimates only as is obvious from the way in which these figures are derived. Nevertheless, considerably more than this area is available, so it is not considered necessary to refer to it as an estimate. It should be noted that the IAS report does not state that this is a contiguous area, though in the Moura to Theodore section of the valley there are significant large areas of single occurrence.

4. Other water use options

(S3, 13, 17, 25, 32, 34, 42, 56)

The study canvassed other water use options as a means of achieving water use efficiency and reducing environmental impact. The soil suitability investigation recommended which soils were suitable for which type of irrigation application. This related specifically to the use of furrow (flood), spray and trickle irrigation systems.

Flood irrigation is the highest water user and is most frequently practised on the level or nearly level floodplains adjacent to the major streams in the Dawson Valley. Land levelling is generally required to achieve designed flow rates. The Consultant has also pointed out that this system has the greatest potential for water loss both through evaporation and groundwater leakage. Nevertheless, system designs are now available where flow rates, furrow slope and length can be adjusted so that deep percolation losses are minimised. It would be appropriate for DNR and DPI to conduct awareness workshops for the farming community to apprise them of this technology.

The IAS report stated that though the technology existed for broadscale use of trickle systems, little was known about its suitability for application on large properties. In spite of the work conducted in the valley on farms up to 29 ha (as quoted in the Comet Dam IAS report), the Consultant still believes that the application has not been proven yet for farms of several hundred hectares and that it is not simply a matter of scaling up the smaller systems. While the Consultant would prefer to see such systems widely applied on both environmental and water use efficiency grounds, it would appear that it is still some way off at this stage. Trickle irrigation may not reduce the total amount of water used as the water application efficiency achieved can be redirected to increase the area to be irrigated.

Spray irrigation is considered suitable for some soils and crop types but not applicable for all situations. It is a more expensive system for large scale production than flood irrigation and requires a larger labour component. It has application for some horticultural crops. It is also suitable for grain crops and pastures/pasture seed under large centre pivot systems.

The advantage of spray and trickle systems is that it is easier to control water application rates than it is with conventional furrow systems. This may not be an issue with the new furrow technology.

5. Loss of land

(S13, 16, 21, 47)

Concern was expressed about the valuable agricultural land which would be lost through inundation above the dam. This is acknowledged in the IAS report as a normal consequence of the construction of any large storage. As alluvial soils are often the most valuable lands for both cropping and grazing, it is inevitable that they will be the first to be lost through flooding. In undertaking an impact investigation it is important to determine whether the area available for irrigation represents a net gain over the loss of lands under the storage. If this were not the case, it is probable that the proposal would be uneconomic and environmentally irresponsible.

The IAS found that approximately 4.4 ha could be brought into irrigation for every hectare of irrigable land lost under the storage. This was found to generate sufficient economic benefit and that the environmental impacts would be manageable.

6. Capacity of floodplains to absorb nutrients

(S27, 31, 56)

Concern has been expressed regarding the ability of the floodplain to absorb the additional nutrients and agri-chemicals applied and not contribute these in runoff to add to the potential for blue-green algal outbreaks in the stream. There are several major soil types on the floodplain with differing P-sorption capacity and, without detailed soil investigations, it is not possible at this early stage to make meaningful quantitative estimates of the likely impact. Similarly with nitrogen fertiliser, there is, as in all agricultural areas, potential for excess nitrates to leach down the profile and enter the groundwater. Groundwater monitoring to date in the downstream area has not shown significant increases in nitrate levels after more than 30 years of extensive irrigation and dryland cropping. — previously said this was small.

The approach used in the IAS to avoid any impact from the new areas to be irrigated is to use effective controls through the water application process (i.e. no water to be supplied to unsuitable soils and an LWMP required to demonstrate sustainability) and through the application of best practice management. Though several reviewers have doubted the ability of farmers to adopt best practice technology, the Consultant contends that such farmers will become unable to compete in the market place if they do not adopt such practices. The need for *clean and green* crops and their products will set market standards that have to be met, and the simple economics of applying excess water, fertiliser and agri-chemicals (or using inappropriate agri-chemicals) will force farmers to comply. The Consultant has great faith that the farming community recognises these issues, is more than capable of adapting to changing circumstances, and that, assisted by technology improvements for irrigation and pest control, will be able to farm the area with increasingly environmentally responsible systems. CRAP *

7. Off-farm impacts

(S17, 31, 37)

Concerns were raised that no consideration was given to the potential for off-farm impacts such as might be generated by spray drift or by cotton trash chemical contamination. Spray drift is a problem in many agricultural areas and is not specific to cotton growing. Established protocols for aerial spray application already exist and are not the province of the IAS. Penalties are specified for failure of operators to observe these protocols and there are examples of enforcement of these guidelines. The dam may provide the opportunity for expanded cotton production and therefore, a potential increase in the risk of accidental off-farm spray drift occurring. However, there is no guarantee that the new irrigation area will be all planted to cotton. Other than recommending the adoption of best practice farming technology and making this a condition of water allocations under the EMP it is difficult to postulate what the IAS could do to prevent accidental drift. Operator and management error are not a direct consequence of the dam and therefore warrant only superficial comment in the IAS. Failure on the part of regulators to implement monitoring and penalty systems is not a reason for criticism of the IAS.

The Consultant is unaware of any impacts from cotton trash chemical contamination. If this refers to an earlier incident involving the contamination of cotton-seed meal, a valuable protein by-product for cattle feed, then this is also not a consequence of the dam and not relevant to the IAS. Similarly, protocols have been established to prevent such an occurrence again. The value of beef exports to the Australian economy is sufficient incentive for the industry to ensure that it does not recur.

8. Irrigation offtakes

(S31, 56)

In the downstream area, many of the riparian properties are already irrigators and have existing pumping facilities established in the river. These are generally located in natural deep pools. It is unknown at this stage how many additional irrigation farms will develop as a result of the increased water supply. Each new property will need to establish pumping facilities in the river as no communal distribution systems are proposed as a public benefit as part of the proposal, though private systems may develop. Additionally, existing irrigators may need to upgrade their pumps should they purchase extra water entitlements to increase their irrigation area.

All pumping facilities in the river must be approved by DNR in terms of size and location. It is possible that, in light of findings from the recent study, particularly the aquatic fauna work, that new guidelines could be established for siting and operation to ensure that river health is not further degraded. This could be achieved through the EMP. One possible improvement could be the requirement for back-flushing capacity which could help aerate deep pools and improve oxygenation of the stream. Pumps should not be sited so as to impede high streamflows. This is generally not the case anyhow as the risk of significant damage to the facility from debris is normally minimised for economic reasons. Any excavation or barrier construction to provide a pumping pool would require investigation and approval by DNR.

As at times of high water demand in the growing season, it may not be possible for the storage operator to deliver sufficient water down the system to meet all users' needs without compromising the environmental flow provisions, disrupting river crossings for extended periods, and impacting on riverine fauna and flora, off-stream storages may be necessary. These can be filled using water-harvesting licences where they already exist or may be approved in future, or by filling them at times of low system demand within the landholder's allocation. Existing waterharvesting licences may be compensated for by the provision of equivalent allocations. Filling off-stream storages could be done for instance during good seasons where sufficient rainfall is received to negate the need for irrigation. As discussed in the Baroondah report to DNR, there are also similar significant environmental and hydrological impacts associated with off-stream storages in the downstream area and these would need to be considered at the time of licensing. If required, these could be included as part of the EMP for downstream irrigation management.

9. Compensation

(S15, 51, 52, 55)

Although contrary opinions have been expressed regarding the fairness of compensation negotiations, the Consultant believes that individual landholders will not be disadvantaged by the process of resumption. Resumption is undertaken under provisions of the *Acquisition of Land Act* and this Act applies to all land resumptions for government purposes in Queensland. Thus, the same provisions apply universally and any concerns regarding fairness or otherwise can be freely tested through established judicial procedures.

The Consultant believes though that a considerable body of goodwill exists with respect to those impacted directly by the loss of land due to the impoundment and that fair dealings will result. Each landholder has the right to legal representation in the compensation process to ensure that all matters are adequately addressed in the negotiations. As has been discussed elsewhere in this report, and in individual letters sent to the riparian landholders surrounding the impoundment, maps in the IAS will not be used as a basis for any compensation negotiations as they are not at an appropriate scale. The acquisition of data at an appropriate scale for each property will be funded by DNR either directly or as a transfer payment in the negotiated compensation.

Compensation should cover all issues of loss in respect of land flooded either permanently or temporarily including relocation or reinstatement of infrastructure such as fences, yards, farm tracks, buildings, bores and watering points. Where access to the river has been restricted, the establishment of watering points will be considered and this has been discussed in respect of training of cattle to their use elsewhere in this report.

As the storage margin retreats with drawdown of the water level, temporary use of the flood margins for grazing may be permitted. There are provisions for grazing licences to be issued for such land under the Water Act. No conditions are specified in the Act under which these grazing licences may be issued. It has been Departmental policy to only permit grazing land use though in some instances, cropping has occurred in places.

As this land loss will have already been compensated for in some way during the compensation process, it will be up to individual landholders to establish guidelines for grazing rights and the allocation of liability. Alternatively, *ex gratia* grazing access may be permitted with management of stock being the sole responsibility of the landholder. The IAS report does not consider that use of this margin for cropping is appropriate.

As these areas will be the first sites to go under water as the impoundment fills again, they will act as a direct source of nutrient, particularly nitrates, to the storage. Unless stock are grazed at appropriate stocking rates, excess nitrates from such areas could impact on blue-green algae growth in the storage. However, as it not anticipated that there will be any net increase in stocking numbers on individual properties to graze these lands, but rather a shift of cattle from one part of the property, there is not expected to be any increase in nutrient runoff as a result of the grazing. ?

10. Stocking rates

(S35)

Stocking rates used in the report were obtained from local land owners and compared with similar country in other parts of the State. The higher stocking rates suggested for the Taroom area may apply to higher quality lands which form components of the Eucalypt Highlands and have not been mapped separately at the scale of work.

11. Whole Property Management Planning

(S11, 13, 18, 21, 22, 27, 29, 31, 32, 34, 37, 38, 42, 43, 44, 47, 51,56)

Just because a water supply is available and an area of land exists, it does not mean that the two are compatible and that irrigation is sustainable. The IAS identified that there were sufficient areas of suitable soils available both downstream and upstream of the dam and that together, these constituted a greater area than could be irrigated by the potential maximum yield of the dam at maximum FSL.

Accordingly a strategy was proposed that water allocations should only be made available to those landholders who could demonstrate the availability of sufficient suitable soils and had the capacity to implement a property management system which would ensure the sustainability of the development. This strategy was based on the preparation of a whole property management plan (i.e. a Land and Water Management Plan) as a precondition of application for a water allocation. The farm plan would have to show the area to be developed, the nature of the development planned, the existence of any rare and endangered species, remnant areas of vegetation particularly those of conservation concern, the soil types to be irrigated and the irrigation layout and operating system. The plans would also have to demonstrate that there would be no net loss (i.e. zero discharge) of irrigation tailwaters containing nutrients or agri-chemicals to the stream, and that there were sufficient monitoring measures in place to ensure that this occurred. Determination of the potential for salinity and watertable problems would be required. All development would be dependent upon meeting statutory requirements of relevant Shire zoning and planning guidelines, the State Tree Clearing Guidelines and other appropriate legislation. Terrible!

These plans would need to be prepared by relevant experts and approved by DNR staff with a clear understanding of the issues concerned. Enforceable controls attached to the Licence conditions would be required to ensure that compliance was achieved. It was intended that the details of these WPMPs would be provided in the final EMP. Such conditions would apply to all new water allocations throughout the catchment.

The cost of preparation of these farm plans would be regarded as part of the irrigation establishment costs of each landholder. It would be possible for several properties to combine in acquiring these data and thereby gain a greater understanding of the potential impacts at a broader level while keeping costs down. This would enable the development of a regional management picture to occur and thus facilitate overall management of the irrigation area.

12. Land Tenure

(S15, 35, 42)

Submissions from Most Affected Landowners pointed to the need to distinguish between Grazing Homestead Perpetual Leases (GHPL) and Grazing Homestead Freeholding Leases (GHFL) which are convertible to Freehold. The latter are a significant part of the tenure pattern in the Dawson Valley. It is acknowledged that it would have been better to sub-divide the leasehold land tenure category on the Land Tenure Map 7 into the main leasehold tenures to distinguish Grazing Homestead Freeholding Leases from other types of lease. However, while a new map could be prepared, such a presentation will have no bearing on the IAS, one way or the other. Colour reproductions of maps are costly and the additional expense could not be justified. The IAS Land Tenure Map will have no bearing on compensation considerations.

The Consultant also acknowledges a number of mistakes in the mapping presented in the IAS. The northern boundary of *Glenella,* is incorrectly shown on all maps. Maps 21, 22 and 23 which illustrate the properties which have areas affected at different full supply levels show incorrect labelling of *Glenhaven* and *Moorang*. *Glenhaven* has been transposed with *Moorang* with the *Glenhaven* name actually straddling *Spring Vale* and *Moorang*. The correct location of these properties is displayed, for example, on Map 28 Landholder Plan.

D. Impacts of Agricultural Expansion

1. Groundwater and salinity

(S13, 18, 21, 22, 25, 29, 31, 32, 34, 36, 37, 38, 42, 43, 44, 47, 56)

Salinity has been acknowledged to be a potential problem in the valley and is recognised as an issue in almost all irrigation schemes/areas world-wide. Salinity is associated with rising watertables which may change because of the increased application of water through irrigation beyond crop needs so that there is leakage to the groundwater. Any such leakage may carry with it excess fertiliser and agri-chemicals which will affect groundwater quality, and subsequently surface water quality should baseflow to streams occur.

Salinity is not restricted to rural farming areas but is also associated with dryland cropping, grazing and urban areas where excessive clearing has sufficiently altered the local hydrology to impact on groundwaters in susceptible areas.

Understanding of the principles and processes which lead to salinity is steadily improving and a good body of knowledge already exists regarding the identification of susceptible areas, their management and rehabilitation. The scope of the IAS did not permit an extensive hydrogeological investigation of the whole benefit area so reliance was placed on published information from DNR studies and an extensive knowledge of the land resource specialists regarding the soils of the area and the geomorphology of the alluvial areas. Consequently, the potential for salinity was highlighted and the need for additional work flagged.

It is easier to prevent salinity than it is to rehabilitate land and deal with the causes of the problem. Therefore, it was proposed that more detailed work be undertaken in the downstream area to support work already undertaken by Gordon *et al.* (1996) and Noble *et al.* (1996). These studies identified the existing situation and assessed water quality in parts of the downstream area. The presence of some agricultural chemicals was noted in some water samples and reported in the IAS. This cannot be extrapolated across the region as it represents a single sampling, but it does give cause for concern that the problem could become more widespread. There is evidence of watertable salinity in neighbouring catchments which, though associated with irrigation, cannot be directly extrapolated to the Dawson Valley owing either to the differences in hydrogeology or geomorphology between the areas.

A significant preventative measure was proposed, therefore, by recommending the need for a whole property management plan (as part of the Land and Water Management Plan) which clearly identifies the soils and areas to be irrigated and the management practices to be applied. Water allocations will only be approved provided these plans meet strict guidelines to be developed as part of the final EMP which will be prepared should the dam proceed. A requirement of the EMP will be that programs be established to monitor watertable height and water quality on-farm as well as regional groundwater changes. The former will be the responsibility of the landholder, the latter the province of DNR as it is currently. Sufficient knowledge exists regarding the soils and landform of the area to identify the areas which are susceptible to salinity or to causing off-site salinity through their use for irrigation.

Guidelines would be established to allow the DNR through its Resource Management group to effectively assess the whole property management plans to prevent the allocation of water to unsuitable areas. Measures would also be required to prevent such areas progressively coming under irrigation in the future unless it could be shown that technology had sufficiently advanced to allow these areas to be sustainably irrigated. These measures would need to be enforceable and be attached to water licence provisions.

Deep drainage of nitrates and some soluble agri-chemicals are the main problems to be managed with respect to watertable contamination due to added chemicals. The release of profile salinity can also be an issue but the determination of suitable soils for irrigation use only should prevent problems arising because of the latter situation. The progressive introduction of best practice farming techniques and the increasing need for farmers to be both environmentally and economically responsible will have a significant impact on reducing the threat of salinity in new irrigation areas. It simply will not pay farmers to apply more fertiliser or water than the crop needs as their economic survival (along with the potential cancellation of their water allocation) depends on the application of sound agronomic practices and the establishment of monitoring programs to measure performance against set criteria.

Salinity is more likely to arise under flood irrigation where groundwater leakage can be greater owing to the manner in which water is applied. It is possible to design furrow layouts and to deliver water in such a manner that leakage is minimal. This will require a change from some existing practices but could be easily be implemented as a function of new developments. Leakage is less likely with low volume application systems but still may occur through insufficient attention to water management. There is some potential for management of watertables through conjunctive use of water (i.e. the use of groundwater on-site for direct irrigation). This may not have widespread application depending on the volumes available and on the water quality. Similarly such waters may not be suitable for pumping and discharge direct to streams to lower watertables as water quality may impact on river fauna and flora.

The Consultant believes that the issue of salinity has been adequately dealt with in the IAS within the limits of the study required. Salinity will not be directly caused by the dam. Rather, it will be the result of bad farm management in areas where the water from the dam is used. Therefore, the responsibility lies with individual landholders who have a duty of care to ensure that salinity does not arise through using only suitable soils and sustainable practices. Likewise, it would be their responsibility to rehabilitate any outbreaks and this approach is reflected in the economic analysis. — how to prove if downstream

There was also one submission which expressed concern about the potential for increased salinity in the estuarine areas due to alteration in the diluting capacity of reduced streamflows. While potentially this could be a problem, it is being addressed by the Technical Advisory Panel to the WAMP process and will be dealt with in deciding on an appropriate environmental flow for the Fitzroy River. The final EMP will establish monitoring and action programs to respond to significant water quality changes should they arise. It should be noted that the estuarine areas have probably stabilised since the construction of the barrage near Rockhampton which now clearly demarcates the upstream extent of tidal influence.

E. HYDROLOGY

1. Water yield

(S21, 34, 36, 38, 42, 45, 47, 55)

Some reviewers raised questions about the yield figures used in the report. The questions fundamentally stem from a lack of understanding of the meaning of the yield figures, which are basically a very simplified expression of some quite complex hydrological assessments.

The yield referred to in the IAS is the incremental system yield (i.e. the additional system yield made available through the addition of the proposed dam to the other supply structures along the river). System yield refers to the total supply that can be made available at various nodes along the river and not the yield available at the dam wall. This allows the transmission losses (i.e. losses due to wetting, deep percolation, evaporation and evapotranspiration) to be factored into the supply demands. Current commitments have been allowed for in the determination of this yield figure. The values quoted are, therefore, the water available over and above existing commitments.

Yield is quoted with a reliability of supply value e.g. 85% monthly reliability of supply. This means that in 85% of months, the nominal allocation will be supplied, while in 15% of months, less than the nominal allocation will be available. These yield figures are derived based on historical rainfall or streamflow records.

It was suggested that the IQQM model is not appropriate for Australian conditions. This model was developed by the Department of Land and Water Conservation, New South Wales for use in planning and evaluating water resource management policies. It is a generalised hydrologic simulation package which is capable of application to both regulated and unregulated streams, and is designed to also address water quality and environmental issues as well as water quantity issues. The model is structured for investigating and resolving water sharing issues at an interstate or international level, or between competing user groups including the environment.

The model operates on a continuous basis and can be used to simulate river system behaviour for periods ranging up to hundreds of years. It is designed to operate at a daily time step but some processes can be simulated at time steps down to one hour duration.

River systems to be analysed are represented as a series of nodes connected by links, where inflows, storages, outflows and other point processes are nodes, while flow and water quality routing processes are associated with links. One of the primary uses of IQQM is to model the operation of regulated storages as well as to determine wetland and environmental flow requirements. It is a state of the art model especially developed for Australian conditions and while it may still have limitations for dealing with complex river systems, once all input assumptions for the WAMPs have been agreed, it has the capacity to resolve the necessary allocations to be reserved for all competing demands of the river.

Some concern was expressed that the yield was overestimated because coral reef cores indicate that rainfall in times prior to recorded history were lower than at present. The Consultant understands that reef cores indicate only large flood events and are not a good indicator of total rainfall. Cover conditions in the catchment would also have a significant impact on the turbidity of any major stream outflow which is one of the principal means of 'markers' being embedded in coral reefs. Thus, many large clean water flows would not necessarily be recorded. Yields are, therefore, calculated using historical streamflow data or streamflow estimated from historical rainfall records.

2. Downstream hydrological effects

(S3, 11, 32, 38, 56)

The WAMP process models scenarios for environmental release strategies and, through community consultation, determines the strategy that will maintain an acceptable level of river health. New water allocations will only be made after meeting that objective and meeting existing use commitments. These allocations will be derived by the IQQM based on parameters and assumptions agreed upon by a number of technical experts on the Technical Advisory Panel (which has broad-based representation), industry groups, the community and the government.

Any changes in flow patterns will obviously result in a response to the altered conditions to some degree by that section subject to the change. That is a fundamental consequence of the change process. The issue is really whether the nature and degree of the change response are acceptable or manageable. Any downstream impacts arising as a consequence of altered flow conditions which cannot be managed with existing technology and knowledge would, therefore, be considered in the decision making process for the proposal. At this point, the IAS indicates that there are no identified impacts that cannot be managed and controlled through an effective EMP.

3. Environmental flows

(S3, 11, 13, 18, 22, 23, 26, 31, 32, 34, 37, 38, 42, 44, 56)

The Consultant recognises that the treatment of environmental flows in the IAS was less than ideal, but this was undertaken in accordance with instructions received from DNR. These written instructions were given when it became apparent that the output from the WAMP on which the environmental flows were largely dependent would not be available in sufficient time for the finalisation of the IAS.

These instructions specifically related to Section 6.4 and Section 7.4 of the ToR. A copy of this letter is attached at Appendix 3.

4. Frequency of flooding of floodplains and wetlands

(S3, 22, 27, 29, 31, 34, 37, 38)

Based on historical data, the current frequency of inundation is already known. These data have been input to the IQQM as part of the WAMP process. Should the dam be built, the frequency of inundation in the future will not be allowed to fall below the conditions specified in the WAMP. – But only to 50% of yield

In some instances, properties utilise the natural secondary channels, billabongs and anabranches of the river for off-stream storage for irrigation. These are filled at periods of high flow naturally or may be filled by pumping using water-harvesting rights. The overall impact of this practice needs also to be considered in the WAMP deliberations on the establishment of floodplain management strategies.

5. Wetlands

(S13, 18, 22, 25, 37, 38)

Refer to Appendix 3. Responsibility for assessing the impact on downstream wetlands was deemed an issue for the WAMP process. It was considered that wetlands upstream of the dam would not be impacted in any way by the dam operation because of the gated design for the proposed structure which would allow floods to pass without flooding the wetlands beyond what occurs naturally.

The boggomoss reserve on Boggomoss Station near the Spring Creek turnoff is not impacted at full supply levels below 185m EL.

6. Water allocation and management planning

(S1, 3, 10, 11, 13, 18, 19, 21, 22, 23, 25, 26, 29, 31, 32, 33, 34, 35, 36, 37, 38, 42, 44, 46, 47, 54, 56)

Many submissions take issue with the fact that the IAS has been prepared prior to the completion of the Fitzroy Water Allocation and Management Planning (WAMP) Process. While the WAMP process will not be completed before mid 1998, the environmental assessment of the project has been considered within the context of the WAMP.

The plan will set the framework under which any new infrastructure can be developed and will assist in setting allocations for new works. In particular, the WAMP makes prior commitments for existing water users and for the environment. This involves complex hydrological analysis using a daily time step model.

It will not be possible to finalise allocations until the WAMP has been completed, though the hydrologic studies have incorporated scenarios for environmental management on the advice of a Technical Panel. It is clear that, even with maximum commitments to the environment, there will be sufficient allocable supply for the economics of the dam to remain strongly positive.

what? ≥50%.

It is perhaps worth noting that it was anticipated that the WAMP would have progressed to the stage of producing a "bottom line" allocatable yield by December 1996. The WAMP process has proven to be much more complex and time consuming than anyone could have anticipated, so that even though the IAS process has been substantially delayed, it is well ahead of the WAMP. Delays in the evaluation process have caused a deal of stress to those citizens directly affected, and the Government has been persistently requested to make an early decision "one way or another" so that people could "get on with their lives".

F. WATER QUALITY

1. Chemicals

(S10, 11, 13, 18, 22, 25, 27, 31, 32, 34, 37, 38, 43, 53, 56)

With the institution of Whole Property Management Plans and the requirements for regular monitoring (including groundwater) and zero discharge designs, effluent will be kept on-farm and normally not enter the drainage system. During major flood events there is always a prospect that some nutrient will escape to the river, but the dilution factor of the large volume of flood water would mitigate adverse effects. The additional area to be potentially developed represents only 0.21% of the total Fitzroy catchment. Provided procedures recommended in the allocation of water, which are based on only using suitable soils and the application of best practice farming techniques and zero discharge drainage, are enforced, it is not anticipated that there should be any increase in chemical hazard due to the dam.

2. Health (human)

(S13, 18, 21, 22, 25, 32, 38, 43, 47, 48, 50, 51, 52)

a) Mudflats and insects

A concern has been expressed that the exposed mudflats generated by a rising and falling dam level will cause midge/sandfly infestations in Taroom creating health and nuisance problems for residents. Such infestations occur naturally following flood events. The concern would be for continuous infestation due to the dam operation.

Inherent in the concern is the notion that there will be rapid rises and falls in water level of the dam, as can occur on weirs such as Glebe Weir, thus exposing large muddy margins. This notion is not quite correct. The wetted perimeter of the impoundment will move slowly downwards in dry periods with natural evaporation, and through water releases for environmental and irrigation purposes. Where the land is flat, then small changes in water level will expose larger wetted areas.

However, the dam would only occasionally be at the full supply level, and even then it would be only at the maximum proposed 185 m FSL that the town would be directly impacted. Lower FSLs would further alleviate the potential problem.

Should a midge/sandfly infestation materialise in Taroom which is attributable to the operation of the dam, then government would take action to alleviate the problem. It would be necessary to develop action plans under the EMP for the operational phase, and for the Taroom Shire Council and the dam operator to develop joint strategies for management.

b) Weeds

Parthenium (and other weeds and non-weeds) are known to have adverse medical effects on some persons, such as asthma or allergic reactions. The issue of weed control has been addressed separately under section III F2b.

c) Water-borne parasites

One submission considered the IAS ill-advised in stating that cattle should be permitted to graze to the edge of the dam owing to the risk of *Giardia lamblia* (also known as *G. intestinalis*) and *Cryptosporidium parvum* being carried by animals, including cattle, which would enter Taroom's water supply. In fact, as indicated in the Main Report p262, Taroom's water source is an unpumped bore on the western edge of town, a resource which is adequate for existing needs and also considered adequate to meet any increase in population which may arise as a consequence of dam construction. The Dawson Dam is not designed as a storage for urban water supply. Several townships downstream of the dam currently draw water supplies from the Dawson River, which is used for domestic consumption after water supply treatment. Municipal drinking water treatment using a multiple barrier approach of filtration and disinfection can reduce the risk of giardiasis and cryptosporidiosis. Most conventional water treatment plants contribute significantly to the removal or inactivation of cysts and oocysts, but only if correctly operated. Sand filtration, for example, has been found to be an excellent barrier to cyst and oocyst transmission.

Giardia lamblia cysts and *Cryptosporidium parvum* oocysts can both be spread by any mechanism which maintains a faecal-oral cycle, including direct person to person contact, contaminated food and contaminated water. However, epidemiological studies have shown that the potential for person-to-person transmission of cysts and oocysts is much higher than that for waterborne transmission. That is, the diseases are more likely to be directly transmitted through faecal/oral contact than from water supplies. Giardia is prevalent in children, for example, in child-care centres.

It should also be noted that *Giardia lamblia* is endemic in the population. Its distribution in medical literature (e.g. Merck Manual) is described as 'cosmopolitan'. Both humans, dogs and wild animals may serve as reservoirs for the disease. However, cattle appear to be the primary source of Cryptosporidium, although it has also been found in humans and other animals. The occurrence of Cryptosporidium is seasonal depending upon runoff and presence of animals, and it is reasonable to expect the parasite anywhere.

It is recognised that the first line of defence against the diseases is to protect urban water supply sources from contamination. However, cattle are currently grazed over large areas of the Dawson River catchment, right down the river through Taroom to the Nathan Gorge and also for many areas downstream of the Gorge. The town common, and cattle saleyards at Taroom abut the river at the western edge of town. The presence of a large storage is unlikely to increase the existing risk of contamination downstream of the dam for several reasons:

- increased retention time for settling of cysts/oocysts and predation by filter feeders such as rotifers, ciliates and micro-crustaceans;
- longer exposure to the environment which degrades the organism; and
- some lands downstream currently used for grazing will be converted to irrigated crop production, thus reducing the contamination risk.

The reality is that there is a risk of infection by Cryptosporidium even in pristine catchments. Contamination is now occurring in the area downstream of the dam and throughout the Fitzroy basin, and will continue to occur if the land continues to be grazed.

The Government already provides free testing of raw water to monitor the occurrence of the organisms. It is recommended practice that treatment plants be operated on the premise that the organisms are present, and to reduce risk by optimising treatment practices.

Outbreaks of cryptosporidiosis such as that which occurred in Milwaukee USA in 1993 occurred as the result of less than optimal water treatment practices. However, it should be noted that even with optimal treatment, certain individuals, particularly those with a weaker immune system such as infants, AIDS victims, the elderly, and those under certain medication such as steroids, remain at risk. The simplest safety measure for such persons is to boil all water used for drinking or cooking (including washing hands) for 3 minutes.

Public health professionals suggest that a major dam would not of itself increase the risk of the spread of disease via protozoan organisms such as *Giardia lamblia* and *Cryptosporidium parvum*. The safety of water supplies from any surface water storage depends to a large extent on the maintenance of an optimal treatment regime rather than any other factors.

3. Blue-green algae

(S10, 11, 13, 17, 18, 21, 22, 25, 29, 31, 32, 34, 37, 38, 42, 47, 48, 53, 56)

Blue-green algae outbreaks are seen as an ultimate consequence of the proposed irrigation development and concerns have been raised regarding the apparent lack of attention paid to this in the IAS. The Consultant believes that the issue was covered in sufficient detail for the purposes of an IAS but additional information is provided below.

The IAS report acknowledges the work by Fabbro (1996) in documenting the risk of blue-green algae and the nature of cyanobacteria present in the stream. The risk attaches to both the downstream area as well as to outbreaks in the storage itself. There is every probability that the risk of an outbreak will increase unless steps are taken to prevent such an occurrence through implementing improved farm management practices and monitoring programs. This has been done through the mechanisms of requiring a whole property management plan which includes a zero discharge design and the application of best practice technology leading to better control over nutrient and agri-chemical application.

Fabbro's work shows there is some potential for outbreaks of blue-green algae in the Dawson River but at the time of writing the report there has only been one recorded instance near Theodore in December 1994 when the sediment load (and hence turbidity) had decreased at the end of the drought. This potential increases with distance down river owing to the increasing area of agricultural and other forms of land use which may contribute excessive nutrients to the river. The use of *best practice* methods of farming will minimise the risk compared to the previous situation where contribution of nutrients from agricultural and urban runoff was unregulated. There are no major industrial sources along the river and most sewage is treated to secondary stage prior to discharge, none of which, as far as the Consultant is aware, goes directly to the main river. Water allocations for irrigation from the Dawson Dam supply (i.e. new applications) will be issued subject to the preparation of an acceptable whole of property management plan which must incorporate evidence of the use of suitable soils for sustainable irrigation and the development of zero discharge systems for tailwater management to prevent the discharge of nutrient-rich waters to the stream.

The conditions under which Blue-green algae outbreaks occur are closely related to temperature and light conditions as well as to nutrient status. Temperature conditions can be managed through carefully controlled flow management in the river as part of the environmental flow management strategy to be developed. Water in the Dawson River is generally highly turbid. This turbidity refracts light and reduces light penetration to some degree. This turbidity will limit the potential for blooms to develop but not eliminate the possibility. Recent evidence from studies elsewhere also shows that river bank collapse and the release of historically entrapped nutrients (i.e. those not of agricultural origin) may be responsible for significant nutrient flushes and blue-green algae outbreaks. It would appear that government-supported approaches to improve land management practices, land user education regarding the adoption of best practice technology, and more effective land management to prevent streambank erosion would assist in preventing the development of conditions conducive to outbreaks.

Blue-green algae occur in all freshwater systems but not all algae are toxic forms. All known toxic forms are, however, present in the Dawson River. It would be necessary to institute a regular monitoring system to detect the onset of likely conditions and to determine if the forms present in the sample were in fact those of concern. If an outbreak occurred it would then depend on where it was i.e. in the dam or downstream. Management intervention has generally been most important where the water supply is for domestic consumption. Downstream communities such as Moura, Duaringa and Rockhampton depend on water from the river for domestic use.

Should an outbreak occur in the dam itself, management would mainly consist of erecting warning signs and declaring the water unfit for any recreational or consumption purposes until inflow occurred and/or thermal stratification conditions changed and the outbreak dissipated. This would be a blow to local tourism activity. If there is a significant expansion of agriculture in the catchment above the dam, there could be an increased nutrient load in the dam if best practice farming techniques are not followed and the monitoring of zero-discharge irrigation is not enforced. There is some potential for a decrease in turbidity within the dam as sediment settles out and this could lead to outbreaks with the subsequent increased light penetration. However, at the same time, some of the nutrients would sink to the bottom of the deeper parts of the storage and it would be necessary to monitor N and P concentrations in the upper parts of the water column as an indicator of the onset of likely conditions for an outbreak.

Treatment of an outbreak within the dam can be achieved by physical disruption of the warm upper water layers by using aerators or bubblers and this has had some success in large dams (economics are unknown and effectiveness is largely dependent on the size of the water body and the actual bloom size).

For a downstream outbreak, release of pulses of water from the dam (if the dam is unaffected) could be used to disrupt the warm water surface layers and break up the algal bloom if sufficient water is available in the dam. The additional studies undertaken by the Aquatic Fauna specialist during the low flow Spring period have demonstrated the potential for reducing stratification by controlling flow releases and this would assist in avoiding the onset of conditions conducive to an outbreak.

Treatment in the weirs can be achieved through aeration, release of bottom water (which is not anoxic) through existing outlets, or siphons (providing the discharge can be aerated) to destroy the thermal layer and dilute the nutrients contributing to the outbreak. Throughflows in the weirs as part of the flow management strategy coupled with regular monitoring will be a major influence in prevention. Normal practice in large river systems has been to let Nature take its course with rainfall flushing and to restrict public access. Water treatment with activated charcoal and membrane technology can maintain quality for domestic consumption. *

The best approach is prevention through land user education, catchment management and monitoring to allow the implementation of measures (flow, aeration, etc.) which can reduce or alter conditions sufficiently to control the outbreak. Irrigation should still be able to proceed but water should not be used for fruit washing or other purposes where human contact is possible. Fishing should not be permitted and fish should not be consumed from rivers or dams affected with the bloom.

The development of a Blue-green algae risk management strategy will be addressed in the Environmental Management Program (EMP) to be prepared for the operational phase of the dam should it proceed. This will be prepared in conjunction with advice from appropriate experts in river water quality management and officers of the Department of Natural Resources with expertise in the area.

It was the responsibility of the IAS to identify the likelihood of blue-green algae being a problem. The Consultant acknowledges that there is a need to include a specific strategy for dealing with its prevention and management as part of the final EMP.

4. Stratification and Deoxygenation

(S13, 18, 23, 26, 29, 31, 32, 34, 38, 42,

Temperature stratification will occur in standing bodies of water. Stratification effects will be less pronounced in a large dam than in the small deep weirs downstream. Additional information is provided in Attachment 2.

The dam design will incorporate multi-level offtakes, permitting water releases to be drawn always from the more oxygenated surface layers.

5. Turbidity and Sedimentation

(S 15, 18, 20, 32, 34, 38)

Turbidity is a measure of the refraction of light by a liquid suspension. While the term is somewhat loosely applied in land use circles to indicate the level of erosion activity, there is in fact no direct correlation between turbidity and suspended sediment volume. Indeed, some soil types, such as kaolinitic soils with very fine clay particles are highly dispersive and in a water suspension register very high turbidity levels when indeed the volume of soil in suspension may be quite low.

The issue of high turbidity in the Dawson River has been raised as evidence of the level of active land degradation occurring in the catchment above the water sample point. One submission claimed hearsay evidence that back in the 1920's the water of the Dawson ran clear even after heavy rains. Another submission claimed that a high turbidity after good rain in the catchment area is normal and "has been happening forever and comes from wherever there has been good rain…not just stream banks…".

With the soil types in the area, such water turbidity is to be expected, and is by no means unusual. The flocculating clay soils disperse in water rapidly to form a cloudy suspension. The clay particles are so fine that they remain in suspension for very long periods. The water is highly turbid and will remain so, consequently the rate of sediment deposition from this turbid water in the impoundment of the dam will be slow, and it is not unrealistic to expect the dam to have a somewhat longer life than may appear to be the case if one assumes a direct correlation between a measure of turbidity and the suspended sediment load.

However, it would be expected that releases of water from Glebe Weir may contribute to the turbidity of the Dawson River downstream of the weir, especially when a major flush release is made where bottom sediments are stirred up. There is certainly a high natural background turbidity in the Dawson River and this is evidenced by historical indicators such as the deposition of extensive clay floodplains along the stream.

At Water Sampling Station *130324A* about 50 km above Taroom recorded turbidities over the 30 year period 1964 to 1994 ranged from 19 to 137 NTU, while for the same period for sampling point *130003A and 130003B* at the Glebe Weir the range was 1 to 200 NTU. However, these Water Resources data are of little value for inferring anything about catchment contribution to water quality as they represent at best only a few samples per year and are made without reference to river discharge at calibrated stream gauging stations. For turbidity information to provide any value, frequent water samples need to be taken during a rainfall event over both rising and falling limbs of the hydrograph on at least an hourly basis and the fluctuation in turbidity graphed against the hydrograph.

Concern has been expressed for the occurrence and rate of sedimentation which might occur in the dam, in the river itself and on the Barrier Reef where deposited sediment would kill the coral. There is no reason why the construction of the dam, or increased agricultural activity through irrigation should increase the rate of erosion and sediment transport above that which currently occurs through the river system with its series of weirs and the Rockhampton barrage to the estuary and out to the reef. A more effective means of protecting the reef against sediment damage would be a concerted effort throughout the catchment in the implementation of effective erosion control programs dealing both with agricultural land and streambank stability.

Particle sizes which reach coral with diff. flowdynamics?

Frequent prior reference has been made to the enforced application of Whole Property Management Plan controls on irrigated properties. In dryland farming areas, mechanisms other than advocacy of best practice agriculture for controlling activity which may generate erosion are not available. However, such activity can not be ascribed to the proposed development of the Dawson Dam and hence is not relevant to the IAS.

Some submissions have referred to the dam having a short life because it will silt up quickly. The erodibility of the catchment is considered in the planning and design stages of the dam and in hydrological studies. It is inconceivable that a dam with a capacity in the vicinity of a million megalitres could silt up within its economic life.

Most of the land to be developed is already under some form of cropping or grazing. Any incremental increase in sediment production from this area, which represents less than 0.21% of the Fitzroy basin, is not likely to be measurable.

G. FISH

1. Recreational and commercial fishing

(S11, 12, 17, 18, 22, 23, 25, 26, 31, 34, 37, 38, 42, 53, 54)

These submissions express concern that downstream impacts from the additional irrigated agricultural activity will reduce the commercial harvest of fish. Output from the WAMP using the best currently available technical advice from scientific and industry members of the Technical Advisory Panel, will ensure that flow in the Fitzroy River basin is maintained at a level which provides for minimal additional impact on the riverine, estuarine and marine environment. This should ensure that there is no measurable impact on the recreational and commercial fishing industries in the downstream reaches of the river.

Monitoring programs to be established as part of the operational EMP will address issues of importance to the fishing industry such as water quality and flow regimes. Additionally the requirement for farming best practices and zero discharge design as a condition of water allocations should minimise the risk of accidental chemical contamination of the stream. From a recreational fishing point of view the IAS has recognised issues relating to migratory needs and trigger flow requirements for breeding for native fish.

The IAS together with this Supplementary Report discuss in some detail the requirements for and problems associated with the installation of fish transfer devices on existing and future water infrastructure on the Dawson River. Opportunities for fish stocking of selected native species have also been discussed, and these may well lead to an increase in recreational fishing.

2. Fishway

(S11, 13, 17, 23, 26, 31, 32, 37, 38, 42)

The IAS reported on the need for a fish transfer mechanism to be incorporated in the dam design while at the same time acknowledging the difficulties of its incorporation. At this time, there is no known effective means of incorporating a fish transfer device in a dam wall as high as that proposed for the Dawson Dam. Fish ladders or lock systems could not be built given the configuration of the site and the proximity of the gorge to the dam wall. Vertical slot systems are not appropriate for such a high wall.

At this time, the DNR has a Fishway Co-ordinating Committee investigating the availability of suitable means to achieve fish migration with respect to the Dawson Dam and their recommendations will be considered in the final approach selected. This Committee may alternatively conclude that fish stocking or fish transportation is the better option until technology improves.

The Consultant has pointed out that any incorporation of a fish transfer device on the Dawson Dam would be of little benefit as long as the downstream weirs had no provision for fish migration. There may be justification for retro-fitting such devices as part of a program to improve fish migration along the whole river system.

3. Fish stocking

(S12, 23, 26, 31, 38, 54,)

One submission set out in some detail the long history of the Dawson River and the changes observed since the river was first regulated at Theodore in relation to fish species, numbers and distribution.

The construction of the dam will drown out the Glebe Weir, replacing that barrier to fish movement with itself. Thus, though it is a higher structure, there is effectively no net change in the number of barriers on the river. The IAS report has discussed the need for the removal of Orange Creek Weir as has already been considered by DNR because of its condition. The aquatic fauna study also advocates this action as it would decrease the length of the river in this section which is covered by weir pools and increase the number of run and riffle zones.

The installation of a fish transfer device on the proposed dam would present some difficulties at this stage as no effective design technology yet exists for such a dam wall height given the site conditions. As mentioned in the report, there is little sense however in installing a fish transfer device on the new dam without at the same time installing similar devices on downstream weirs which have been shown to effective barriers to fish movement. The DNR Fishway Co-ordinating Committee is investigating various options including the possibility of manual transfer of native fish populations at critical times. This would be supplemented by fish stocking programs which are well proven and already operate for other storages in Australia.

Fish stocking programs are primarily based on species which are known to survive well in impoundments and are suitable for recreational fishing. There is no reason to believe that such programs will not become increasingly available for the more important native fish in future. There is some evidence from the aquatic fauna survey that, in spite of the impacts of the existing weirs on the river, several fish species known to have migratory requirements had adapted well and were found in large numbers.

Concerns about stocking programs impacting on genetic diversity within populations should be managed through better control over breeding programs and the introduction of genetic material from other sources rather than inbreeding as is probably occurring in the river at present.

H. BIOLOGY

1. Biological sampling

(S18, 32, 38, 48)

Concerns about apparent deficiencies in the duration of field studies for fauna and flora were raised early in the IAS process following a review of the original draft documents. The Consultant was aware from the beginning of the contract that this would be a problem because the time frame did not permit seasonal sampling, although this was called for in the ToR. DNR agreed to support supplementary flora and fauna studies. The additional terrestrial fauna studies in 1997 were intended to amplify work undertaken in 1996, while the further flora study focused on defining more clearly the likely impacts on identified rare plant species. These additional studies were reported in the final Main Report and Supporting Documents; the outcome of further aquatic fauna studies is attached to this Supplementary Report.

As DNR was aware of the need for field data over more than one season, it engaged Ison Environmental Planners to carry out surveys in the vicinity of Nathan Gorge downstream of the dam site during summer 1995-1996. This information (Ison 1996) supplements data obtained by the Hyder Environmental.

The actual time spent on any phase of field sampling was dictated by the time constraints of the ToR and practical considerations. The Consultant considers that the information from prior studies, Hyder Environmental's 1996 field work, and the additional 1997 studies, together with data obtained from the Queensland Museum's extensive database, have remedied any apparent deficiencies in terms of an IAS. (For further discussion on mapping of remnant vegetation downstream, refer to Section H4.)

2. Habitat

(S13, 14, 18, 22, 25, 27, 31, 32, 34, 37, 38, 56)

The Consultant considers the discussion of habitat in the Main Report adequately addresses all issues necessary to the assessment of any change in habitat resulting from the dam construction and operation. In particular, the report recommends the early revegetation of impoundment margins to re-establish riparian vegetation and corridor connections between Lake Murphy Conservation Park and the downstream riverine corridor. Additionally recommendations were made regarding the relocation of hollow trees and nesting sites as an interim measure, and the reservation of standing trees in the margins of the dam to provide both roosting habitat and a shelter for aquatic fauna.

While commercially saleable timber from trees in the riparian zone would be salvaged, there will inevitably be many residual logs which have no commercial value, such as those with a high level of defect (eg hollow logs), and these will provide habitat for aquatic species.

The reference in the Main Report at E3b to burning of remnant vegetation is unclear. It was not intended to convey the meaning that the non-commercial boles of trees (including logs with a high level of defect) would be burned. Indeed it is quite difficult in practice to burn such large boles, especially logs with mudgut. However, the heads of felled or pulled trees should be burned and subsequently reheaped and reburned to reduce water quality problems and minimise other dam-gate operational concerns. These inundated logs would provide habitat for fish and other aquatic fauna.

The IAS also discusses leaving vegetation on land which will become islands in the storage (and the subsequent enrichment of the vegetation), as well as existing trees in the easement or margins of the impoundment.

The WAMP will establish streamflow regimes which will ensure, to the maximum extent possible, the preservation of downstream riverine habitat. Further discussion of riparian habitat and remnant vegetation in potential development areas is provided in several places in this Report in relation to the use of whole property management plans as a condition of applications for water allocations.

3. Boggomosses

(S3, 13, 18, 21, 24, 25, 31, 32, 34, 35, 37, 38, 41, 42, 44, 47)

Many of the concerns raised about boggomosses have been addressed thoroughly in the boggomoss studies undertaken by the Queensland Herbarium, the Queensland Museum and the Resource Sciences Centre under a separate contractual arrangement. There is also a simple answer to the question posed by some submissions of why the boggomoss reports were not included with the IAS documents. The final reports of these studies were made widely available by DNR in early 1997, and, indeed, the same submissions refer to them. The role of the Consultant was merely to draw from those documents what it considered to be the most salient points, and it attempted to do this in its discussion of boggomosses at pages 88, 146-147, and 227-228 of the Main Report. In addition, specific reference was made to the importance of the boggomosses to Aboriginal people which had, along with animals, used the boggomosses as refugia in droughts when the river dried up.

In terms of the number of boggomosses that are flooded, even at the reduced full supply levels above 180 m FSL, the Consultant has expressed concern that important wetland habitat will be lost. However, it is incorrect to describe the boggomosses as unique; unique means "no other" and that is not true of boggomosses (which is a local name for mound springs which occur in many places in the Great Artesian Basin). Even at 185 m FSL, of the 12 boggomosses which had populations of a vulnerable species (*Arthraxon hispidus*) 6 of these would not be flooded, nor would the boggomosses which contained the single population of (*Thelypteris confluens*) (vulnerable) and the two populations recorded of an endangered *Myriophyllum* species.

Perhaps the point was not sufficiently strongly made in the Main Report, that boggomosses themselves can stop flowing (and thus the dependent biota may die), and the geological evidence strongly supports the view that, in lying so close to the Precipice Sandstone aquifer intake, and with the additional head due to the impounded water, new boggomosses are likely to form further upslope of the existing chains of non-riparian boggomosses. To express how many might form would be pure conjecture.

The point was also obviously not clearly made in the Main Report, that while 69 boggomosses were studied and reported, it is known that this number does not represent all of the boggomosses in the area. A study of Map 28, for example, where the studied boggomosses are represented by green dots, does not include a number known to occur on properties on the south of the Dawson River, including on Cockatoo Creek. On the north there are more in the Palm Tree Creek area.

Many of the existing boggomosses are islands within an area cleared long ago for grazing purposes and used for stock water and other purposes for an equally long time. It should also not be forgotten that the entire series of described riparian boggomosses along the Dawson River have been removed from the dam impoundment by shifting the axis upstream, an action which also preserves a number of both riparian and non-riparian boggomoss types in the Price Creek catchment.

4. Remnant vegetation

(S3, 13, 22, 32, 34, 35, 38, 42, 56)

One submission expressed concern about the lack of mapping of remnant vegetation communities in the water use area downstream. Though these areas were not mapped they were assessed in the field and comments made regarding the significance of the remaining communities. The Consultant acknowledges that mapping could have been done, but given the length of the river in this area and the scale of mapping required to effectively show small and isolated remnants, the number of maps would have been greatly increased with little commensurate benefit other than a visual representation to the textual coverage.

Nevertheless, the importance of remnant vegetation was considered by the Consultant. This is particularly important in the benefited area where few significant stands remain owing to the extensive clearing which has already occurred for both grazing and cropping development in the area. A more useful and appropriate solution to the mapping of remnant vegetation was seen to be encompassed in the recommendation for the preparation of whole property management plans (or Land and Water Management Plans (LWMP)) as a condition of application for a water allocation. These plans would have to include, among other issues to be specified by a final EMP, the type and distribution of soils, soil suitability for sustainable irrigation, remnant vegetation, the presence of any rare and threatened species or communities of conservation concern, existing property land use and infrastructure, and proposed development. Water allocations would only be made where these LWMPs were considered appropriate and where further development was acceptable under the State Tree Clearing Guidelines.

Though this approach was perhaps not enunciated specifically in the IAS, it underpinned the intent of the whole property management planning recommendation. The whole property management planning was designed to ensure that only sustainable land development occurred, that soils were only used for either irrigated or dryland cropping or grazing according to their potential, and that only best practice agronomic and irrigation technology would be used. This included the need for zero discharge systems to restrict tailwater egress and the possibility of conjunctive water use to accompany groundwater monitoring. To some degree this proposal has obviated the need to map the remnant vegetation areas as these areas would be thus identified in more detail at property scale and if needed, a composite map could then be prepared.

5. Aquatic fauna

(S3, 18, 24, 31, 32, 34, 37, 38, 42, 46, 53, 56)

a) Turtle

The aquatic fauna study investigated the habitat requirements of *Rheodytes leukops* as far as they are currently understood and has commented on likely impacts of the operation of the storage on its survival. At this stage there have been no reported sightings of the turtle in the upstream reaches of the Dawson River above Theodore.

Management of the riverine environment and flow regimes to meet environmental needs are key components of the WAMP and reflect inputs from relevant experts on the Technical Advisory Panel. Everything practicable should be done to ensure that there are no adverse environmental impacts on the turtle population and mitigating measures would be specified as soon as a clearer picture of the turtle's needs are identified. (See also Section 5c on run and riffle zones.)

DNR is currently funding a long-term study by DoE of the effects of storages on the sustainability of turtle populations in the Fitzroy, Mary and Burnett River systems. The results of this study would be incorporated in the detailed EMP for the operational phase of the project.

b) *Macroinvertebrates*

Submissions expressed concern that the monitoring of macro-invertebrates had been ignored, or overlooked, as the most appropriate indicator of water quality. The need for seasonal monitoring of macro-invertebrate communities in the EMP was urged to ensure that short-term and long-term impacts on water health are detected. These submissions considered there was an urgent need to develop a baseline for macro-invertebrates as part of the IAS.

While macro-invertebrates do serve as an indicator of river health, so do vertebrates. Environmental impact statements are not, and were never intended to be, a surrogate for a State of Environment report. The purpose of an IAS is to assess current and likely impacts, and consider how, if at all possible, they might best be mitigated. To place matters in perspective, the Consultant's fauna specialists from the Queensland Museum have indicated that a full survey could entail more than 10,000 invertebrate species, many of which are not yet fully described and details on their life cycles unknown. The utility of such detailed data, even if it were possible to collect, would be debatable and their meaningful interpretation for impact determination suspect.

If the intent is to assess river health, then it was considered quicker, and less costly and just as effective *for the purpose of the IAS* to concentrate on fish species, and environmental parameters such as temperature in the water column and dissolved oxygen levels, noting any condition peculiar to the system.

The aquatic fauna survey was undertaken upstream of the proposed dam site and downstream to the Dawson junction with the Mackenzie. As reported in the Main Report and in the Aquatic Fauna Supplementary Report at Attachment 2, the regulated section of the river is not healthy, with pronounced stratification in the weir pools and deoxygenation to the point where fish can survive only in the surface 1-2 metres under the described conditions. But the survey also reported that pronounced stratification and deoxygenation occur in the natural pools which are the only refuge for fish during periods when the river ceases to flow. Hence the lengthy discussion on the volumes and timings of water releases from the proposed dam to *improve or at least maintain* the existing health of the regulated section of the Dawson.

The Consultant also considers that an efficient way of assessing the state of riverine health is to use high-information invertebrate species such as land snails, slaters and spiders as target indicator groups. There is a growing body of evidence that these target species can be used as indicators of both ecosystem health and of any change in environmental. The use of these indicators can often indicate in advance of major impact, the initiation of change. The Consultant agrees that such surveys of indicator species should be undertaken at least 4 times per year (seasonally) rather than the 2 times per year suggested in the EMP to provide timely information for revision of the environmental management plan.

c) *Run and riffle zones*

The IAS reported on the significance of run and riffles in maintenance of river health and highlighted the critical reduction in these areas along the river. Suggestions were made in the IAS that the installation of artificial riffle zones was feasible. This suggestion for increasing the number and performance of riffle zones has been taken seriously by DNR who recognise their importance in the maintenance of water quality as well as for fauna needs. Many of these zones have been drowned out by the weir pools and only become active at periods of low storage and flow.

Ironically, the existence of a large dam upstream of the weirs may improve the activity of these zones by allowing the weirs to be kept at lower levels than is currently the case. This could be co-ordinated to meet the times identified by the WAMP and the fauna and flora studies as critical to river health and fauna/flora needs. If it is not considered possible to match these performance criteria specified by the WAMP, then this will have to be taken into account in the government decision to build the dam in weighing impacts against benefits.

One submission recommended the construction of artificial riffle zones. The Consultant had previously recommended such an approach to DNR in associated impact assessment scoping studies for Paranui Weir and Baroondah Dam, and fully supports this suggestion. Artificial riffle zones can be used to improve in-stream oxygenation and replace important habitat lost under existing weir pools. These could be created relatively easily at key locations. Should Orange Creek Weir be removed, further opportunities in this regard would occur.

6. Supplementary aquatic surveys

(S31)

The Main Report referred (p280) to the DNR funding supplementary aquatic fauna studies in late 1997 to continue investigations of temperature stratification and deoxygenation problems (in the Regulated Dawson) and provide additional information to improve knowledge of the environmental effects of flow regulation and assist the development of environmental flow options.

Supplementary studies of water quality, cross-section depth, sediments and aquatic fauna (focusing on fish) were conducted in September, October and November 1997 during high and low flow periods in the Dawson River, between Glebe and Theodore Weirs.

A report of this supplementary work is appended as Attachment 2.

The study reinforced the findings presented in the Main Report that temperature stratification led to severe deoxygenation below the thermocline during low flow periods throughout the survey area. The deoxygenation to toxic levels (<1ppm) extended to within 1 metre of the water surface at most sites in shallow runs sections (2 - 3 metres deep), in natural pools, and in the weir pools (>10m deep).

The temperature stratification persisted in Gyranda weir pool at times of high flow (>100 ML/day) only in the deeper parts.. The environmental implications of the deoxygenation are discussed in Attachment 2 in terms of loss of usable water column, loss of detrital production, potential fish kill problems, and interference with fish movement breeding, spawning and rearing. The effect on the shallow riffle and run areas was regarded as the most important issue as much of this habitat has already been lost through inundation in the weir pools. It was shown that the deoxygenation developed more rapidly in the shallow areas once the flow stopped.

With much of the run and riffle areas of the Dawson River downstream of Glebe having already been lost through inundation by weirs, the effect on the run and riffle areas was considered the most important.

The supplementary fauna report suggested that environmental flows of 25-50 ML/day are required to stop the stratification from developing during the warmer months of the year and to keep the run and riffle areas functioning by maintaining depth and wetted perimeter. It was suggested that such environmental releases could be made without necessarily consuming the water by simply changing the way the weirs are managed. However, further studies are required to determine the actual discharge required to achieve this.

The fauna report further suggested that such environmental releases could be made without necessarily consuming the water by simply changing the way the weirs are managed. Ideally the maximum benefit in terms of reactivating riffle and run habitats is to draw down Gyranda weir pool, keep it at a reduced water level, and then run the 'environmental flow' through the weir. This would reactivate riffle and run areas at the upstream end of the weir pool that are normally inundated. It would ensure that the entire bottom substrate was covered with aerated water in the shallower areas, and it would probably maximise the benefits in the deeper pool areas by reducing overall depth.

The attached report of these supplementary studies responds also to such questions as:

- how quickly does the deoxygenation develop once flow stops?
- are deoxygenation and temperature stratification in spring and summer natural phenomena?
- has the construction of the weirs on the Dawson and the flow regulation substantially increased the time during which deoxygenation events affect the river?
- what flows are required to break down the stratifications at least in the riffles, runs and shallow pool areas?

How would this affect natural stratification in deep pool

It was suggested that a series of experimental releases are required to accurately determine the flows needed to break down the stratification and to prevent it reforming during the critical Spring and early Summer period. Such study should be undertaken whether or not the development of the proposed Dawson Dam proceeds, as the data obtained from such study would provide an early guide for environmental flow strategies for other dams in Queensland.

Ideally several sites downstream of the release point should be monitored simultaneously with the flow at the monitoring sites. This would help translate the results into an environmental flow recommendation that took account of transmission losses and local variation in site responses.

7. Birds: wading and migratory

(S18, 22, 25, 38)

The great majority of the birds recorded during the fauna survey are considered to be forest or woodland inhabitants. Neither the impoundment area nor the area downstream has been identified in the literature as having any special attributes for migratory terrestrial species, the DoE Toowoomba Office did not indicate such a concern for the study area (Terrestrial Fauna Report Part A, page 1), nor did the field surveys undertaken by the Consultant suggest there was any special association of the area with migratory birds.

More to the point, Lake Murphy, which is a breeding area for water birds and of significance for migratory avifauna, is a declared Conservation Park. This area has special importance under the JAMBA and CAMBA international agreements to which Australia is a signatory. However, this Conservation Park is not impacted by the development proposal.

Wading birds downstream may be affected by the range of discharges from the dam and weir system, but it is suggested little different from the natural conditions expected of a non-perennial water course when the birds either use the margins of the weirs or fly elsewhere. The dam will provide a large expanse of water which will favour wading birds and other water birds.

I. SOCIAL ISSUES

1. Baroondah dam and upstream equity

(S9, 13, 21, 29, 35, 38, 47, 51, 55)

Several submissions reiterated concerns expressed frequently at the public consultations that the dam would provide no benefits to landholders in the Shire above Taroom. This was based on the understanding that the principal irrigation area to benefit was downstream of the dam. It was recognised that those landholders riparian to the impoundment would have access to water use but that this was a function of location and the existence of suitable lands for irrigation. For instance, properties near the headwaters of the impoundment may have suitable soils but for periods when water levels were lower than FSL, it may not be possible to access the storage to pump water to site. No public scheme was proposed by DNR or considered in the IAS.

The water demand study clearly identified a demand for water in the catchment above Taroom and this was considered in the IAS. Both the Baroondah and the IA studies identified the existence of significantly large areas of soils suitable for irrigation in the upstream area above Taroom.

The Consultant recognised the equity issue and on several occasions initiated discussions with the DNR to seek to resolve these concerns. As a consequence, the Consultant was requested to undertake an impact assessment scoping study to investigate the likely environmental and technical impacts of constructing a dam at Baroondah on the upper Dawson River. That scoping study concluded that:

- it would be possible to construct and operate a dam at either of the two sites investigated at 468.6 and 472.6 km AMTD;
- further investigations of fauna, flora, heritage, hydrology, technical design parameters, social and economic issues and land use constraints were required;

- significant areas of suitable irrigable soils currently used for grazing or dryland cropping (some limited irrigation) could be developed if reliable water supplies were available;
- based on the cost/ML of irrigation yield, the Baroondah dam, by itself or when considered as a package with the Dawson Dam, is uneconomic unless community benefit and rural, regional sustainability issues were taken into account; and
- there was potential for government-assisted development of off-stream, on-farm storage as an alternative to the dam, though detailed environmental, hydrological, technical and economic investigations were first required.

The major issue in considering this proposed package of two dams option was the significant hydrological impact that Baroondah Dam would have on the overall system yield of the river if built in association with a reduced storage above Nathan Gorge. There would be increased costs to all users from this proposal and an associated reduction in the efficiency of the system. On this basis, the use of off-stream storages in the upper catchment may be a more effective option with a commensurate alteration in the conditions of streamflow at which water harvesting could commence. DNR is currently evaluating an off-stream storage. Alternatively, water harvesting entitlements could be set aside for upstream users.

Were there to be a significant increase in upstream irrigated agriculture, it would be important that the managing authority (i.e. DNR) apply the same requirements to these new water allocation applications as are recommended for all new applications for water from the Dawson Dam, should it proceed. Otherwise, the major storage could be contaminated with nutrients and agri-chemicals from the newly expanded upstream agriculture. Thus, all new water users (both upstream and downstream) would have to develop a whole property management plan which set out soil suitability, farm layout, methods of water distribution and other management practices such as zero discharge and systems to prevent contamination of surface waters or groundwaters with agricultural chemicals. Obtaining a water allocation would be conditional on preparing such Land and Water Management Plans.

As part of the EMP which would follow a decision to build a dam, monitoring programs would be established to detect the early onset of groundwater issues such as raised watertable levels or contamination, as well as surface water quality deterioration. The responsibility for management of this would rest in part on both the landholder (ensuring compliance with the Licence conditions) and on the operator (i.e. DNR) to ensure that stream water quality was maintained. It is assumed that the EMP would have defined corrective actions to respond to emerging situations and that enforceable regulatory controls, such as (ultimately) Licence withdrawal, would be imposed.

DNR has acknowledged the importance of the equity issue in setting aside this amount of water and in seeking ways to assist landholders by investigating off-stream storage options. Modelling has also been undertaken to assess the impacts on streamflow and operation of the Dawson Dam should a landholder upstream of the dam be allowed to harvest a passing flood earlier than is currently permissible.

The Consultant has recommended the need for resolution of the equity issue but acknowledges the problems faced by DNR in implementing a suitable and economically viable solution. This is essentially a government decision based on resolving economic efficiency and equity issues.

2. Downstream impacts

(S21, 29, 31, 37, 38, 45, 47, 52)

The Dawson Valley Local Authorities of Taroom, Banana, and Duaringa, are responsible for the operation and maintenance of urban facilities in the study area for the IAS. However, the effects of the construction of a major storage on the Dawson River will be felt from Toowoomba and Roma northwards to Rockhampton and Gladstone. It is clear that there will be a positive flow-on impact in regional economic growth (see previous discussions on multipliers) as a consequence of the proposed dam.

These 3 Shires of Taroom, Banana, and Duaringa have a great potential for increased economic development. Urban development in the 19 towns of the 3 shires is restricted because of the lack of water, and the recent spate of water shortages and restrictions during the extended drought serves as a disincentive for investment in the area in new ventures, and does nothing to attract people to live in these rural towns.

At the assumed figure of 6 ML of water for 1 ha of irrigated cropping, the dam yield would permit a total of about 30,000 ha of additional cropping land at maximum development to be brought into irrigated production. Of this area, 5,000 ha could be supplied upstream of the dam. The remaining 25,000 ha would be downstream within the reach of the Dawson River from a point about due west of Cracow to Duaringa and the Dawson-Mackenzie junction..

With the construction of the dam and the realisation of that increased irrigation potential, an increase in population in the downstream area would be expected, but where that population will occur and the relative impacts on each town downstream of the dam is quite conjectural at this stage. This is because determination of dam size must necessarily precede the determination of system yield, and be decided in the context of the WAMP.

The Economic Analysis stated that every 1,000 ha of irrigation farming provides 32 jobs in the regional economy compared to only 8 jobs with dryland farming. Thus, if we assume an additional area of 30,000 ha, with 25,000 downstream and 5,000 ha around the dam, then there could be some 720 additional jobs generated in the regional economy. This is only a rough estimate because there is an inherent assumption that this 30,000 ha area is currently dryland cropping, when in fact a considerable area of it is grazing land.

Those 720 jobs themselves would have a further multiplier through families. However, the proportion of those jobs which would be generated in the Dawson Valley itself would be considerably less than the regional multiplier.

The expectations of a considerable increase in employment due to the dam in the downstream area should be tempered by the findings of the DNR Water Demand Study (1997) which indicated that the interest for additional water downstream, at the suggested price, comes mainly from existing farmers along or near to the river. There was also interest from prospective new farmers from outside the area. Thus the multiplier in the existing irrigation area might be smaller than otherwise anticipated.

a) Workforce/employment

The size of the workforce which will be required for the expanded agricultural production can be estimated when the size of the dam is known. Industry specific employment multipliers are available which are satisfactory for the broad purpose of the IAS for the anticipated additional agricultural and industrial activity.

Should the dam development proceed and when the dam size (the Full Supply Level) is specified, then the additional water yield available for consumption will be determined. That water yield will govern the area of additional cropping land which can be brought into production, and thus the additional workforce needs estimated, providing a realistic assessment can be made of the type of irrigated crops which will be grown, because the workforce needs and the timing depend on crop type. For example, the workforce required for irrigated cotton production is considerably lower than that required for horticulture, with a much greater workforce required for irrigated tree crops. However, the seasonal timing of crop production might mean that labour engaged on cotton production for part of the year might later in the season be employed on tree crops, for example at harvest.

This distribution of additional labour, and hence the towns in which immigrant labour might choose to reside with their families, will also depend on the take-up rate for irrigation, The DNR Demand Study indicates that the take-up rate will be very rapid, but which areas of the valley might move faster than others is purely conjectural. Thus, the distribution of the increased workforce in the downstream area can not be determined at this stage, and hence it would be nonsensical to attempt to specify additional health, education. and other service requirements which might be required by each town downstream of the dam at this point, in other than a general way.

b) *Economic impacts*

In the absence of a definitive yield data it is difficult to predict other than in general terms the likely level of economic development which will flow from the operation of the dam. Preliminary data indicate a rapid expansion of agricultural production by some 30,000 ha. Until the market place defines the relative distribution of this development in terms of cropping opportunities such as cotton, horticulture, tree crops and other alternatives including industrial development, it is not possible to assign likely growth and employment beyond the general multipliers referred to in the IAS.

There is a clear recognition of the need for increased housing, welfare and social services with the increased employment which will flow from the development. Once the growth potential is more accurately defined following the completion of the WAMP, it will then be possible for relevant government departments or agencies to adequately scope the likely increased demand for services in education, health and welfare, and other infrastructure such as transport and power.

This may also impact on other government departments such as DPI and DNR who will be required to provide support services to the expanded agricultural community.

3. Visual and aesthetic quality

(S52)

Any assessment of visual quality must necessarily be highly subjective. A vista over a large body of water would be as appealing to some people as the existing vista of a landscape highly modified for pastoral pursuits and agriculture is to others. It is not considered realistic to call for a detailed visual and aesthetic appraisal of the proposed dam and its surroundings based on value judgements under these circumstances.

4. Tourism

(S3, 18, 22, 28, 29, 50)

The Main Report and the Social Factors Report recognised the potential for tourism development and the flow-on economic opportunities for Taroom and the region associated with the water body created by the dam. It is unrealistic to suggest that the potential ecotourism value associated with the inundation of 50% of mound springs (at maximum development level) would outweigh the greater regional economic benefits due to agriculture, industrial and tourism growth.

The WAMP will provide the basis for the maintenance of environmental flows and ensure that there are manageable impacts on the estuarine area and marine resources. To suggest that the dam will have a measurable impact on maritime tourism is tenuous at best.

J. HERITAGE ISSUES

1. Glebe Homestead

(S3, 29, 32)

Submissions in general supported the IAS recommendations on the Glebe Homestead, and saw the recommended preparation and implementation of a conservation management plan as essential, whether or not the homestead had to be moved. However, the IAS referred to the relocation of the entire homestead precinct. One submission (S29) strongly disagrees with any attempt to relocate the entire precinct, referring to the inability to re-establish the precinct with the same connection to the river. The river connection would certainly be lost, but it is not inconceivable that a foreshore and dam vista might not be equally agreeable for the relocated precinct. It was also noted that the shearing shed which was possibly of greater heritage significance than the house has recently burnt down. The need to relocate the homestead obviously depends on the height to which the dam is constructed.

S32 also notes that if the homestead is relocated, then an archaeological survey of the house site should be undertaken before inundation. The original Glebe homestead which occupied the site burnt down in 1915.

2. Aboriginal

(S3, 18, 32, 34, 35, 37, 44)

Some submissions call for the protection of the entire 'Bundulla Aboriginal Reserve' *in situ*. There is an apparent misconception that the Taroom Aboriginal Reserve merely formed part of *Bundulla* station. The Taroom Aboriginal Reserve, which was split off from *Markland* Station, was originally (in 1909) only 686 ha in area, but this grew to 3,023 ha by the time the Reserve closed in 1927 (L'Oste-Brown *et al* 1995). *Bundulla* is the name today for the property on which the Taroom Aboriginal Reserve was located. Today *Bundulla*, 2,835 ha in area, is a well developed property suitable for cropping and cattle fattening, and a potential area for future horticultural production under irrigation. Note that *Bundulla* is smaller than the Reserve area. The Taroom Aboriginal Reserve, included the main settlement area (with offices, housing for officials, school, court house, jail, hospital, retail store, sawmill, girls' dormitory, horse yard, sheep yards, and cattle yards), Aboriginal camps, orchard, a large agricultural area, and two cemeteries, of which nothing remains apart from the cemeteries.

There is no point in reserving the whole property, as has been suggested, as the area has been ploughed and cropped for many years. Particular attention has been directed to the two Aboriginal cemeteries on the property, and especially Cemetery No 2 which lies closest to the river and would be half-inundated at 185 m FSL(See Map 26). There is full agreement by all parties that appropriate action be taken to protect the cemetery. With the co-operation of the owners, the need for further archaeological study of the old administrative centre and camp sites might be indicated, particularly in areas to be inundated, to supplement the work of L'Oste-Brown *et al* (1995, 1996). *Bundulla* is a Grazing Homestead Freeholding Lease with about 5 years to run under normal circumstances before it becomes Freehold.

The Aboriginal Cultural Heritage Study was undertaken under DNR auspices by a separate Aboriginal Consultant. Their field work (reconnaissance survey) was essentially confined to the inundation area, including some boggomoss areas, but extended outside the immediate impoundment to nearby ridge lines and similar features. Downstream, the Aboriginal study referred to Aboriginal settlements such as at Gibber Gunyah near Theodore. However, it is pure conjecture to state that the dam project is likely to have more impact on Aboriginal cultural heritage than is stated in the IAS report. Downstream areas which will be directly affected by water releases from the dam for environmental and irrigation needs have been regularly flooded (and severely) by natural flood events down the Dawson. The Aboriginal Cultural Heritage Officer which the IAS suggests be engaged for the dam pre-construction and construction phases would co-ordinate further field studies, with archaeological assistance. A further arrangement would need to be set in place in the EMP for the operation phase to ensure salvaged artefacts continue to be curated properly and Aboriginal cultural interests associated with the dam generally protected.

K. MISCELLANEOUS

1. Catchment management strategy

(S18, 25, 32, 42)

The Consultant has consistently recommended the need for a basin wide study to incorporate the development and operation of all storages and to consider all environmental, land use, biophysical, economic, social and other impacts. This was first recommended in the Paranui IASS and subsequently as a means of dealing at a 'big picture' level with the consequences of an incremental development of water resource infrastructure which had first commenced in the 1920s. Progressively, separate studies have been undertaken but no single study has ever attempted to pull together such a wide range of diverse and complex information in one appraisal.

This basin-wide study also suggested that a start be made on a co-ordinated approach to the collection of baseline data on a range of selected parameters (i.e. including water quality, fauna and flora) so that as other studies for proposals came on stream, there would be validated data available to the consultant at the time, thus obviating the need for the collection of data over a short time frame. Such data are always suspect in value as they are constrained by the timing, duration and nature of the project and generally fail to span a sufficient seasonal range to be representative.

It is worth noting that recent moves to establish a series of Catchment Co-ordinating Committees throughout the Dawson Valley are a positive step in this direction as such data collection projects could well constitute projects worthy of their attention.

It may well be useful to incorporate in some way, this group and their activities in the final EMP.

2. Downstream crossings on the river

(S56)

Impacts on river, tributary stream and property crossings in the impoundment area were discussed in the IAS report. A comprehensive list is tabled setting out the major access impacts but not including the numerous farm tracks which will need re-alignment. Major downstream crossings were not covered but were discussed in the Paranui report, with the exception of the Gyranda and Delusion Creek crossings which lie above Theodore and downstream of the proposed dam.

Large releases from Theodore Weir already impact on two crossings at Woodleigh and Nunns Crossing and these may require upgrading to improve access as any releases from the dam are likely to exceed present releases from the Theodore Weir. The Paranui crossing is already affected by the headwaters of the Moura Weir at full storage. This may also need raising if Moura Weir is kept at full storage for increased periods.

Until storage volumes (and, therefore, irrigation yields) and the environmental flow requirements are known, it is difficult to quantify the impacts on the other crossings on the river. It is probable that these crossings may need to be modified or raised to allow passage of larger regular flows than commonly occur at present. Any modification at the Delusion Creek crossing would have to be sensitive to the presence of the *Adclarkia dawsonensis* snail population identified as part of the fauna study.

3. Cumulative impacts

(S3, 18, 32, 34, 38, 41, 42, 44)

Several submissions refer to the need for cumulative impacts to be assessed down the downstream reaches. This is in line with the Consultant's recommendation for a basin-wide study to be undertaken (See Supplementary Report section K1 and K4). Such a cumulative impact study is clearly outside the parameters for the IAS.

Much of the modern literature makes reference to cumulative impacts, and to some extent, this has become part of the accepted terminology of catchment management studies. However there are no widely accepted, effective, methodologies for undertaking comprehensive and meaningful studies of cumulative impacts to deal with all issues of importance. For those issues where good quantitative data exist (or can be obtained), cumulative impact assessment can be modelled to produce results with a degree of confidence. However, a lot of data are qualitative in nature, and the treatment of such information is more difficult. It is easy, but unacceptably simplistic, to provide motherhood statements of cumulative impacts. As such an approach providing general statements of impact, which cannot be substantiated and quantified provides little meaningful direction to DNR, the Consultant did not adopt this line.

4. Fitzroy to reef

(S11, 17, 18, 22, 23, 25, 26, 31, 34, 36, 37, 38, 41, 42, 44, 53, 56)

The assessment of land use potential and environmental impacts was undertaken only as far as the junction of the Dawson and Mackenzie Rivers. This issue is also discussed in the *Introduction* section of the Supplementary Report.

It was not considered appropriate by the Consultant (and this was affirmed by DNR) that the assessment of impacts beyond the junction of the two rivers would provide any meaningful data to assist in definition of impacts due to the proposed Dawson River Dam. The principal reason was that '*... there are no credible* *baseline data available on system inputs from other sub-basins in the Fitzroy catchment (i.e. Mackenzie, Nogoa, Comet, Callide), or point and non-point sources to the Fitzroy River from the lower reaches. Therefore, only incremental inputs from the Dawson River could reasonably be considered. A further major consideration was the concurrent conduct of the WAMP for the entire Fitzroy River basin, data from which were expected early in the study.'*

The Consultant has acknowledged this issue throughout the IAS report and has recommended the need for a basin-wide study to deal with the cumulative impacts arising as a consequence of the progressive development of a series of storages in the Fitzroy system since the 1920s. A similar recommendation was also made in the reports on the proposals for the Paranui Weir and the Baroondah Dam. The scope of the study, the duration and the budget required would have to be greatly increased to allowed such a wide ranging investigation to occur. The acquisition of baseline data, if it is to be useful, takes many years and must cover a sufficient number of seasonal differences to be meaningful. The Government imperative for this dam, established initially in the 1995 *From Strength to Strength* statement under the previous Government did not allow for the collection of such time-dependent data, so existing information and that collected during the study had to be used. Nevertheless, the Consultant still believes that a broader study is required and a strategy was set out in the IAS Report (p267, K2) to this effect. It is acknowledged that some of these data will be acquired as part of the WAMP process but there are still issues besides the essentially hydrological and environmental parameters of the WAMP which need to be assessed.

It is not scientifically feasible to undertake a study on the Dawson River catchment and ascribe with any confidence impacts, arising as a consequence of the proposed dam development, on the Fitzroy and through to the estuarine area and out to the reef. The Dawson River represents only about 36% of the total catchment and the likely maximum additional area to be irrigated from the dam represents about 0.21% of the Fitzroy Catchment. The IAS, therefore, set out to determine any incremental impacts which could be attributed to the new development and to consider these as a point source input at the river junction.

This will permit future work to aggregate the inputs from other tributary streams and indeed runoff impacts from larger centres such as Rockhampton as part of an assessment of the total system.

5. Future additional studies

(S13, 15, 31, 32, 34, 37, 38, 56)

The consultant recognises the need for additional studies to extend the knowledge base to allow DNR and the government to make soundly-based decisions on the construction and operation of the dam. During the conduct of the IAS a series of studies were identified to assist DNR in its decision making process, including further sampling for seasonal variation. Several of these studies have already been acted upon by DNR eg the aquatic fauna, terrestrial fauna, flora, social impacts, and economics.

Section K of the IAS at page 267 *et sequo* details several recommended studies arising out of the IA study.

Some further investigations were recommended from associated scoping studies undertaken for a weir at Paranui and a dam at Baroondah.

6. Seismic studies

(S36, 38)

The ToR did not require any geotechnical investigations or an evaluation of dam design parameters. Preliminary design investigations were undertaken under separate contract and are reported in Russo (1995, 1996 in the IAS).

7. Agency inputs

(S31, 32, 52)

These submissions suggested that the Consultant contact a series of reference people for specific issues relevant to the interpretation of IAS findings and the development of the EMP. Discussions were held with the FYCC on issues raised in the submission and these have been accommodated to the extent considered necessary by DNR to finalise the IAS. The extent of detail referred to in most other cases is more appropriate to development of the final detailed EMP.

8. Review process

(S35)

It has been suggested that one way to facilitate the public review process would be to provide copies of the IAS report and accompanying documents on disk or CD-Rom. While acknowledging that this may assist perusal of the document, the Consultant does not support it.

The major concern is that the document could be used, altered or manipulated in such a way as to have the integrity of the document(s) compromised. This would be unacceptable to both the Consultant and to the Principal.

9. COAG

(S11, 18, 22, 23, 25, 37, 38, 41)

Several reviewers have suggested that the proposal may potentially breach various elements of the COAG Water Reform Agreement.

In the light of the outcomes of the IAS and other detailed studies undertaken by DNR, these suggestions appear to be baseless. However, in the opinion of this Consultant COAG, NCP and related issues are outside the scope of the IAS and are a matter for discussion with DNR and Government.

L. DRAFT ENVIRONMENT MANAGEMENT PLAN

(S11, 18, 21, 22, 24, 32, 42, 47, 56)

Several submissions dealt with apparent lack of detail in the EMP. It should be noted that, at the request of DNR, the EMP was only required as a draft document to indicate the major issues to be managed as part of the construction process and the subsequent operational phase. Until a decision has been taken to proceed with the dam and a range of design parameters established (i.e. location, height, FSL, yield ...) it is premature to develop final EMP statements as they could only contain highly conditional information or comprise a series of 'motherhood' statements. The latter would be unacceptable and therefore result in largely meaningless documents.

Several typographical errors in the draft EMPs have been corrected and recommendations for additional Elements in the EMP have been made. Uniformity of titling of responsible staff in the implementation section of the EMP will be addressed in the final EMP documents.

The Construction Phase relates to all activities in relation to the design and construction phase once a decision to build has been taken and a contractor appointed. Development of the final EMP will involve the contractor, the DNR, the community and other relevant government agencies and industry bodies. The construction phase continues until all preparation, construction, cleanup and site rehabilitation activities have ceased. Revegetation programs which commence as part of the site rehabilitation work will most likely be subsequently managed under the Operational Phase. It is probable that a 'warranty' period of perhaps twelve months will apply to the contract so that the costs for ensuring the rehabilitation work is successful will fall to the contractor.

The Operational Phase relates to all activities from the time of commissioning of the dam and continue for the life of the storage except for those EMP Elements which have a finite lifecycle. It is recommended that all Elements be reviewed at regular intervals to ensure that they are achieving the desired outcomes and modified if necessary. This process should involve the operator, the community, industry and relevant government agencies.

Other submissions pointed to the need for additional management plans or plan elements, or for a more detailed specification of the management actions under strategies already identified. These would be prepared at the time the detailed Operational Phase EMP is developed. They would include:

Aboriginal Cultural Heritage Management	a) Refinement of Strategy 1.1 in the Conservation Management Plan Element 1 Heritage and Archaeological Management b) a new Cultural Heritage Management Plan in the Operational Phase two strategies, one for Aboriginal Cultural Heritage and the second for European Cultural Heritage
Social Health Management Plan	
Macroinvertebrate Baseline	This should be included as and monitoring could be an action under Aquatic Fauna and Flora
Environmental flow monitoring	
Irrigation Management (a new	

M. ALLEGED CONFLICT OF INTEREST

(S18, 19, 22, 34, 37, 41, 42, 44, 50)

During the Public Review period, two allegations of conflicts of interest were promoted by certain interests.

The first, which was pursued by some respondents both in their submissions, and in the media, took the form of an alleged conflict of interest for the Consultant in that Hyder Environmental had been engaged to undertake the IAS (with the exception of boggomosses and aboriginal cultural heritage issues), while a separate arm of Hyder plc, Hyder Consulting, later became involved in a consortium bidding on an infrastructure development package for the Surat-Dawson Valley Basin. This ill-informed and malignant campaign caused both Hyder Environmental and its sub-consultants considerable concern.

The second area of expressed concern was an accusation of there being a conflict of interest within DNR with respect to the Dawson Dam IAS between the Resource Management Division and the Regional Infrastructure Development Group, in that RID were the effective proponents and RM were responsible for the IAS Review Process. A response to the two allegations is provided below.

1. Hyder Environmental Conflict of Interest

Several submissions either directly state, or imply, a conflict of interest of the Consultant in relation to the conduct of the IAS. This is an affront to Hyder Environmental's consultants and by association to the Hyder Environmental's team of independent sub-consultants.

It is clearly evident from the submissions which claim there is a conflict of interest (Refer Tables 1, 2) that there is a strong connection between the authors of these submissions.

These allegations are disturbing because the submissions were written well after a LMG meeting in Taroom, where Hyder Environmental made it patently clear that it had been subjected to a government-funded, independent probity audit and officially cleared of all suggestions of impropriety. A continuing campaign on this theme of conflict of interest, orchestrated through the media by some of those organisations responsible for the above submissions, has included personal attacks on Hyder Environmental's team.

A review of the sequence of events shows that the original contract for the IAS project was awarded in September 1996 to Axis Environmental Consultants Pty Ltd, an independent business entity under the global parent company Hyder plc, based in the UK. In September of 1996, Axis Environmental Consultants Pty Ltd underwent a name change to Hyder Environmental as part of the process of bringing all Australian business units under the parent company's name.

Hyder Consulting, an engineering and infrastructure arm of the company in Australia, and Hyder Environmental operate from the same business premises in South Brisbane. Hyder Consulting through its infrastructure investment interests has associated with a number of other private sector companies to form a consortium to bid on a range of investment opportunities in the Surat-Dawson Basin. This is in response to a Government initiative seeking private sector development in public infrastructure in Queensland.

The charge has been that Hyder Consulting gained an advantage over competing consortia because it had privileged access to information held by Hyder Environmental relevant to the Dawson Dam, while a possible private-sector construction of the Dawson Dam was part of the Surat-Dawson Basin investment package. Allegations that Hyder Environmental falsified the data to permit the dam to proceed to the benefit of the Consortium in which Hyder Consulting is a member. It would be sheer stupidity, apart from ethical considerations, for Hyder Environmental to saddle Hyder Consulting with an environmental disaster to manage. Also DNR suggested that if any bias in reporting could be detected it would be investigated. No instances were identified.

Hyder Environmental unequivocally states that it has not contributed in any way to the development of the Consortium's proposals in which Hyder Consulting has an interest.

Under the Company's Control System, Hyder Environmental manages and operates all security-classified projects under a secure part of the office IT network. The IT Manager has established Trustee Rights which exclude unauthorised users from that secure directory. This security cannot be over-ridden by anyone other than the IT Manager (who has restricted access rights to the server). No one in Hyder Consulting, from the Regional Manager downwards, can gain access to the secure directory. Additionally, Hyder Environmental staff working on security-classified projects like the Dawson Dam IAS have special password protection even within the secure directory which further ensures that only authorised persons can access sensitive information.

The only reporting systems within the Brisbane office between Hyder Environmental and Hyder Consulting concern the financial performance of the company, as financial control is co-ordinated nationally through the Sydney office for all of Hyder plc's Australian business. There is no unauthorised access in the IT network to technical information in relation to security-classified projects. Hard copies of reports on such projects and information not readily available in the public domain are held in locked cabinets.

So any claim of conflict of interest must infer that Hyder Environmental consultants engaged on the Dawson Dam IAS have breached security and provided classified information or documents to Hyder Consulting. That is a serious charge, and one in which the probity audit instigated by the Department of Economic Development and Trade (which controls the Surat-Dawson Basin initiative) found no substance whatsoever.

Hyder Environmental is and will remain an independent business unit within the overall Hyder plc structure. Its staff have high professional standards and enjoy a reputation for scientific integrity. There is no question of compromise for some perceived commercial gain.

Thus it was disappointing to Hyder Environmental to see the allegations of conflict of interest continuing in submissions on the IAS, despite the Government's public announcement that an independent probity audit had cleared Hyder Environmental of any charge of impropriety.

2. DNR Conflict of Interest

Several submissions have suggested that there exists within DNR a serious conflict of interest in that the project proponent (the developer) and the resource manager (the approval body) are one and the same.

The project proponent, Regional Infrastructure Development (RID) and the Approval Body, Resource Management (RM) are entirely separate business groups within DNR. In reviewing any IAS material, RM seeks input from a number of referred agencies such as DoE, FYCC, and DPI. These are all agencies of the State Government and could be accused with equal logic of having a conflict of interest.

The fact of the matter is that scientific data are provided from a number of sources including independent, professional consultants, and these are subjected to public review. Some components are subject to review by other independent consultants or agencies, such as Treasury. All Cabinet Submissions are reviewed by line Departments before a decision is made by the Government.

IV. IMPACT OF SUBMISSIONS ON MAIN REPORT FINDINGS

The Consultant has undertaken a comprehensive evaluation of the 56 submissions received as part of the public review process. Significant typographical mistakes and errors of fact identified both by the consultant and these submissions have been addressed in the Supplementary Report. Where necessary additional work has been undertaken to further investigate or clarify issues of concern. The outcomes of these investigations are reported in the supplementary report in the general sections or separately as in the case of the revised Final Economic report which is attached to this document.

DNR Resource Management has separately undertaken an evaluation of the IAS and additionally sought advice from Queensland Treasury in relation to the economic analysis. Queensland Treasury has advised that, overall, the conduct of the economic assessment was sound. (See Appendix 2)

Throughout the Consultant's evaluation and preparation of this supplementary report close liaison has been maintained between the DNR Resource Management officers and the Consultant to ensure that all matters of substance were adequately addressed and in a manner that would meet the requirements of the review process.

The Consultant has commented on all matters where appropriate, undertaken additional map interpretation, recommended additional work as necessary and clarified issues where these were unclear or perhaps ambiguous to the general reader. This information, together with the revised Economic Report and the additional Aquatic Fauna studies report are provided in this Supplementary Report.

The Consultant has concluded that there are no substantial changes to the conclusions of the original draft IAS with the exception of revised economic performance. However, as this is still strongly positive, it does not materially affect the outcomes of the initial report.

V. ERRATA TABLE

This Errata table does not address minor editorial errors, such as spelling or grammatical mistakes, but attempts to correct errors of fact or, to rephrase wording which is ambiguous or can be otherwise misconstrued, and in a couple of instances to complete sentences from which some material had inadvertently been deleted and had been robbed of their meaning as a result.

Main Report

Page No.	Section/Para/Table	Correction
35	last para	For *mitigate* read *militate*
39	para 8	10 m up Nathan Wall
3	Third dot point	Replace single asterisk after Department of Families, Youth and Community Care with a double asterisk
8	para 5	Read 19 October 1996 and 17-19 April 1996
9	6.b)	For *Social Impacts Report* Read *Social Factors Report*
16	2 para 1	Read: *"Environment Protection (Impact of Proposals) Act 1974*
17	4. para 2	Insert new para after para 2 to read: ***National Principles for the Provision of Water for Ecosystems,*** *ARMCANZ/ANZECC Report 1996.*
19	Table 2	Caption for Table 2 should read: *"The scaled agricultural demand for water by Dawson Valley sector for different scenarios (Rolfe and Teghe, 1997)"*
196/197	c) para 2/1	Jeff Lloyd is a Senior Hydrologist, DNR, Rockhampton
39	D. para 1	Read under Gyranda Weir: *"This would raise capacity to 22,300 ML increasing yield by 7,000 ML (Russo, 1996), but the enlarged weir pool would flood a large area of productive land... ".*
40	E. para 3	Delete "and gate heights". Read: *with a maximum FSL 185 m, gate heights of 7 m, 8 m, and 9 m, the dam crest would be... "*
43	D. para 2	Read: *"... about 14 m"* not *"about 14 km"*
44	3.	Insert *disposed of* in line 3 to read *"...facility or disposed of according to Taroom Shire Council requirements."*
47	H.	The last sentence is incomplete. Read *"... straight on to the Newell Highway in NSW, and could make the proposed dam an important component of an appealing tourist package for the Taroom area."*
64	1.a) para 2	Insert new sentence after Table 23. *Map e was derived from a reinterpretation of mapping by Forster 1985.*
72/73	Tables 29/30	Add to the Table captions: "*- in a 5 km wide strip either side of river*
92	Table 41	Add note to foot of table: *Nathan Gorge gauging station closed in 1986, and Glebe Weir data were used from that time to 1997*
116	e)	Read instead of Table 1, *Appendix 4*
11	2	Read instead of Table 1, *Appendix 4*
117	2.a) para 3	Read instead of Table 1, *Appendix 4*
118	b)	Read instead of Table 1, *Appendix 4*
118	d) (1)	Read instead of Appendix 4, *Appendix 5*
137	para 2	Last sentence read: *" Details on the boggomosses area presented separately."*
148.	b)	Read: *"For example, in 1996 in Taroom Shire, 1,639 persons or 60% lived outside the main townships of Taroom and Wandoan."*
167	para 3	Read *Reflecting* not *reflected*
180	4.c) para 2, 3rd dot	Add: *The 25 GL here refers to a high security supply of water (HNFY). Table 8 refers to 35 GL at 85% monthly reliability. The 25 GL at HNFY is equivalent to about 35 GL at 85% reliability (Refer page 23, para 2).*
194	Tables 84/85	Alter Table numbers to *Table 85A* and *Table 85B*.
194	c)	Alter Table 87 to read *Table 86*
197	a)	Repeated phrase. Delete one *the bottom of the dam.*
198	C.1.	Alter Table 88 to *Table 87*

204	last line	Alter Table 89 to *Table 88*
207	para 1	Alter Table 90 to *Table 89*
207	para 2	Alter Table 91 to *Table 90*
209	para 3	Alter Table 92 to *Table 91*
217	E.1. para 3, 3rd dot	Read *"the loss (at EL 185 m) on the inundated boggomosses, and"*
218	c) para 1	Alter Table 89 to *Table 88*
219	E. 1 first dot point	Read *tailwaters* not *tailgaters*
219	E. 1 third dot point	Read: *"the loss of vegetation on inundated boggomosses, and"*
219	E. 1. Last para	Read: Some 50% of the 69 boggomosses...will be flooded at the maximum 185 m FSL, including...".
226	E.3.b) para 3	Read: *"The remaining standing vegetation of no salvage value should be pulled, and the heads from salvaged trees, together with the sawn-off heads of pulled trees and other leafy material heaped and burned, and subsequently, if necessary, reheaped and reburned. The boles of the non-commercial trees should be left in situ to provide fish habitat."*
227	d) para 2	Read" *if further field survey is undertaken...* "
227	last para	Read: *"On the basis of the original dam site and the 185 m FSL, Fensham and Wilson (1996) concluded that 6 out of 12 boggomoss populations... "*.
231	3.a)	Alter Table 18 to *Table 92*
231/233	last para	Misalignment of bullets: Insert bullet for *"The discharge of the aquifer system... "*, delete bullet before *"though the deep drainage water... "*
233	G. 1. para 1	Alter Table 94 to *Table 93*
249	b) para 2	Read: " *as dam size decreases to the 180 m EL contour level... "*
254	r) para 1	Read: *"The property can carry 1000 - 1200 head of fats now... "*
257	para 1	Alter Table 93 to *Table 94*
260	para 2	Read: *"... through which local people have been consulted. In response to this situation, the DNR established a local Dawson Dam project liaison office in Taroom... "*
261	a) para 2	Read: *"To integrate a short-term workforce into the local community, but... "*.
261	7. last para	Read: *"If children have to travel daily from a camp near the dam site... "*.
270	L.1 para 3	Delete A. to read *"DNR should establish... "*
278	last para	Correct upstream irrigation area figure. Read *"This would permit a further 5,000 ha of suitable land ... "*.
279	para 4	Read: *"The site of the Taroom Aboriginal Reserve (Bundulla) has significance for both European and Aboriginal people... "*.
280	para 1	Read: *"... to equate to regional ecosystems and four were... "*.
282	para 7	Read: *"There is public concern expressed that, with the construction of large dams, the Fitzroy system... "*.

European Cultural Heritage Report

Page No.	Section/Para/Table	Correction
19	6.1.11	para 1 For "...sold it to Dick Williams" read: *"... sold it to Billie Williams."*) para 2 For "...between the present Llewellyn home and the Glebe Weir Road" Read *"... between the present Llewellyn home and the Leichhardt Highway."*)
19	6.1.13 & 6.1.14	For Keil, read *Kehl*
21/22	6.1.21 & 6.1.22	For "...when the Rigby properties were auctioned off in 1958", read " *when the Ribgy properties were sold in 1958"*.
24	5.	For "It was constructed in 1976." read: *"Construction was completed in 1972."*
24	3. para 1	Correct to read: *"It has never run dry and is equipped with a pump with an output of 700 gallons per hour and waters approximately 500 head of grown cattle."*
28	6.2.10	For "Interiors lined with beaded cypress tongue & groove boarding." read: *"Interiors are lined with shiplapped cypress boarding."*

Social Factors Report

Page No.	Section/Para/Table	Correction
5	2.1.4 para 2	Read: *"Since the closure of the Taroom Aboriginal Settlement… ".*
7/8	2.1.7 Table 6	Add to the left-hand column under *Professional Services* Pharmacist. Add to the right hand column of Table 6 the following: Under *Urban Facilities,* add Taroom Shire depot and workshop, and under *Sport Facilities* add: Pistol Range, Football Grounds, Rodeo Arena, and Polocrosse Field.
15	3.1.1/para 4	Read: *Landholders Affected by Nathan Dam* not Landholders Against Nathan Dam.
57	3.4.3.2	In the RH Comment column, the comment should be inserted against M. Becker, *Spring Creek,* that *"Six watering points will be lost plus one pump on the river that feeds water to a turkey nest dam which supplies water to all watering points west of Spring Creek."* (It should be noted that Section 3.4.3.2 is prefaced by the statement that the information had been provided by landholders to the DNR liaison officer in Taroom and that the information might be incomplete.)

EMP Report

Element No.	Strategy	Correction
4	4.1, item 8	Read: *"Encourage landowners to practice conservation farming techniques and minimise stubble burning".*

APPENDIX 1

APPENDIX 1

SUB-CONSULTANT LETTERS ON HYDER ENVIRONMENTAL'S TREATMENT OF THEIR WORK

APPENDIX 1

SUB-CONSULTANT RESPONSES

The following responses were provided by Hyder Environmental's sub-consultants at the request by the Dawson Valley Development Association, Inc. in order to satisfy the concerns of Management Committee Members that Hyder Environmental had indeed faithfully represented the work and findings of its sub-consultants.

Statements were received from the following sub-consultants and immediately passed on to DNR for their transmission to the DVDA. The DVDA acknowledged receipt of these statements on 11 February 1998. That letter is also attached.

Sub-Consultant	Organisation	Input
Ralph Dowling	Department of Environment.	Flora
David Halford	Queensland Herbarium	
Ailsa Holland		
Ian Whan	Alliance Resource Economics	Economics
Tonia Walker	Consultation and Liaison Services	Community Consultation - within
Terry Paxton		Social Factors Report
John Stanisic	Queensland Museum	Terrestrial Fauna - Part B
Glen Ingram		
Ann Wallin	Ann Wallin & Associates Pty Ltd	European Cultural Heritage
Michael Strong		
Sharmil Markar	Water Studies Pty Ltd	Hydrology

A response to an earlier request to John Anderson of Southern Cross University who undertook the Aquatic Fauna surveys is awaited. Dr Anderson has since completed a Report on Supplementary Aquatic Fauna Surveys which is published with this report.

A further consultant, Dr Amy Jansen, who prepared Part A of the Terrestrial Fauna study in 1996 could not be contacted. She has moved interstate.

GI:JT

museum

Hyder Consulting

17 DEC 1997

SM

~~DO~~

FILE

ACTION

Tuesday, 16 December 1997

Mr Stuart Macnish
Hyder Consulting
(Australia) Pty Ltd
Level 1, 27 Peel Street
SOUTH BRISBANE QLD 4101

Dear Stuart

Many thanks for your letter of 6 December. As to the affirmation you seek the document titled "Impact Assessment Study for proposed Dawson Dam Terrestrial Fauna Part B" is a replica of the report "Dawson Dam Impact Assessment Study. Terrestrial fauna Supplementary Report" prepared by us for Hyder Environmental. As to Dr Thistlthewaite's preface on page 1, we feel his summary is excellent and does not misrepresent our findings.

Yours sincerely,

Dr Glen Ingram
Senior Curator
Vertebrate Section

Dr John Stanisic
Senior Curator
Malacology

Queensland Museum: PO Box 3300 SOUTH BRISBANE Q 4101 Ph: (07) 3840 7635 Fax: (07) 3846 1918 www.Qmuseum.qld.gov.au
At the Queensland Cultural Centre, South Bank and the following branches: Queensland Sciencentre Brisbane Museum of Tropical Queensland Townsville Cobb & Co. Museum Toowoomba WoodWorks Museum Gympie Museum of North Western Queensland Mount Isa Lands Mapping and Surveying Branch Brisbane

ANN WALLIN
& ASSOCIATES PTY LTD
ACN 072 525 725

CULTURAL HERITAGE CONSULTANTS

Hyder
Consulting
16 DEC 1997
SM
FILE:
ACTION

Stuart Macneish
Director
Environemnt Queensland
Hyder Consulting
PO Box 3799
South Brisbane 4101

15 December, 1997

Dear Stuart

As far as we can see, the final report of the Nathan Dam Cultural heritage assessment (European CHS), accurately reflects the report given to Hyder at the completion of the project, together with subsequent changes discussed with Bob Thistlethwaite from time to time.

The report relied on oral comments from a number of property owners and every effort was made to ensure the accuracy and consistency of these.

Yours sincerely

Michael Strong
ANN WALLIN AND ASSOCIATES

Clare Place PO Box 333 The Gap Qld 4061 Telephone 07 3300 1080 Facsimile 07 3300 3830 E-mail AnnWallinandAssoc@on australia.com.au

Alliance Resource Economics
ACN 080 640 704

Consulting

REC'D
18 DEC 1997
SW
FILE:
ACTION

16 December 1997

Mr Stuart Macnish
Director Environment Queensland
Hyder
PO Box 3799
South Brisbane Qld 4101

Dear Stuart,

I have studied the Hyder *Economics Impact Assessment Study* (October 1997) for the proposed Dawson Dam as initially prepared by myself and wish to report I found no changes of any substance.

Yours sincerely

Ian F Whan

Ian F Whan
Managing Director

19 Brereton St, PO Box 3112 South Brisbane Qld 4101
Telephone: 07-3255 0811 Facsimile: 07-3844 5501
email: <iwhan@ozemail.com.au>

Consultation & Liaison Services

Stuart Macnish
Director of Environment, Qld
Hyder Consulting Pty Ltd
P.O Box 3799
South Brisbane, Qld 4101

Dear Mr Macnish,

As requested I have examined that section of the "Social Factors, Impact Assessment Study for the Dawson Dam", prepared by Consultation and Liaison Services, (Section 3.2 to section 3.2.8, inclusive) and compared it with the documentation provided by us to your company and found it accurate, in letter and spirit, in representing our findings.

I trust this is all you require of us at this time

All the Best

TERRY PAXTON
<u>Community Consultant</u>

Hyder Consulting
RECD
16 DEC 1997
FILE:
ACTION

Ph 61 7 3844 1220 Fax 61 7 3846 1941
PO Box 5596 West End Qld Australia 4101
Email twalker@ca.com.au

LR A&M
LAND RESOURCE ASSESSMENT AND MANAGEMENT PTY. LTD.

22 December 1997

Mr Stuart Macnish
Director Environment Queensland
Hyder Consulting (Australia) Pty Ltd
PO Box 3799
South Brisbane QLD 4101

Dear Stuart,

IMPACT ASSESSMENT STUDY for PROPOSED DAWSON DAM

I have perused the a copy of the Hyder Environmental report titled "Impact Assessment Study for Proposed Dawson Dam" which is based largely on work originally prepared by me.

I believe the Hyder report faithfully reflects in all matters the material that I initially submitted.

Yours sincerely,

PJ Shields

Peter Shields
Director

LAND RESOURCE ASSESSMENT AND MANAGEMENT PTY. LTD. PH: (07) 3849 2874
38 PAREENA CRESCENT, MANSFIELD, BRISBANE QLD. 4122 FAX: (07) 3219 4135
ACN 059 780 602

WATER STUDIES
59 CAIRNS TERRACE RED HILL QUEENSLAND AUSTRALIA • PO BOX 80 RED HILL 4059 AUSTRALIA

J 580

12th December 1997

15 DEC 1997
SM.
FILE:
ACTION

Stuart Macnish
Director
Environment Queensland
Hyder Consulting (Australia) Pty Ltd
Level 1, 27 Peel Street
SOUTH BRISBANE Q 4101

Dear Stuart,

Subject: Dawson Dam Impact Assessment Study

As requested, I have perused my report and the main report prepared by Hyder Environmental on the Dawson Dam Impact Assessment Study. I am satisfied that all matters of substance in the material provided by me are accurately represented in the above reports compiled by Hyder Environmental.

Yours faithfully,

SHARMIL MARKAR
DIRECTOR
WATER STUDIES PTY LTD

TELEPHONE +61 7 3369 6499 • FACSIMILE +61 7 3368 1466
EMAIL wstudy@waterstudies.com.au • WEB http://www.waterstudies.com.au
WATER STUDIES PTY LTD
A.C.N. 010 476 294

DAWSON VALLEY
DEVELOPMENT
ASSOCIATION INC.

The Boulevard
P.O. Box 165
Theodore Q. 4719
Ph: (079) 93 1855
Fax: (079) 93 1887

Hyder
Consulting
REC'D
20 FEB 1998
FILE:
ACTION

February 11th, 1998

Mr Stuart Macnish
Hyder Consulting Pty Ltd
PO Box 3799
SOUTH BRISBANE Q 4101

Dear Stuart

On behalf of the Management Committee and staff of the Dawson Valley Development Association, I would like to thank you for the efficient way in which you handled our queries (which were directed to you by DNR) regarding the Impact Assessment Studies for the proposed Dawson river dam.

We are most grateful for the information you provided, which directly addressed the concerns of Management Committee members.

Thank you once again for your assistance.

Yours sincerely

Kevin McConnell
President.

APPENDIX 2

APPENDIX 2

QUEENSLAND TREASURY RESPONSE TO DNR RESOURCE MANAGEMENT'S REQUEST FOR REVIEW OF THE IAS ECONOMIC ANALYSIS

QUEENSLAND TREASURY

FACSIMILE

Economics Division
100 George Street
BRISBANE Qld 4000

To: **Ken Watson**
Regional Infrastructure Development
Department of Natural Resources

Fax: (07) 3224 8205

From: **David Smith**
Assistant Under Treasurer
Economics Division

Phone: (07) 3225 8226

Fax: (07) 3210 0814

Date: 27 February 1998

No. Of Pages (inclusive) 6

Subject: Supplementary Report on the proposed Dawson Dam

I refer to my previous comments on the economic impact assessment on the proposed Dawson dam and your request to permit the consultants Hyder Environmental to use it in their supplementary report.

In general, I have no objections to the use of these comments in Hyder Environment's supplementary report. However, I would like to make the following change to the report to clarify our position.

p16. last paragraph. The last sentence should read:

"Their review pointed out that some assumptions stated in various submissions on environmental costs could not be substantiated. However, Treasury found that the project showed a net benefit even when these assumptions were used."

I understand that Attachment 2 of the report contains the Treasury's comments as of 12 February on the October draft of the report. I have provided since then comments on the 25 February on the final version of the report to Terry Loos in Resource Management. The latter comments acknowledge some of the changes made in the final report. It would be more appropriate to use these comments in the supplementary report. These comments are attached for your information.

Yours sincerely

(D J Smith)

Sent 25/2/98.

QUEENSLAND TREASURY

FACSIMILE

Economics Division
100 George Street
BRISBANE Qld 4000

To: **Terry Loos**
Manager (Environmental Coordination)
Resource Management
Department of Natural Resources

Fax: (07) 3224 2270

From: **David Smith**
Assistant Under Treasurer
Economics Division

Phone: (07) 3225 8226

Fax: (07) 3210 0814

Date: 25 February 1998

No. Of Pages (inclusive) 4

Subject: Comments on the Final Report of the Dawson Economic Impact Assessment

I refer to the final report of the Dawson Economic Impact Assessment prepared by the consultants, Hyder Environmental for the Department of Natural Resources (DNR). I understand that you are seeking Treasury's comments on the report and that it is your intention to quote these comments as part of your review of this report. You will find my comments on the report appended at Attachment A.

My main comments are as follows:

Overall, the methodology of the Dawson economic impact assessment is sound. The project, as assessed, demonstrates a net positive economic benefit for certain combinations of environmental flows and elevation levels.

The viability of the scheme, as assessed, is heavily dependent on the continued profitability of cotton and horticulture in the region and would be sensitive to movement in product prices. Further, the viability of the scheme is likely to improve if the analysis adopts a project life longer than 20 years to reflect the permanent nature of dam constructions.

A discount rate of 8 per cent would be more appropriate where economic viability is being tested (rather than selecting between alternative proposals).

Yours sincerely

(D J Smith)

ATTACHMENT A: DAWSON DAM

The Department of Natural Resources (DNR) is undertaking a series of studies to assess the overall impact of a proposed dam on the upper Dawson river. As part of this impact assessment process, DNR has sought an independent consultant, Hyder Environmental, to report on the economic impact of the proposed scheme. A draft report was released in October 1997 for public consultation and DNR received 56 responses to that report, including criticisms of its methodology. The final report was released in February 1998 and incorporates some of these criticisms. DNR has asked Treasury to review the economic evaluation and provide comments to DNR regarding the methodology of the final report. This attachment will address these issues.

The report assesses the overall net economic impact from the proposed construction by measuring the expected benefits of the project to irrigators with the direct costs, costs of lost opportunities and environmental costs of the scheme. The report provides multiple scenarios to accommodate different full supply levels, different reduction in yields for environmental flows and the possible development of a coal-fired power plant.

The report determines the expected benefits to irrigators by calculating the increase in net profits as a direct result of an increase in irrigable land. This is done by assuming a crop mix of horticulture and cotton and applying an expected level of profits for these two crops. Some submissions note that these assumptions are unrealistic.

- The Department of Primary Industries would be best placed to confirm these assumptions. However, they appear to be reasonable for several reasons. Water should move to its highest valued use provided the scheme incorporates an effective water pricing, allocation and trading system that encourage individual irrigators to grow crops that will offer the highest returns. Historically, it is difficult to determine, prior to construction, what crop mix would eventuate. Given the previous surveys have indicated that there is likely to be a high demand for water by cotton growers, this assumption would be based on current available information.

  Accepting such an assumption, it is important to note that the viability of the scheme as assessed is heavily dependent on the continued profitability of cotton and horticulture in the region. As calculated, the economic benefit would be sensitive to changes in product prices.

  Also, it would be prudent to note the following issues in the cotton industry. Indonesia forms 28% of Australia's cotton export market. The economic conditions in Indonesia are likely to adversely impact on Queensland's existing cotton sales. Relative to the life of the project, this would present a source of uncertainty in the short to intermediate term. In addition, DPI is concerned that the resistance of heliothis to insecticides is high and growing such that the future of the cotton industry in Central Queensland is not guaranteed in the medium term.

The report applies a discount rate of 6 per cent to determine the economic benefits of the proposed scheme. The report suggests that this rate reflects the low interest rates applicable in the late '90s. The report also provide sensitivity analyses for different rates of discount and concludes that 8 per cent would not significantly threaten the economics of the project.

- While the Treasury Project Evaluation Guidelines specify a discount rate of 6 per cent to facilitate the comparison and ranking of projects within and between portfolios, a discount rate of 8 per cent would be more appropriate where economic viability is being tested (rather than selecting between alternative proposals).

The report assumes a finite project life of 20 years as it suggests that the project will have to prove its economic worth in a comparatively short time span, to be deemed socially acceptable.

- This assumption appears to be excessively restrictive. It may be more appropriate to consider the project within a longer timeframe. If properly maintained, dam constructions are generally regarded as permanent structures. As the costs of the project are predominantly expended in the construction phase and the returns of the project continues throughout the useful life of the scheme, extending the life of the project will increase the overall net benefit of the project (though future benefits are less certain and thus have diminishing impact). For example, increasing the finite project life to 30 years at a discount rate of 6% under the report's case 1 scenario would add $112 million to the net present value of the project and increase the cost benefit ration to 3.03 (from 2.28), significantly boosting the attractiveness of the scheme.

The report attempts to account for some of the indirect effects arising from the project, including the opportunity costs of the scheme. Several submissions, however, cited externalities that are not incorporated into the report. Some factors, if included, would improve the social returns of the scheme, including the benefits from flood mitigation and the recreational benefits from the project. Other factors would reduce the overall social returns, such as a loss of habitats and heritage areas and adverse effects on downstream industries.

- Generally, the costs of externalities are very difficult to measure reliably. Several submissions offer contingent evaluations as a means of quantifying the costs of heritage and environmental externalities. However, contingent valuations tend to overestimate the overall effects. Officers in the Department of Primary Industries (DPI) note that there is insufficient information to quantify reliably these external effects. Another submission quantifies the costs of externalities, such as the potential costs of blue-green algae cleanup, and impacts on the downstream fishing industry and costs of a fish ladder. The total net present value of these externalities, as provided, equals $39 million for a 20 year period. Its inclusion in the analysis would not make the scheme uneconomical. Also, as the values for such effects as the clean-up of blue green algae and the impacts on the downstream fishing industry are not substantiated or sourced from other material, caution must be exercised in the use of these figures.

The distribution effect refers to the differing levels of impact on different sections of the community. Naturally, the community costs of the Dawson scheme would be more concentrated in the areas to be flooded. Several submissions note that the report does not examine adequately the distribution effects of the project, citing the existence of a net positive benefit in itself is not sufficient to guarantee that a project would improve overall community welfare.

- For the purpose of an economic impact assessment, demonstration of a net economic benefit over costs would be sufficient if all relevant costs are accommodated in the overall analysis. Governments have the option of redistributing the gains to compensate individuals who have been disadvantaged by the scheme. However, issues regarding the appropriate means of compensation should be considered separately and only after demonstration of a net economic benefit.

Contact: Bruce Wan
Division: Economics
Telephone: (07) 3224 4544
Doc Id: I:\DIVDATA\WP98\MICRO\NDDEV\F2WATER2.BW

APPENDIX 3

APPENDIX 3

DNR INSTRUCTIONS

15 September 1997

6060
Contract

The Queensland Manager
Hyder Environmental Ltd
Level 1 27 Peel Street
SOUTH BRISBANE QLD 4101

ATTENTION: MR STUART MACNISH

Dear Mr Macnish

DAWSON RIVER DAM - TERMS OF REFERENCE FOR IMPACT ASSESSMENT STUDY

I refer to the Terms of Reference (ToR) for the Impact Assessment Study (IAS) of the Dawson River Dam proposal and specifically to Sections 6.4 and 7.4 which deal with the hydrology of the area expected to be affected by the construction and operation of the dam.

The expectation at the time of drafting the ToR and the IAS consultancy brief was that the Water Allocation Management Planning (WAMP) process for the Fitzroy River Basin would have, by early in the IA process, progressed to the stage where interim results could have been provided to the consultant for use in the study.

However, the WAMP process and the hydrologic model for the system have turned out to be far more complex than originally thought. This has resulted in substantial delays in the provision of hydrologic information for the conduct of the IAS.

Following joint discussions with Hyder Environmental to resolve this continuing dilemma and to seek a way to finalise the IAS, our letters of 3 and 23 July 1997 instructed that, given this situation, the impacts of a range of environmental flows be addressed by reducing the incremental system yield in steps up to 50 per cent. This would then allow those aspects of the IAS which require, as input, details of the amount of water available for consumptive use (eg economics and land resources) to proceed.

A further issue which has become clearer as the WAMP process proceeds concerns the extent of the interaction between the WAMP and the IA processes.

Enquiries to: Ken Watson Your Ref: Our Ref: (:)
Mineral House, 41 George Street, GPO Box 2454, Brisbane Q 4001
Telephone (07)322 47662 Facsimile (07)322 48205

When the ToR were being drafted, the extent of the interaction between the two processes was unclear. It has since become evident that some specific dot points of the ToR are conflicting in that they should be addressed specifically in the WAMP process rather than the IA process.

These processes are to a certain extent independent; the WAMP being generally a 'whole of basin' process which is undertaken on a far greater scale than is an IAS for an individual structure on a watercourse within a catchment.

In order to avoid a duplication of effort and to allow the IAS to proceed to a satisfactory completion independently of the WAMP process, which has its own program and community consultation phase, some variations to relevant sections of the ToR dealing with hydrology are considered necessary.

Terms of Reference, Section 6.4

Fifth dot point

It is now clear that the flow rates required to satisfy environmental flow requirements will be dealt with under the WAMP process and this should be stated when addressing this point. This part of the IAS report need therefore only be addressed in an overview summary as discussed verbally on 9 September 1997.

Terms of Reference, Section 7.4

Second dot point

While the IAS should address the potential effects of the proposed development on any upstream wetlands, downstream wetlands are an issue for the WAMP process and this should be stated when addressing this point.

Third dot point

While the IAS should address the potential effects of the proposed development on any upstream flood plains, downstream flood plains are an issue for the WAMP process and this should be stated when addressing this point.

Sixth dot point

The development of an environmental flow release strategy will clearly be dependent upon the outcomes of the WAMP process and this should be stated when addressing this point.

The IAS could suggest flow characteristics/patterns, necessary for the survival of aquatic species, which would need to be addressed in the WAMP process but again, the Technical Advisory Panel to the WAMP will do this.

Eighth dot point

The effect of the environmental flow regime on yield will be addressed by the WAMP process and this should be stated when addressing this point.

The IAS could refer to our letters of 3 and 23 July 1997 to outline the steps taken to complete the IAS given the delays in the WAMP process.

Please proceed with the conduct of the IAS on this basis.

Yours sincerely

W Eastgate
EXECUTIVE DIRECTOR
REGIONAL INFRASTRUCTURE DEVELOPMENT

ATTACHMENT 1

DAWSON DAM IMPACT ASSESSMENT STUDY

ECONOMICS

Final Report

by

Ian Whan
Alliance Resource Economics
PO Box 3112, South Brisbane, 4101

Prepared for Hyder Environmental
February 1998

PREFACE

This report presents the economic impact assessment study for the proposed dam on the Upper Dawson River. The first draft, which was completed in December 1996 addressed the original Terms of Reference specifying a dam site located at 313.9 km AMTD, about 0.5 km upstream of the Nathan Gorge, and a maximum Full Supply Level of 185 metres elevation.

The need to examine a range of dam sizes up to the maximum FSL and a decision by the Department of Natural Resources to move the dam axis to a site 1.4 km further upstream at 315.3 km AMTD to reduce environmental impacts, necessitated re-analysis of the economics. In mid 1997, DNR also requested that a further FSL of 183.5 m EL be considered by the analysis.

A report with the above inclusions, was released for public comment in October 1997. This report incorporates feedback from the public review process and is identified as Final Report, February 1998.

The analysis has attempted to determine the value of the Dawson Dam proposal to the total community, not merely at the local level. This has been done by inclusion of all private and social impacts expected to stem from usage of the water for irrigated agriculture and industry.

The analysis addressed 40 combinations of dam size, environmental flow allowances, and a with and without a power generation option. Lack of information regarding the economics of water-cooled power generation mean the net present values generated for the 'with power' option should be interpreted with caution. However it is safe to assume that the power generation option would improve the overall economics of the project.

On the basis of the analysis it is concluded that the proposed development of a single large dam on the Dawson River is economically sound. Indeed the economics of the project are sufficiently robust to absorb likely adverse movements in key production parameters such as commodity prices, water take-up rate, and costs and yields. The capacity of the project to absorb downside risks will be assisted by achieving an optimal balance between the availability of commercial water and some allowance for environmental flow.

The analysis identified a 'likely zone', from which the dam configuration should be chosen. The 'likely zone' was based on an environmental allowance in the range 10-30% of total yield. From this 'likely zone' a selection could be made that would be both environmentally and economically sound.

The analysis discards as completely uneconomic any proposal for a series of small weirs as an alternative to a single large storage.

The economics of the project were assisted on this occasion by use of a discount rate of 6%, reflecting the low interest rates applying in the late '90s. A sensitivity analysis found that increasing the discount rate to 8% would not significantly threaten the economics of the project.

Given the reality of low interest rates and the growing pressure on water supplies throughout Australia, it is concluded that, from the economic viewpoint, there could never be a better time than now to proceed with the Dawson Dam.

Dr Robert J. Thistlethwaite
Hyder Project Manager

TABLE OF CONTENTS

LIST OF TABLES

ACRONYMS

$m	**Millions of Australian dollars**	**km**	**kilometres**
%	**per cent**	**m**	**metres**
AMTD	**Adopted Middle Thread Distance (kilometres)**	**ML**	**megalitres**
EL	**Elevation above Australian height Datum**	**ML/yr**	**megalitres per year**
FSL	**Full Supply Level (metres)**	**MW**	**megawatts**
ha	**hectares**	**NPV**	**Net Present Value**
HNFY	**Historical No Failure Yield**	**SMEC**	**Snowy Mountains Engineering Corporation**
IRR	**Internal Rate of Return**	**ToR**	**Terms of Reference**

GLOSSARY

AMTD	**The distance from the most downstream point of the watercourse.**
Dead Storage Level	**The level below which water can not be withdrawn from a storage.**
Hectare	**10,000 square metres or 2.47 acres.**
HNFY	**The maximum volume of water that can be withdrawn annually from a storage during the historical period of analysis with the storage level not falling below the Dead Storage Level.**
IRR	**The nominal interest rate at which the present value of the range of benefits equals the present value of the range of costs.**
ML	**One million litres, 1,000 cubic metres, or 100 millimetres over 1 hectare, or 0.81 acre feet.**
NPV	**The present value of a range of benefits of a project less the present value of the range of costs.**

ECONOMIC ANALYSIS

1. INTRODUCTION

1.1. THE ROLE OF FORMAL ANALYSIS

The Australian decision making process requires that large public works proposals be tested for social and economic merit before they can become tangible projects. The test of a proposal's social acceptability is judged in terms of its overall impact, including its economics. The latter refers to the return to the State (or nation), region and local community taking into account the expected flow of benefits and costs if the project went ahead. If all the costs are borne locally (as the *user pays principle* would have it) then the results at all three levels will be the same (because the State and region embrace the local level). But if some costs are borne by the State, due to the State's 'interest' in the development, a greater net benefit may accrue at the local level than occurs at higher levels (see further comment below).

A comprehensive economic analysis will capture and summarise virtually all of the technical, social and communal dimensions of a proposal. Since the Terms of Reference confine the present study to a particular option on the Dawson River, it can do no more than prove whether or not this option is economic in an absolute sense. It should be appreciated however, that the present study was preceded by an appraisal study[1] and scoping study[2], which identified the best options for detailed analysis.

For the benefit of decision makers, however, the study briefly reviews various options that could apply to the current proposal. There are practical limits to the options available to the Dawson Valley because demonstration of a net benefit is the fundamental pre-condition of socially acceptable projects. In a particular situation, the decision maker may find it desirable to sacrifice some economic efficiency in order to achieve an outcome seen to be more acceptable to affected parties. Finding the optimal trade-off between wealth creating opportunities and the distribution of wealth is the proper domain of our elected representatives.

The underlying purpose of the study therefore is to provide the State's decision makers with an objective basis for resolving whether or not to proceed with the development of a dam on the Dawson River as specified in the ToRs. If the analysis indicates a net social gain due to the development, decision makers will be equipped with an economic rationale for adopting the project. In practice, the Crown may reject an economic project, but the reason for so doing would likely be some overwhelming consideration that does not readily lend itself to expression in dollar terms.

---

[1] *Dawson Valley Appraisal Study, Water Resources, Department of Primary Industries, February, 1994.* A group of landholders formed a group called LAND (Landholders Affected by Nathan Dam) to counter what they considered were inaccurate data and misleading findings of the Appraisal Study. LAND issued a *Response to the Dawson Valley Appraisal Study* in 1994. Aboriginal groups have also objected to what they claim is erroneous cultural information included in the Appraisal Study.

[2] *Report to Queensland Treasury: Scoping Studies on the Economic Appraisal of Proposed Projects for QIFF*, Uniquest Ltd., March 1995.

1.2. THE SHAPE OF THE PROJECT

Efficient and effective project analysis requires pre-feasibility study to allow clear specification of the physical dimensions of the scheme in terms of the project's objective, where it is, how big it is, its time frame, who is affected, etc. The current project has been highly specified so that stakeholders know what is being investigated and why. The critical details are as follows:

- The development objective is to provide communities and industry in Queensland's Dawson Valley with a large, regulated supply of water as a foundation for further regional growth and prosperity.

- This foundation will be a single large water storage in the Fitzroy River basin located on the Dawson River at 315.3 km AMTD (originally specified as 313.9 km in the ToRs), approximately 2 km upstream of the throat of the Nathan Gorge. The maximum full supply level (FSL) to be considered for the dam was specified as 185 m elevation, beyond which level Taroom township would be directly affected. Depending on the chosen elevation of the dam wall, varying land areas will be flooded. The analysis will consider five possible FSL: 185m, 183.5m, 182m, 180m, and 172m. In the course of the analysis, each of these dam configurations will be subject to critical tests of performance that will ultimately reveal which one is the best option to actually develop from an economic viewpoint.

- Each dam wall elevation would have the following storage capacity and annual yield of water at 85% level of reliability[3].

Dam Wall Elevation (metres)	Storage Capacity (ML)	Annual Yield @ 85% reliability (ML)
185	1,078,980	220,000
183.5	880,000	190,000
182	710,360	171,000
180	520,898	144,000
172	51,250	26,000

A monthly reliability level of 85% means that the nominal monthly allocations for irrigation will not be fully met in 15% of months. It is assumed by the analysis that in half of that 15% there will be only minor detriment to farm returns while in the remaining half there will be little or no crop yield. Obviously operating costs will be reduced in periods of no production. In the analysis, the adoption of 85% water reliability is explicitly accounted for by reducing net farm income and benefits to 95% of the total reliability level.

[3] Water can be differentiated in the market place according to quantity, quality, reliability and location and the mix of these attributes, together with supply and demand, will determine its price. High quality and high reliability water will command a higher price while smaller parcels might by expected to have high value uses and be relatively expensive. As a general rule, urban and industrial users will require high reliability water while agriculture can operate effectively with less than total reliability. A combination of high and low reliability demands will make the most effective use of a given water storage.

Later in the analysis, the adoption of 85% water reliability is explicitly accounted for by reducing net farm income and benefits to 95% of the total reliability level. An 85% monthly reliability is considered a practical ideal for agriculture as it effectively increases dam yield (compared to 100% supply reliability) while not overly diminishing the production advantages of irrigation. Reducing delivery reliability beyond a critical point however will force the economics of irrigation to fall and eventually equate with that of dryland agriculture.

- "Environmental flows are those features of a river's natural flow regime which are set aside to maintain the physical integrity of the watercourse, the species it supports and the functional riverine ecosystem."[4] The actual quantity of water that will be allowed for environmental flow has not yet been determined but it is important to establish at this stage what impact a range of environmental allowances will have on economic performance. This has been achieved in the present analysis by incorporating reductions in the total yield of 0%, 10%, 30% and 50%.

- The commercial water from the dam will support an expansion of irrigated agriculture, urban growth and industrial development in the region. The precise nature of this incremental expansion and its economic impact are the subject of this analysis.

- The major industrial use for water in the Dawson Valley would be for cooling during coal fired electricity generation. Thus local coal could be burnt to generate power provided water is available for cooling during the process. The analysis considers the basic options of 'with and without' power generation. In the case of the 'no power' option, all commercial water will go to agriculture. Unlike agriculture, urban and industrial water supplies are normally allocated on the basis of maximum reliability i.e., 'historic no fail yield' (HNFY). All yields in this analysis are expressed at 85% agricultural level of reliability, and therefore the quantities required for urban and industrial use have been factored up accordingly.

- There are no plans to include a distribution system (irrigation scheme) in the public component of the scheme. As such, users will reticulate the water from the river at their own cost.

Implicit in the above analytical framework are 40 possible combinations of water use, dam size and environmental flow. For the purpose of this analysis, these combinations are coded 1 to 40 as follows:

1-20 All commercial water allocated to agriculture

1-5	No allowance for environmental flow for 5 dam sizes
6-10	10% of total yield allowed for environmental flow for 5 dam sizes
11-15	30% of total yield allowed for environmental flow for 5 dam sizes
16-20	50% of total yield allowed for environmental flow for 5 dam sizes

[4] Arthington, A. 1997. Wounded rivers, thirsty land: getting water management right. An Inaugural Lecture, Griffith University Faculty of Environmental Sciences, April 1997, page 8.

21-40	**Power generation included as the priority user of commercial water**	
	21-25	No allowance for environmental flow for 5 dam sizes
	26-30	10% of total yield allowed for environmental flow for 5 dam sizes
	31-35	30% of total yield allowed for environmental flow for 5 dam sizes
	36-40	50% of total yield allowed for environmental flow for 5 dam sizes

To keep the presentation simple, the intermediate consequences of all the 40 combinations are not shown in the explanatory text. However a full and transparent explanation is given for the example of one combination (viz., Combination 1 defined as maximum dam size, all water allocated to agriculture, and no allowance for environmental flow). A summary of the economic performance for each single combination is provided in Table 12. The object of the analysis is to show the impact on economic performance of the various combinations of water use, environmental flow and dam size.

The set of 40 combinations assumes a single dam site (at 315.3 km AMTD) and does not attempt to examine the economics of an alternative series of small weirs, which together would still only supply a fraction of the yield of the single large storage. However the environmental costs associated with a single large storage are certainly much higher than would be the case with of a series of small weirs, where the storage is mainly confined within the river banks. With the single large dam, tracts of land are inundated, some of it with excellent agricultural potential and most riverbank and other riparian vegetation is lost.

However, the costs per megalitre of water stored and available for use is very much lower for the large storage alternative. Additional benefits of a large dam with flood gates (as has been proposed for the Dawson Dam) is that there is usually greater efficiency in the use and regulation of water compared with overflow weirs. Finally a large inland storage has greater potential to provide water through drought periods than does a small storage or series of small storages. The greater temporal reliability of a large storage could be critical to attracting industrial development to the region.

2. METHOD OF ANALYSIS

The economic analysis will address three basic questions:

1. Will the project be economic because expected benefits exceed expected costs?

2. Will the project be acceptable, because those people adversely affected by the dam's construction are adequately compensated?

3. Will the current policy framework achieve an appropriate balance between equity and efficiency?

2.1. PRIMARY OR DIRECT BENEFIT

The primary benefit due to a water development is the additional output of products from irrigation or other goods. The 'other goods' in the case of the Dawson Valley, refer to the possibility of power generation at Wandoan (for details refer *Water for the Dawson Valley*, April 1996). Power generation at Wandoan is relevant for the following combination of reasons:

- Local coal reserves are massive.

- The water needs associated with power generation could be met from a new water resource development on the Dawson River without denying existing users (a situation unlikely to apply with competing power generation proposals further south)[5].

- Given a rail link with Moura, coal from Wandoan and districts could also be exported out of Gladstone. ("In total there are 36 km of track between Moura and Theodore to be extensively upgraded and approximately 170 km of new track between Theodore and Wandoan" [statement by *Queensland Rail*, April, 1996]).

- The Dawson Valley economy has suffered from a protracted slump in the rural sector and its social fabric and youth retention rate would benefit from secondary, institutional and industrial development. Such development could be expected to manifest itself in local employment opportunities.

- The generation of power made possible through an available water supply from the Dawson River would boost the economics of the dam proposal.

Queensland's power generation agencies are expected to commission 600 megawatts of additional capacity before the end of the century. From information provided by the Department of Natural Resources, the proposal for a power station at Wandoan has favoured a coal-fired, water cooled system which would require a water allocation of about 22,000ML/yr at HNFY by the year 2005, with a further 3,000ML/yr for the coal mining operations and additional urban requirements for Wandoan township. For the purposes of the present study, a total of 25,000ML/yr has been allocated for urban and power. The water allocated to agriculture is net of this amount and an environmental flow allowance. An allocation of 25,000ML/yr HNFY to urban and power needs is equivalent to about 35,000ML/yr (Table 3b) at the 85% reliability level. Any storage option, therefore, that

[5] The social merit of using water-cooling for power generation in a country so short of water remains an issue. It is technically feasible now, although more expensive, to use air-cooled gas turbine power generation. The cost of construction and maintenance of a pipeline from the Dawson to a power station near Wandoan would be a major component of the cost of water-cooled power generation at that proposed site. However, even with an air-cooled power station, a 600 megawatt plant would still require some 3-5,000ML/yr of water. Market forces will allow the use of water for cooling unless the government intervenes on the grounds of the market failing to adequately protect a scarce resource. Any new power station established in the Condamine Basin is unlikely to attempt water cooling because the water resource of the Condamine basin are already fully allocated.

delivers less than 35,000ML/yr will not be viable for water-cooled, coal-fired power generation[6].

It is apparent that development of the Wandoan coal fields and associated power generation will not be possible without a significant and reliable supply of water. As such, the consumer surplus from power generation and sale can be counted as a direct benefit to the water development. Due to the complexities of deriving the net benefit to the State from power generation via the usual comparison of benefits and costs, the surplus will be captured through the profit component of the power's sale price. A surplus from the sale of 600 MW of power equivalent to $500 per megalitre of water used for cooling is assumed[7]. Implied is a power generation net benefit from the dam of $17.5 million per year. This benefit stream is assumed to commence in Year 9 of the project and continue throughout its life.

2.2. OPPORTUNITY LOSSES

Viability of the development depends on generation of net gains over the existing production system. The existing production system equates to a 'do nothing' scenario if we assume it remains relatively unchanged over the next 20 years. Thus the development would cause loss of production from the flooded area and replacement of the existing production system in the designated irrigation area.

In practice, the viability of the 'do nothing' option will depend on the size of costs and losses from the flooded area relative to the potential of the designated area. If, for example, a large quantity of water can be impounded and distributed at low cost per megalitre and the region is endowed with a climate and soils suitable for high value crops, then the area will have an attractive development potential and should have no trouble generating a net gain over and above the 'do nothing' scenario. The flooded area itself may include soils suitable for irrigation, but this will be fully recognised in the analysis. The first imperative of a feasibility study therefore, is to define the *status quo* and objectively assess the target area's contingent economic potential.

2.3. EXTERNAL EFFECTS

For a development proposal to be economic, there must be a clear dominance of benefits over costs. For the estimation process to be valid, however, both intended and unintended effects must be taken into account. Unintended effects are referred to as *externalities* when their effects are not captured by the market. If the irrigation development resulted in losses to neighbouring farms and families, for example due to pollution, without any alteration to production practices or offsetting payments, this would constitute an externality and should be costed against the scheme so that its full social consequences are properly captured.

Some indication of the nature and extent of externalities likely to stem from the development can be gleaned from the experiences of previous irrigation schemes in Central Queensland.

---

[6] The power generation proposal refers to two possible phases. With increasing demand for power, a second phase is flagged for well into the 21st century which would require a further 23,000 ML/yr HNFY water allocation. The economic analysis makes no provision for this additional water, on the assumption that it would have to be purchased – if and when required – from existing users, or that some alternative technology to the profligate waste of water for cooling a power station would be developed by that time.

[7] Note this is not the sale price of a water entitlement. It is the imputed profit per megalitre used for power generation.

For a particular development, it is quite conceivable for the sum total of externalities to be negligible, *providing all adverse consequences have been properly recognised and offset* (for example by adoption of best practices that obviate potential externalities). In the case of both agriculture and power generation developments, it is assumed the nature of externalities is fully recognised and appropriate compensation or mitigation schemes put in place.

If the dam water was used only for irrigation, the basic formula for establishing the economics of the project from a national perspective could be summarised as follows:

Net Benefit to the Nation = (Income from irrigated land) – {[cost of developing the scheme] + [income foregone from the flooded area] + [dryland income foregone from the irrigation area] + [externalities]}

The benefit due to power generation could be incorporated into the above formula after taking into account the flow-on consequences of less water going to agriculture.

The analysis is performed at a national level in order to capture the total economic impacts. The primary benefits will stem from additional net income which would not be possible without the water. The primary costs will include the cost of constructing the dam (including resumption costs for land flooded, and compensation for or resumption of grazing properties rendered non-viable, etc) the costs of developing the productive resources (in this case irrigable land) and the cost of operating the dam. If the latter costs are included in the cost of crop production (as a water usage charge) it is not necessary to count them again.

The essential difference between national and regional level analyses will depend on how costs are distributed through time. With most water developments, the government undertakes the financing role and this bestows an additional benefit at the regional level even if all the costs are eventually passed on to the users. It can generally be assumed that if the scheme is economic at the national level it will be economic at lower levels, providing the water pricing is fair and reasonable (as discussed below).

2.4. PERFORMANCE CRITERIA

With the full data set in place, it is necessary to employ financial techniques to reduce the data to a single (net benefit) figure that tells us whether or not the project has sound economic prospects. This analysis will employ the following standard financial performance criteria:

Net Present Value: This gives the current dollar value of a future cost and income stream. Future sums are reduced to their present day equivalence by discounting. The discount rate equates future dollars with present day dollars commensurate with the community's preference for consumption now rather than later. The strength of this preference is usually pegged at the real rate of interest (assumed by this analysis to be 6% according to the Queensland Treasury *Project Evaluation Guidelines*, March 1997). Providing all benefits and costs have been included, a positive NPV will indicate the project is economic considered on its own. An implicit allowance for risk can be built into the analysis by setting the acceptable NPV greater than zero.

Internal Rate of Return: This is the discount rate that equates the present value of cash inflows with the initial investment, thereby causing the NPV to equal zero. To be acceptable, the project's IRR will need to exceed the opportunity cost of capital.

Benefit-Cost: This expresses the relationship between the benefit stream and the initial investment, as a ratio. It is calculated by dividing the present value of cash inflows by the initial investment (including any opportunity losses). To be economic, a project must indicate a ratio greater than one. While the BC ratio has the appeal of simplicity, it gives no indication of the absolute magnitude of the project. In the case of the present analysis, most reliance is placed on the NPVs.

Break-even Period: This is the period (in years) required by the project for the sum total of benefits to equal the sum total of costs. Obviously the shorter this period, the more viable and attractive the project at all levels. Rarely will irrigation projects break-even in less than 10-15 years because of the massive up-front investment to make the project operative, and the long lead time before full production can be achieved.

2.5. SENSITIVITY AND RISK ANALYSIS

Since we cannot know with certainty the future pattern of development, or the returns from additional economic activity, analyses of this type usually include a sensitivity analysis which will show the sensitivity of project returns to possible development scenarios eg, fast/slow rates of development, different usages of the water, different storage options and different discount rates. For this analysis, the chief sensitivity concerns the configuration of the dam and its water yield (given by the size of the dam and the quantity of water allotted to satisfy environmental needs). In addition, the sensitivity of performance to minor variations in the discount rate is tested.

The water take-up rate assumed by the analysis is based on the current state of development and the land suitable for irrigation in the Dawson Valley. Apart from this, the water take-up rate is expected to be rapid as a market for regulated water has already been identified and potential users already have plans for development with a view to intensive crop production.

An understanding of how and when the water will be used gives decision makers an appreciation of the economic risks associated with the project. The proposed project also carries certain environmental risks but these will be relatively easy to quantify given the community's considerable experience with water storage developments for expansion of agriculture. Many of the environmental risks will be obviated by responsible adjustments to production systems.

2.6. SECONDARY BENEFITS

The direct impact of the proposed development is confined to changes in final output (i.e., of crops, coal, etc). To achieve this output there is obviously a need for additional inputs. This demand creates a flow-on effect or secondary benefits. These benefits are particularly important at the regional level since they will increase employment and commercial activity generally. Previous studies[8] have demonstrated that irrigation has four and five times the impact of dryland agriculture on employment and output or income respectively at the regional level. For example, every 1,000 ha of irrigation farming provides 32 jobs in the regional economy compared to only eight with dryland farming[9].

If part of the rationale for development of a water resource is to boost a particular regional economy, then the existence of secondary benefits is very important. Thus a major water storage on the Dawson River could be used to facilitate regional power generation and eventually the emergence of light industry and social infrastructure. Such developments would provide leverage to the water supply in generating massive secondary benefits.

However the economic acceptability of any investment project must rely in the first instance on demonstration of a direct net benefit as secondary benefits tend to be common to large projects regardless of where they are located. In the case of this analysis, no reliance is placed on the substantial secondary benefits the project will generate. It should be noted however that scope will exist to add value to products within the region and this will directly boost regional income. Cotton, for example, can be ginned locally to increase its exit value.

3. DATA AND ASSUMPTIONS

The greatest challenge for analyses of this nature is the generation of data associated with the expected flow of benefits and costs. For the Dawson Dam proposal, quantification of the direct economic impact will involve the following:

- Quantifying the 'do nothing' option with respect to the designated irrigation area and the flooded area.

- Quantifying the effective amount of water available for irrigation and other purposes such as mining and communities. Economic utilisation of the water body will mean acceptance of some trade-off between annual yield and reliability. As previously indicated, a reliability level of 85% is adopted for the study across all uses (with adjustments to the quantity allocated where high reliability is required). Water demands at the HNFY reliability level, for example for urban and power use, have been converted to an 85% reliability level by applying a general factor of 1.5. This figure is realistic for the purposes of the analysis, although it is appreciated the precise conversion factor will vary somewhat from one storage configuration to another.

- Apart from dam size and yield reliability, the volume of water available for commercial usage will depend on the quantity earmarked in the first instance for environmental flow. The analysis uses a range of allowances for environmental flow ranging from nil to 50% of the total annual yield. An allocation of water released for irrigation may, in its passage downstream, concurrently satisfy environmental flow requirements.

---

[8] McMeniman, S.L., Passmore, J.G.I., and Smith, K.P. (undated). *Economics of irrigated cropping in the Upper Condamine Irrigation Area*. Queensland Department of Primary Industries, Project Report Series QO 92013.
[9] *Ibid* Table 49.

- Estimating the capital costs of impounding the water body and developing land to make it suitable for irrigated agriculture. Included in the capital cost of constructing the dam will be compensation to property holders directly affected by the dam's construction and operation. Land development costs clearly exclude the land's unimproved capital value as this component is unaffected by the project.

- Specifying the year by year pattern of development over the life of the project.

- Identifying the crops that will be produced under irrigation together with yields, prices and production costs over the life of the project.

Data with respect to the above have been secured from several sources. Firstly, DNR project engineers and the various 'options' reports previously completed (eg, SMEC, *Comparative Study Dawson River Storages*, 1996) provide data relevant to the amount of water to be made available over time and the contingent costs (capital and operating). The capital costs relate to the dam itself and the water distribution system. The latter costs will be borne by either riparian or group users. Riparian user typically apply the water adjacent to the river while groups may reticulate the water some distance from the river. The effective water yield is generated by models based on the catchment size, historical rainfall patterns, losses due to evaporation and distribution and agreed release patterns. The release pattern will take into account inflow and demand considerations over several years along with environmental flows to protect water quality and riverine 'health'.

Water availability in conjunction with soil maps indicate the total area of land likely to come into production. Armed with this information, assumptions have been developed regarding the annual areas that will go under irrigated crop by type (eg, cotton, sorghum, peanuts, seed, horticulture), together with yield and cost of production data.

The size and nature of negative impacts have been derived by close examination of established irrigation areas and through consultations with local parties. In summary, the feasibility study has necessitated detailed field work to generate accurate input data.

Regardless of the attention paid to data generation, future streams of benefits and costs are based on **assumptions** about the physical changes which will be initiated by construction of the dam. Assumptions are also made about resource management because management can have a bearing on how effectively and efficiently the water body is used. These assumptions apply at two levels which can be thought of as foundation or *macro* scale and operational or *micro* scale.

3.1. MACRO ASSUMPTIONS

3.1.1. Project starting point

The impact of the project will be measured in relation to the existing situation in the target area i.e., against the 'without' option. Thus an early task for this analysis is to provide a situation statement. In a geographic sense, the target comprises three areas: one that stores the water, a second that serves as a flood margin around the water body, and a third (downstream from the dam wall) that primarily uses the water[10]. Each of these three areas varies according to the particular dam size adopted. The approximate land areas by class that will be flooded for the five dam sizes examined are shown in Table 1.

Table 1: Inundation Areas by Dam Size*

Land Class	Dam Size (ha) according to Full Supply Level				
	185m EL	183.5m EL	182m EL	180m EL	172m EL
Eucalypt Flood Plains - alluvial flats & back plains	4,580	3,505	3,040	2,935	1,205
Eucalypt Flood Plain- levees	480	475	450	400	50
Eucalypt Flood Plains - tributary valley flats	1,835	1,710	1,570	1,325	170
Brigalow Uplands	1,215	980	770	570	5
Softwood Scrub Uplands	150	115	85	50	0
Eucalypt Uplands	4,070	3,465	2,765	1,995	380
Eucalypt Highlands	540	465	390	305	55
Softwood Scrub Uplands	205	170	135	100	5
TOTAL	**13,075**	**10,885**	**9,205**	**7,680**	**1,870**

* These areas do not correspond exactly with the resumption areas shown in Table 4, which include a small flood margin.

The resumption value of this land, which should capture its productive value in perpetuity, is discussed later. (Refer Section 3.1.7)

The second opportunity loss attaches to the downstream land area that will be irrigated once water becomes available. It is estimated that one third of this area is presently devoted to dryland cropping while the balance is used for bullock fattening. To estimate the opportunity loss following removal of these enterprises, it is necessary to consider the average profit margin over 20 years, taking into account such things as drought, fluctuations in the cost/price relationship and normal rotations. On this basis the loss of dryland farming has been valued at $30/ha/year and cattle fattening $20/ha/year.

Excluding allowance for environmental flow, and allocating all commercial water to agriculture, the gross opportunity losses for the five dam sizes tested are shown in Table 2.

These opportunity losses will be smaller when allowance is made for environmental flows and if an allocation for power generation is included.

[10] It is also proposed that property owners bordering the dam will be offered water allocations, but the main water use will be downstream of the dam.

Table 2: Annual Opportunity Loss Due to Conversion of Land Use from Dryland Cropping and Grazing to Irrigated Cropping

	Dam Size According to Wall Elevation at 315.3km AMTD				
	185m EL	183.5m EL	182m EL	180m EL	172m EL
Cropping area converted to irrigation, with no Env. Flow Allowance	12,200 ha	10,550 ha	9,500 ha	8,000 ha	1,440 ha
Grazing area Converted to irrigation, with no Env. Flow Allowance	24,450 ha	21,100 ha	19,000 ha	16,000 ha	2,890 ha
Total Opportunity Loss, with no Env. Flow Allowance	**$855,000**	**$738,000**	**$665,000**	**$560,000**	**$101,000**

3.1.2. Project life

The proposed project is large scale with the potential to generate economic benefits for many generations i.e., the total system will be sustainable for a socially acceptable period[11]. In a technical sense therefore, it would be possible to assign the project a productive life of at least 50-60 years. From the point of view of economic and social acceptability however, the project should be able to prove its effectiveness within a comparatively short time span. Indeed the quicker the project can break-even and go on to generate net gains the more attractive it will be. Furthermore, future benefits are worth less than immediate benefits, so the economics of the project will be enhanced by moving as quickly as possible from the construction phase to full production. Against these considerations, the analysis will assume a finite project life of 20 years. Naturally the economics of the project would be assisted by adopting a longer period (possible in a technical sense) but this is unnecessary if the project can demonstrate it's effectiveness within 20 years or less. In a chronological sense a project becomes economic when it breaks-even (i.e., when benefits overtake costs). Clearly this criteria is an important measure of project performance.

3.1.3. Distribution of water rights

An early policy problem will be the distribution of the available water among users in a manner that will be seen to be fair and effective. It is assumed here that water rights will be auctioned to users before the dam is commenced. This approach would have the following benefits:

- it will give purchasers (who must be bona fide users) the comfort of knowing they have the property rights to a block of water as specified (see below);

- the purchasers will make a capital contribution to construction of the dam, and in the process indicate to government the overall economic merit of the offer. Any shortfall between user outlay on water rights and the capital cost of the dam will reflect the

[11] Sustainable resource management is required to afford future generations with the same production capabilities as presently exist with or without productivity gains due to improved technology.

public's commitment to the project. The margin (i.e., government equity) will be made up of a user's risk discount plus a public good component. The term *public good* refers to such things as recreational value, flood mitigation, environmental flow and possibly drought mitigation;

- apart from the impact of specifying the water allocation, the auction process will tend to place the water where it will generate the highest return; and

- the process will ensure a degree of equity between users and non-users (i.e., non-users will have the comfort of knowing users have paid market prices for their water allocation).

The success of the auction approach will depend on the selling authority being able to indicate with some precision what it is they are selling. Thus any given parcel of water must be specified in terms of amount, minimum reliability over some defined period (eg, the three year moving average), location, payment terms, conditions of sale and recourse in the event of product failure. Competition will be enhanced if water is offered as 'common currency' eg, 500 ML blocks at 85% reliability at the user's particular off-take point. It would then be up to the buyer to purchase the number of blocks or units required for their business. The different needs of buyers will tend to improve the pricing efficiency of the market.

The water offered for sale will be net of the environmental allowance. It is contended that the environment should be given first claim to the water body. Market forces will allocate the remaining (commercial) water among users according to the buyers' capacity to pay. Presumably urban and industrial users will have the greatest capacity to pay. In this case, the water that goes to agriculture will be the residual or 'what is left over'. This reality is reflected in the Table 3 allocation figures.

Obtaining a significant capital contribution (to the dam) through the auction approach will also depend on the supply and demand relationship. It is already known that a strong demand for irrigation and industrial water from the Dawson River exists and it is expected this will translate into high prices for water usage rights[12]. In practical terms, a high price for usage rights, will mean a rapid take-up of the water and efficient allocation between competing uses. Since the use of market forces as an allocation mechanism is a comparatively recent innovation, we should expect its application to the Dawson Dam water to result in superior economics relative to past water resource projects.

Hydrology: The annual water yields at 85% monthly reliability for five dam sizes, together with the priority allocations, are shown in Tables 3a and 3b. In Table 3a, it is assumed all commercial water is allocated to agriculture. In Table 3b, an urban and power allowance of 35,000ML/yr is included. This water would be piped from the dam to near Wandoan.. Agricultural water will be allocated to landholders who may have riparian holdings or who belong to groups established to pump water at their cost from the river to holdings suitable

[12] The Department of Natural Resources surveyed producers of the Fitzroy River Basin in September 1996 to determine their demand for regulated water. Before this, anecdotal evidence of a strong demand for bulk water could be seen in existing irrigation developments along the Dawson River and elsewhere throughout Queensland. Thus it is safe to assume allocations from a Dawson River storage will face strong demand.

for irrigation. The practical significance of this decision is the elimination of any joint distribution costs once the water leaves the dam. Irrigation water rights will be distributed among landholders according to their individual purchases.

Table 3a: Projected Water Release from Dawson Dam, Excluding any Allowance for Urban and Power (ML)

	Dam Sizes According to Full Supply Level				
	185m EL	183.5m EL	182m EL	180m EL	172m EL
Max. Yield at 85% reliability (ML/yr)	220,000	190,000	171,000	144,000	26,000
10% Yield reduction	22,000	19,000	17,100	14,400	2,600
Agriculture	198,000	171,000	153,900	129,600	23,400
30% Yield reduction	66,000	57,000	51,300	43,200	7,800
Agriculture	154,000	133,000	119,700	100,800	18,200
50% Yield reduction	110,000	95,000	85,500	72,000	13,000
Agriculture	110,000	95,000	85,500	72,000	13,000

Table 3b: Projected Water Release from Dawson Dam, Including 35,000ML/year for Urban and Power

	Dam Sizes According to Wall Elevations				
	185m EL	183.5m EL	182m EL	180m EL	172m EL
Max. Yield at 85% reliability (ML/yr)	220,000	190,000	171,000	144,000	26,000
10% Yield reduction	22,000	19,000	17,100	14,400	2,600
Urban + Power	35,000	35,000	35,000	35,000	*23,400*
Agriculture	163,000	136,000	118,900	94,600	-
30% Yield reduction	66,000	57,000	51,300	43,200	7,800
Urban + Power	35,000	35,000	35,000	35,000	*18,200*
Agriculture	119,000	98,000	84,700	65,800	-
50% Yield reduction	110,000	95,000	85,500	72,000	13,000
Urban + Power	35,000	35,000	35,000	35,000	*13,000*
Agriculture	75,000	60,000	50,500	37,000	-

The immediate significance of Table 3b is to eliminate the option of a 172m EL dam as this size would not provide the minimum volume of water required for the high priority urban and industrial uses. (The numbers in italics are less than the minimum of 35,000ML/yr required).

3.1.4. Water Pricing

Once the rights to use a specified parcel of water are acquired, charges will be confined to actual consumption. It is assumed by this analysis that the charges placed on users will reflect the cost (to DNR or a local supply authority)of operating the system. Thus water users will shoulder the full cost of dam operation, maintenance and administration. Since the water charges are included under crop production costs, it is not necessary to show them (again) as a dam operating cost.

Actual charges for water will have a large bearing on the profitability of its usage by farmers. Therefore the operation and maintenance of the dam should be cost effective (to keep water charges to a minimum). Additionally, the operational functions should be exposed to competitive forces and the costing procedures should be open to the scrutiny of users.

3.1.5. Management of the water body

The trend is toward devolution of responsibility for operation of the water storage to local authorities. Ideally, this system will introduce competition so that the water will be priced within the context of market forces. Apart from competition, delivery cost will be affected by how intensively the water body is exploited. It is envisaged that with increases in the exploitation rate operating costs will be reduced, and returns to the nation will increase. However the amount of water released from the dam must be realistic from both hydrologic and environmental perspectives. As previously indicated, a reliability factor for agriculture of 85% is possibly the optimal mix between exploiting the water body and maintaining the advantages of irrigated cropping.

3.1.6. Equity

The general acceptability of water resource developments partly depends on equitable treatment of all affected parties. For one thing, there needs to be the appearance of a fair trade between winners and losers. Thus the winners should pay a fair market price for the water they get and the losers should be fully compensated for what they must give up for the dam project to proceed.

However the public consultation process that preceded this study revealed an additional equity issue that needs to be discussed and evaluated. The consultation process discovered that residents of the Taroom district would consider the situation inequitable if all the regulated water from the Dawson River was allocated to users downstream of Nathan Gorge. To achieve equity along the length of the river (i.e., spatial equity), Taroom Shire residents want to see a 'fair' allocation of irrigation water to users upstream from Taroom township. Information provided by DNR indicates that some 20,000 ML (at 85% reliability) could be supplied by constructing a weir at Baroondah. However, there appear to be significant technical problems with the construction of a weir and, from an economic perspective, it would be sub-optimal as such a weir would substantially increase the cost per megalitre of water delivered to users and compromise the prospects of power generation within Taroom Shire.

The problem for equitable water distribution is its (adverse) impact on economic efficiency. Typically there will be a trade-off between the cost of equitable distribution and efficiency. As mentioned in the introduction, decision makers are usually obliged to select the option that offers the best return to society as a whole. This course can be pursued while not making any particular group worse off.

In the light of such considerations, it is considered the best economic option for delivering equity to the population upstream of the storage is through creation of local employment opportunities. The project could initiate development and operation of coal mining and power generation at Wandoan. These developments would be dependent in the first instance on a reliable supply of water from the Dawson River. Regional development options which address the equity issue, and the flow-on effects of those options, are discussed in more detail in the separate report dealing with Social Impacts.

3.1.7. Compensation

With large public projects, it is often the case that a minority of individuals will be made demonstrably worse off. The situation can be accentuated by the tendency for the winners to be concentrated in one geographic area and losers concentrated in another area. This dichotomy need not threaten the overall economics of the project, but the political acceptability of the project will be enhanced if those who lose out are satisfactorily compensated.

The fair-trade principle is that the winners (usually taken to be society in general) will compensate the losers (individuals who have suffered demonstrable losses). Clearly this process should be managed by a neutral third party (in this case a state government department) who will ensure the compensation rates are fair. It is equally important to ensure individual winners are not seen to be getting 'something for nothing'. Indeed a common fault with irrigation schemes in the past has been rough justice for those in the flooded area and windfall gains for those landholders downstream who are assigned allocations for no other reason than being in the right place at the right time.

The apparent victims with the construction of large dams are the people and places that are displaced due to flooding. Often large dams are constructed in remote, barren areas and the resultant flooding is of minor consequence in terms of displaced habitation. On the other hand, dam sites chosen for their 'lack of impact on existing habitation' may be poor sites from the view point of storage efficiency (i.e., $/ML stored). In the case of Dawson Dam, there are 41 properties in the immediate impoundment area, of which 14 will suffer some loss of land. In several cases the viability of continued cattle fattening and irrigated cropping on the remnant portions would be threatened by loss of scale.

The scope of losses within the impoundment area will be related to the following:

- Agricultural land with varying degrees of output capability – depending on its natural fertility and stage of development (described in terms of land classes above).

- Loss of scale (i.e., a smaller property may not be a 'living area' in its traditional use) and need to re-organise the property according to its new shape. The latter may include re-location of buildings, roads, fences, watering points, cattle yards and other facilities.

- Fluctuating water levels with possible consequences for fencing-out areas, bogged cattle, insect infestation, etc.

- Environmental impacts a) flora and fauna in the catchment areas, b) conservation and recreation values, and c) diverted and reduced downstream flow, and cold or dead water effects.

- Loss of heritage values.

There may be some partial offsets to the above. For some properties, the contiguous flooded area may be so minor as to be complementary. On the other hand, the proposed dam has generated considerable stress and anxiety for most people living in the impoundment area and a marked level of social division and disharmony within Taroom Shire and the Dawson Valley as a whole.

The Government could dispel much of the uncertainty hanging over the Dawson region by taking a definite decision about the shape and timing of the dam. This would allow affected people to take the contiguous implications on board and then get on with their lives.

In financial terms, the minimum compensation owing to these people would be market price for their land (before any mention of a dam depressed local values) plus any relocation expenses. In practice, the actual dollar amounts will be negotiated and agreed by informed representation from both sides (under the terms of the Land Acquisition Act or some form of market determination).

The cost to the project of inundation for each of the dam options considered is shown in Table 4. It will be noted that the resumption cost from the largest to the smallest dam is not proportional – despite a substantial fall-off in the area submerged. This comes about for two reasons. Firstly the afflux at full storage associated with the smaller dams is proportionally greater and secondly, the area of potential irrigation country lost with the smaller dams is proportionately greater. It will also be appreciated that neither variations in the environmental flow nor water use have any implications for the area inundated.

For the purpose of the analysis, it is assumed the resumption costs shown in Table 4 are evenly spread over the first two years of the project. Once the project is formally gazetted, the assigned resumption values remain unchanged and most landholders will elect to take any moneys owing quickly.

Table 4: Submerged Area and Notional Project Cost for Each Dam Option

	Dam Size According to Full Supply Level				
	185m EL	183.5m EL	182m EL	180m EL	172m EL
Area resumed (ha)	16,445	13,700	11,527	9,448	3,485
Resumption Costs ($'000)	15,000	12,400	10,200	8,600	3,200

Environmental impacts can be positive as well as negative and eventually have to be judged on a case by case basis. For example, dam catchment areas can protect flora and fauna as well as contribute to their destruction. Also recreational values can be enhanced as well as destroyed and catchments can mitigate flooding effects on land, people, flora and fauna. These observations need to be applied in the context of the Dawson Dam. In any case, it is not proposed that an individual or business be compensated for negative impacts that presently belong to the public in general (i.e., individuals or groups can only be compensated where they hold real property rights or title to the affected good). If the project proceeds, after all environmental impacts have been identified and evaluated, it must be presumed that society, as a whole, has judged any loss as bearable.

The last of the flooding losses identified above concerned recognition of certain heritage values, both Aboriginal and European, in the inundation area. Important among European heritage considerations is Glebe Homestead which would be marooned at 180 m FSL and flooded above that level. If the heritage value of Glebe Homestead is to be preserved by re-location to a site above flood level, the associated costs will be due to the project. Likewise, costs associated with the collection and preservation of Aboriginal artefacts are due to the project. The figures in Table 4 include a notional estimate for heritage preservation purposes.

3.2. MICRO ASSUMPTIONS

The policy and background setting are critical to the political acceptability of the scheme but once agreement to proceed is reached, the economics will depend on the relationship between benefits and costs over the project's nominal life. Below we detail the basis for deriving the direct benefits and costs expected to stem from the scheme.

3.2.1. Development costs

These refer to the capital costs of making the scheme operational in the first instance. The largest single outlay is for the dam and associated infrastructure – ranging from approximately $103m to $39m, depending on dam size, outlaid over four years. The other capital cost is that associated with the area of land lost to flooding (details shown above in Table 4). The dam and associated infrastructure costs over the development period are shown in Table 5. The figures include the cost of re-routing roads and bridges, etc so that local access suffers no loss in amenity. Again it will be noted there is no interaction between the cost of building the dam and the allowance made for environmental flow.

Table 5: Cost of Building the Dam Over Four Years ($'000)

Construction period	185m EL	183.5m EL	182m EL	180m EL	172m EL
Year 1†	15,400	14,500	13,500	10,080	5,900
Year 2	36,100	33,800	31,500	23,520	13,700
Year 3	36,100	33,800	31,500	23,520	13,700
Year 4	15;400	14,500	13,500	10,080	5,900
TOTAL	**103,000**	**96,600**	**90,000**	**67,200**	**39,200**

† For the purposes of this analysis, the project period runs from Year 1 to Year 20. Year 1 is the commencement of dam construction. Irrigated crop production does not commence until year 5 so, with a total planning horizon of 20 years, there are only 15 years of income to make the scheme economic.

The major private capital outlay will be for on-farm development. This expenditure will include pumping stations, clearing and levelling land, construction of head-works, etc., to allow effective utilisation of the water. Clearly the nature of this expenditure will depend on the existing state of the land, the types of crops that will be grown given additional water, and their extent. Table 6 provides a breakdown of the land classes within a five kilometre envelope along either side of the Dawson River between Theodore and its junction with the Mackenzie River. The figures indicate that availability of suitable land should not be a limiting factor. Based on 6 ML/ha, there will be sufficient water for only about 36,000 ha given the largest dam option and no environmental flow (i.e., Combination 1).

Table 6: Land Suitability for Irrigation Downstream of Nathan Gorge

Land Type	Irrigation Suitability	Area (ha)
Coolibah/Bluegum woodlands	Suitable for flood irrigation of cotton and spray irrigation of cereals and pastures	14,125
Brigalow scrub (mostly cleared)		23,110
Coolibah/Bluegum open woodlands	Suitable for spray and/or trickle irrigation of citrus, grapes, peanuts	1,350
Coolibah/Bluegum open woodlands	Less suitable for flood irrigation of cotton and/or spray irrigation of cereals, citrus, grapes, peanuts	17,210
Brigalow scrub		1,125
TOTAL		**56,920**

The land development costs will depend on crop options in relation to the land areas (characterised by farm size, soil types, natural slope, etc.) and the existing stage of development. Some of the land to be irrigated is already cultivated (so will not require clearing) while some is totally undeveloped. The unit cost of $2,000/ha shown in Table 7 reflects best practice, which includes the construction of farm dams to permit water conservation. On the other hand, the amount growers spend on land levelling and headworks is somewhat discretionary and this fact is also reflected in the figures (i.e., 2nd class development). A breakdown of the various development costs for flood irrigation, taking into account the fact that some of the land involved is already fully or partially developed, is shown before Table 7[13]. These cost estimates were obtained directly from practising cotton growers.

Land clearing	$200/ha
Survey and design	$20/ha
Levee construction	$100/ha
Land levelling	$450/ha
Tail drains and water return	$100/ha
Supply channels and head ditches	$130/ha
Water storage	$300/ha
Pump station	$580/ha
Pipes and control gates	$120/ha
TOTAL	**$2,000/ha**

[13] Land development costs do not include machinery costs; these have been included in the total costs of crop production shown in Table 9.

Table 7: Costs of Bringing Land into Production Based on Current State of Development and Best Practice Irrigation

	Area (ha)*	Cost to Develop	Total ($'000)
Flood (1st class)	15,000	$2,000/ha	$30,000
Flood (2nd class)	19,170	$1,800/ha	$34,500
Spray	2,500	$1,950/ha	$4,875
Total	**36,670**		**$69,375**

* This is the maximum development area and refers to Combination 1; other combinations will have smaller areas and smaller total development costs.

It has been assumed most of the land development will be carried out in the years immediately preceding availability of the water i.e., years 4 and 5. However some phase-in of the irrigated area is assumed to reflect the size of the task. Thus availability of finance, land resource skills and contractors will impose practical limitations. The timing of the land development process adopted for Combination 1 is shown in Table 8.

Table 8: Land Use Areas and Initial Development Costs, Assuming Development over Five Years

	Year 4		Year 5		Year 6		Year 7		Year 8	
	Area (Ha)	Cost $'000	Area (Ha)	Cost $'000	Area (Ha)	Cost $'000	Area (Ha)	Cost $'000	Area (Ha)	Cost $'000
• Flood	10,000	19,000	12,000	22,700	6,000	11,400	4,000	7,600	2,000	3,800
• Spray					1,590	3,100	910	1,800		
TOTALS	**10,000**	**19,000**	**12,000**	**22,700**	**7,500**	**14,500**	**4,910**	**9,400**	**2,000**	**3,800**

The cumulative totals for the Combination 1 land area developed and the associated cost (based on a weighted average figure of about $1,900/ha) are as follows:

Year 4	10,000ha	$19,000,000
Year 5	22,000ha	$41,700,000
Year 6	29,670ha	$56,200,000
Year 7	34,670ha	$65,600,000
Year 8	36,670ha	$69,400,000

3.2.2. Net Income Stream

Once the water becomes available from the dam, and the land development phase is completed, production will follow immediately. (This is a reasonable assumption as usage of the water is the only way producers will be able to make a return on their investment to that point in time). The primary determinant of net farm income will be yields and prices (giving gross income) and production costs. Each of these can vary through time but the benchmark rates for the analysis are as shown in Table 9.

Table 9: Benchmark Income Determinants for Irrigated Crops

Crop	Yield	Price	Gross Income	Total Costs*	Expected Net Income
Cotton	6.5 bales/ha	$450/bale	$2,925/ha	$2,200/ha	$725/ha
Peanuts	3.75t/ha	$700/t	$2,625/ha	$1,200	$1,425/ha
Mungbeans	1.9t/ha	$460/t	$874/ha	$250/ha	$624/ha
Soybeans	3.75t/ha	$330/t	$1,237/ha	$370/ha	$867/ha
Sunflower	1.8t/ha	$260/t	$468/ha	$300/ha	$168/ha
Sorghum	6.25t/ha	$150/t	$937/ha	$400/ha	$537/ha
Prime Wheat	3.7t/ha	$180/t	$666/ha	$350/ha	$316/ha
Chickpeas	2.5t/ha	$240/t	$600/ha	$260/ha	$340/ha
Grapes	7,500kg/ha	$4/kg	$30,000/ha	$18,500/ha	$11,500/ha
Citrus	2,100c'ts/ha	$20/carton	$42,000/ha	$33,000/ha	$9,000/ha

* The costs reflect a total scheme situation. Thus total costs include both fixed and variable costs for specialist crops such as cotton, citrus and grapes but only variable costs in the case of crops such as mungbeans, sunflower etc as these will be grown in rotation (meaning they need only carry a portion of fixed costs). The citrus figures reflect both oranges and mandarins.

It is assumed the main crop grown will be cotton. This crop has a strong track record in irrigation schemes throughout Australia. Moreover cotton is already successfully established in the Dawson Valley, albeit on a relatively small scale. These background considerations mean there is little risk about cotton fulfilling expectations as prescribed by the project assumptions. As the project matures, it is likely other crops will be rotated. The net income figures shown in Table 9 suggest that crops such as cotton, peanuts, soybeans, sunflower and perhaps others, will readily substitute for one another as cost and price relationships change at the margin. Ultimately, the viability of the project will stem from the competitive advantage of irrigation over dry land farming rather the sustainability of one particular crop.

In terms of annual crops, those shown in Table 9 will be grown for within farm agronomic and economic diversification purposes. Tree crops such as grapes and citrus and even irrigated wood trees can utilise lighter soils and are desirable from the standpoint of regional diversification.

Net income figures by crop and year (after commencement of construction) for the total irrigation area are shown in Table 10 for Combination 1. These figures have been derived from the unit incomes and the total areas anticipated for each crop. It will be noted that full production and total income do not stabilise until year nine because cropping is not possible until the year following land development. For the first four years the only annual crop is cotton, but for years 9 to 20, other annual crops are grown and the net income is reduced accordingly. It is assumed the 2,670 ha of 'other' crops will comprise mainly citrus and grapes. These crops have very high income per unit area but their total area has been limited in accordance with market prospects. For combinations, with lesser amounts of available water, the area of 'other' crops decreases and eventually cuts out completely.

Table 10: Expected Income Stream from the Additional Irrigation Area

	Total Area (Ha)	Gross Income ($'000)	Production Costs ($'000)	Net Income ($'000)
Annual Crops				
Year 5	10,000	29,250	22,000	7,250
Year 6	22,000	64,350	48,400	15,950
Year 7	28,000	81,900	61,600	20,300
Year 8	32,000	93,600	70,400	23,200
Years 9 – Y20	34,000	99,450	74,800	24,650
Other Crops				
Year 5	-	-	-	-
Year 6	-	-	-	-
Year 7	1,670	50,100	30,900	19,200
Year 8	2,670	80,100	49,400	30,700
Years 9 – Y20	2,670	80,100	49,400	30,700

4. RESULTS

We are now in a position to construct a table of the expected benefits and costs due to the scheme. Table 11 does this for the case of Combination 1.

Table 11: Summary of Benefits and Costs Associated with Combination 1 ($'000)

Year of Project Life	Net Farm Income	Establishment Costs: Dam*	Resump. Costs	Land Dev't†	Opp't Loss‡	Total Estab'mt Costs	Net Benefit
1	-	15,400	7,500			22,900	-22,900
2	-	36,100	7,500			43,900	-43,600
3	-	36,100				36,100	-36,100
4	-	15,400		19,000		34,400	-34,400
5	7,250			22,700	855	23,555	-16,305
6	15,950			14,500	855	15,355	595
7	39,500			9,400	855	10,255	29,245
8	53,900			3,775	855	4,630	49,270
9	55,350				855	855	54,495
10	55,350				855	855	54,495
11	55,350				855	855	54,495
12	55,350				855	855	54,495
14	55,350				855	855	54,495
15	55,350				855	855	54,495
16	55,350				855	855	54,495
17	55,350				855	855	54,495
18	55,350				855	855	54,495
19	55,350				855	855	54,495
20	55,350				855	855	54,495
PVs at 6%	**367,897**					**160,614**	**207,282**

* Includes the dam construction and infrastructure costs, maintenance of amenities.
† See Table 7 and 8 for details of land development costs; they do not include machinery costs.
‡ Opportunity costs attached to the land converted from dryland to irrigation by the scheme. See derivation under the heading 'project starting point'.

Based on the benchmark benefits and costs shown in Table 11, it is possible to derive several performance criteria relevant to judging the economic viability of the development. The actual results after 20 years of the project, in the case of Combination 1, are as follows:

Net Present Value	**$207m**
Internal Rate of Return	**17%**
Benefit Cost Ratio	**2.29**
Break-even period	**12 years**

However no adjustment has yet been made for the fact that the irrigation water is only 85% reliable, implying a reduced water allocation in 15 years out of every 100. As explained earlier (in section 1.2) the risk associated with a reliability of less than 'no fail yield' should be explicitly recognised. This has been done in the present analysis by reducing the net present value of 'net farm income' and 'benefits' by 5% for every combination. The figure of 5% has been used to reflect the fact that there is likely to be little or no detriment to yield in half of the 15 years and reduced farm costs in those remaining years when there is a complete yield failure.

In the case of Combination 1, the adjustment for a 5% reduction in net farm income and benefits has the effect of reducing the NPV from $207m to $197m and the benefit cost ratio from 2.29 to 2.18. The summary results given in Table 13, have all been adjusted to reflect a reliability factor for irrigation water of 85%.

Combination 1 has been used throughout this analysis to show the precise detail of how assumptions are applied, calculations made and conclusions derived. It will be appreciated however, that the results shown above for Combination 1 will have little application in reality because Combination 1 assumed no allowance for environmental flow. Realistic combinations of environmental allowance and economic performance can be chosen from among the 40 combinations tested by this analysis. It could be reasonably assumed, for example, that the environmental allowance should be at least 10% of the total yield. It could be further assumed that the environmental flow should be no greater than (say) 30% – in order to provide enough commercial water to permit economic viability.

The net present values for every combination, before any adjustment for less than complete water reliability, are shown in Tables 12a and 12b. The combination of outcomes within the twin borders are considered 'most likely' as they are the result of a reasonable compromise between allowance for environmental flow and economic viability. Bargaining within the likely zone, to arrive at a particular combination, will be driven by the environmental or economic perspective of particular interest groups.

Table 12a: Net Present Values when all Commercial Water is Allocated to Agriculture

Environmental Flow as a % of Total Yield	Dam Sizes According to Wall Elevation				
	185m EL	183.5m EL	182m EL	180m EL	172m EL
No En. Flow	$207m	$187m	$163m	$155m	$2.5m
10% En. Flow	$180m	$165m	$137m	$122m	$2.1m
30% En. Flow	$127m	$108m	$94m	$88m	-$9m
50% En. Flow	$67m	$50m	$45m	$42m	-$19m

Table 12b: Net Present Values when 35,000ML/year is Allocated to Urban and Power

Environmental Flow as a % of Total Yield	Dam Sizes According to Wall Elevation				
	185m EL	183.5m EL	182m EL	180m EL	172m EL
No En. Flow	$260m	$253m	$211m	$195m	-
10% En. Flow	$240m	$211m	$191m	$168m	-
30% En. Flow	$176m	$151m	$135m	$133m	-
50% En. Flow	$108m	$94m	$87m	$86m	-

The only dam that is uneconomic in an absolute sense is the 172m EL option. Indeed this dam is technically non-viable with respect to power generation as it does not provide the minimum of 35,000ML/a required. Once the 172m EL dam and 'no environmental flow' are taken out, a range of viable options remain from which to choose. As would be expected, the highest returns to the nation are offered by the combinations with the highest yield of commercial water. Thus the opportunity cost of opting for a particular combination can be quantified in relation to the maximum performance of about $240m (i.e., 185m EL dam, 10% environmental allowance and inclusion of power generation). If, for example, the collective decision making process were to opt for a 183.5m EL dam with a 30% environmental flow and all commercial water allocated to agriculture, the net present value would be $108m but the opportunity cost to the nation would be about $132m (i.e., $240m – $108m).

The project's performance will depend to some extent on variations in key inputs. With respect to agriculture, the most important of these are the reliability of irrigation water and the area of land irrigated. Indeed we know from the experience of existing irrigation schemes that water availability (between years, in total and per hectare developed) is often critical to success. A second influence likely to be important is the rate at which the land area is developed and brought into production. The impact of a 10% reduction in area available and phase-in to full production over 10 years rather than five – as used by the benchmark case – were tested for several likely combinations. The results indicated that the scheme is tolerant to a modest reduction in the availability of water and commensurate area. However, a slow uptake of the water (with full utilisation not occurring until year 15) would make the scheme marginal.

It is important, therefore, that the planning process be conscious of the economic imperative of a relatively rapid water up-take rate. As previously noted, we believe the 'rate of up-take risk' implicit in the project is minimal because a strong demand for irrigation water exists downstream of the storage. For example, many successful irrigation farmers are already in operation and could take up more water within a short time of it becoming available.

The analysis has placed a high dependency on profitable cotton production. We believe this is justified by the strong record of irrigated cotton over the past 20 years. In practice, other crops will be substituted for cotton as crop economics change at the margin. Thus relatively small movements in the economics of a raft of alternatives such as peanuts, soybeans, mungbeans and horticulture will cause substitution to take place without causing any significant detriment to the economics of irrigation within the region.

The project's anticipated performance has undoubtedly been assisted by the use of 6% as a discount rate. This rate is considered realistic in the prevailing economic climate and can be thought of as a favourable consequence of low interest rates. The prevailing phase in the economic cycle could thus be viewed as particularly favourable for investment in projects such as the proposed Dawson Dam. Notwithstanding prevailing circumstances, the sensitivity of specified combinations to discount rates of 4%, 6% and 8% have been explicitly tested.

Thus Tables 13a and 13b show the net present values and benefit cost ratios for three discount rates and the 'most likely' combinations taken from Tables 12a and 12b respectively. The results also reflect the fact that agricultural returns will be reduced in some years because the water is only 85% reliable. As previously explained, this level of reliability has been incorporated by reducing the net present value of total net farm income and total net benefits by 5%.

Table 13a: Net Present Values and Benefit Cost Ratios at Three Discount Rates for Likely Combinations when all Commercial Water is Allocated to Agriculture, and Explicit allowance made for 85% Supply Reliability

'Likely' * Combinations	Net Present Values ($m)			Benefit Cost Ratios		
	Discount Rates			Discount Rates		
	4%	6%	8%	4%	6%	8%
6	249	171	113	2.73	2.30	1.96
7	226	157	106	2.84	2.41	2.05
8	190	130	85	2.30	2.27	1.92
9	168	116	79	2.41	2.04	1.74
11	182	121	76	2.13	1.79	1.51
12	136	103	62	1.93	1.62	1.37
13	136	89	54	2.02	1.70	1.43
14	125	84	54	2.20	1.84	1.56

* See the combination codes on pages 3 and 4 to position the most likely codes shown in Tables 13a and 13b.

Table 13b: Net Present Values and Benefit Cost Ratios at Three Discount Rates for Likely Combinations when 35,000ML/year is Allocated to Urban and Power, and Explicit allowance made for 85% Supply Reliability

'Likely' Combinations	Net Present Values ($m)			Benefit Cost Ratios		
	Discount Rates			Discount Rates		
	4%	6%	8%	4%	6%	8%
26	320	228	160	3.00	2.51	2.11
27	282	201	141	3.10	2.58	2.16
28	256	182	127	2.97	2.48	2.08
29	224	160	112	3.24	2.69	2.45
31	242	168	113	2.64	2.20	1.84
32	208	144	96	2.68	2.21	1.84
33	188	129	90	2.56	2.12	1.76
34	179	127	87	2.96	2.45	2.04

The results in Table 13 indicate that the Dawson Dam proposal has strong economic prospects, even at a discount rate of 8% and relatively unfavourable combinations of environmental flow allowance and dam size. In terms of selection criteria, most reliance should be placed on the net present values.

It is important to appreciate however that the economics of any proposal could be pushed to the break-even level by a particular combination of adverse movements. The real issue is the practical likelihood of such movements. For example, it is our judgement that uptake of the water will be rapid, that irrigated cropping will remain viable and interest rates will remain low in the short and medium terms. Ultimately, the greatest risk to the project's viability will rest with the supply of water as determined by the final scope of the dam (i.e., size, place and delivery options). This conclusion suggests that any trade-offs between water availability and constraints tied to dam size and environmental flow, should be limited.

5. CONCLUSION

The analysis has attempted to determine the value of the Dawson Dam proposal to the total community. This has been done by inclusion of all private and social impacts expected to stem from usage of the water for irrigated agriculture and industry. The analysis incorporated a range of dam sizes, environmental flows and a with and without power generation option. Lack of knowledge regarding the economics of water cooled power generation mean the net present values generated for the 'with power' option should be interpreted with caution. We believe it is safe to assume however that the power generation option would improve the economics of the project and the figures (shown in Tables 12 and 13) certainly show this to be the case.

On the basis of the analysis we found the development proposal to be highly economic. Indeed the economics of the project are sufficiently robust to absorb any likely adverse movements in the production risks identified within the analysis, eg, commodity prices, water take-up rate and costs and yields. The capacity of the project to absorb down-side risks will be assisted by achieving an optimal balance between the availability of commercial water and some allowance for environmental flow. The analysis identified a 'likely zone' from which the dam to be built should be selected (see Tables 12a and 12b). This zone was defined by not less than 10% and not more than 30% of yield, allocated to environmental flow.

The economics of the project were assisted on this occasion by use of a low discount rate, reflecting the low interest rates applying in the late '90s. A sensitivity analysis found that increasing the discount rate to 8% would not significantly threaten the economics of the project.

Given the reality of low interest rates and the growing pressure on water supplies throughout Australia, we believe there could never be a better time than now to proceed with the Dawson Dam.

ATTACHMENT 2

Dawson River Dam Proposal - Supplementary Water Quality, Instream Habitat and Aquatic Fauna Studies

Dr. John R. Anderson and Michael B. Howland

January 1998

Centre for Coastal Management
Southern Cross University
P.O. Box 5125
East Lismore NSW 2480

A Report Prepared for Hyder Environmental

ABSTRACT

Supplementary surveys of water quality, cross-section depth, sediments and aquatic fauna (focusing on fish) were conducted in September, October and November 1997, during high and low flow periods in the Dawson River between Glebe and Theodore Weirs. The aim of the project was to provide additional information to assist in understanding the environmental effects of flow regulation and for developing environmental flow options.

Temperature stratification led to severe deoxygenation below the thermocline during low flow periods throughout the survey area. The deoxygenation to toxic levels (<1ppm) extended to within 1m of the surface at most sites in shallow run sections (2-3mdeep), in natural pools and the weir pools (>10m deep). At times of high flow (>100ML/day) the stratification persisted only in deeper parts of the Gyranda weir pool. The environmental implications of the deoxygenation have been discussed in terms of loss of usable water column, loss of detrital production, potential fish kill problems, and interference with fish movement breeding, spawning and rearing. The effect on the shallow riffle and run areas was regarded as the most important as much of this habitat has already been lost through inundation in the weir pools. It was shown that the deoxygenation developed more rapidly in the shallow areas once the flow stopped.

Environmental flows of 25-50ML/day are suggested as being required to stop the stratification from developing and to keep the riffle and run areas functioning by maintaining depth and wetted perimeter. Further work is required to determine the discharge required to achieve this. It was suggested that such environmental releases could be made without necessarily consuming the water by simply changing the way the weirs are managed.

Ideally the maximum benefit in terms of reactivating riffle and run habitats is to run the environmental flow through the Gyranda weir pool that had been drawn down and kept at a reduced water level. This would reactivate riffle and run areas at the upstream end of the weir pool that are normally inundated. It would ensure that the entire bottom substrate was covered with aerated water in the shallower areas, and it would probably maximise the benefits in the deeper pool areas by reducing overall depth. It was suggested that experimental releases are required to accurately determine the flows needed to break down the stratification and to prevent it reforming during the critical Spring and early Summer period.

1. INTRODUCTION

This study was initiated to provide extra information about water quality and the importance of riffle and run habitats to assist in developing an environmental flow strategy for the Dawson dam proposal. The original study of water quality and aquatic fauna (Anderson and Howland 1997) found that there were major potential problems with water quality associated with temperature stratification and deoxygenation below the thermocline during periods of low flow and flow stoppages. The distribution, severity and duration of such deoxygenation problems and their link with discharge was unknown. This preliminary study only showed that the problem could occur. Therefore there was a need to better understand the size, severity and duration of these problems and how they were linked to the flow regime.

The initial study also highlighted the loss of natural stream bed through construction of weirs in the regulated Dawson River. Of the 98 km of river between Glebe and Theodore weirs, 65 km (66%) of the original stream bed is currently inundated by Gyranda, Orange Creek and Theodore weir pools at full storage. Only a relatively small percentage of the remaining natural stream bed habitat is riffle and run habitat. Telfer (1995) found that riffles represented only 19%, and runs 50% of the length of stream surveyed in the Regulated Dawson River, when these habitat types were present. Riffle and run habitats are relatively rare in the area between Glebe and Theodore weirs. It is therefore important to understand where these remnant habitats occur, how they are likely to be affected by changes in the flow regime, and what water quality problems may occur at times of low flow.

Loss of habitat, particularly of the shallow run and riffle types, has potential major consequences for the aquatic fauna because many species are known to use such areas as feeding and spawning sites and for the rearing of juvenile fish. Most of the previous surveys of aquatic fauna have focused on pool areas, and there have been very few run and riffle sites surveyed under differing flow conditions. It is likely that many species of fish and other aquatic fauna may make use of these areas when they are available, that is, when there is sufficient depth and flow of water through them, and water quality conditions are not unfavourable.

It was therefore considered important to survey these areas under both low and high flows to quantify their use and value. Without such surveys it is difficult to understand and quantify the importance of these habitats to the aquatic ecosystems and therefore to understand their value and relevance as a focus for environmental flows. Obviously it is the riffle and run habitats that are effectively lost during flow stoppages and at times of low flow. Likewise while the weir pools can be regarded as modified pool habitats, the inundation of the stream bed in the weir pools totally destroys the riffle and run areas. Understanding the importance of the remnant riffle and run areas, particularly those which will not be flooded by the proposed dam, is therefore important in trying to minimise the environmental impact of the dam.

This study also aimed to compare the water quality and habitat availability under a variety of flow conditions in order to provide some recommendations on the size of environmental releases required to minimise environmental impact and to retain environmental values.

Three additional surveys focusing on water quality and habitat values and aquatic fauna in riffle and runs areas of the regulated Dawson River between Glebe and Theodore weirs were undertaken late in 1997 to meet these objectives. The Spring and early Summer period were considered likely to be the most important period as this is when flows are naturally low, and are also low as a result of flow regulation. This is also the time when most of the fish species spawn and rear their young and is thus regarded as a critical period in the life-cycle of the aquatic fauna. For example, the eel-tailed catfish (*Tandanus tandanus*) generally spawns in Spring and early Summer and builds nests in coarse sand and gravel substrates which are generally only found in the shallower riffle and run areas, not in the deeper pools. Golden perch and silver perch also spawn in the summer months.

2. METHODS

2.1. Water Sampling Strategy and Outcome

The original intention was to make use of the variety of flows that occur either naturally or as part of the normal regulated release patterns during spring and early summer. The aim was to compare water quality, wetted perimeter and depth through shallow riffle sections and aquatic fauna distribution and abundance under the following range of conditions:

- 3-4 weeks after releases have ceased and flows were very low or zero
- after 3-4 weeks of consistent high flows around 300 ML/day
- after at least 2 weeks of flow around 50 ML/day.

It was thought from previous studies (Anderson and Morison 1989) that flows of around 25-50ML/day would be required to break down the temperature stratification observed in the Dawson River during the surveys in 1996.

Ideally what was required was a set of experimental releases specifically designed for the project. However we were advised that this would not be possible, and that we would have to use whatever natural and release flows occurred during 1997.

The original plan was to organise the surveys around the first releases at the start of the season. Usually no releases are made during July and August. Releases usually commence in September to prepare the soil for planting cotton. The releases then cease during October and start again during November. The normal practice was to initially release about 50-100 ML/day for 2 weeks and then to increase it to 200-300ML/day. The strategy, therefore, was to survey the river initially at the end of the low flow period in August. This would be followed by a survey after the first releases had been running for 2 weeks when the flows were small (around 50-100ML/day). The final surveys were planned for the end of the release period, after the high flows had been sustained for 3-4 weeks.

This would have provided a scenario that closely corresponded with what was thought to be needed as an environmental flow to overcome the water quality problems. It should be stressed that this was far from the ideal in terms of precisely defining the environmental flow requirements. Better definition would have consisted of (1) a set of experimental releases made after a long period of low flows; (2) river survey at the end of the long, low-flow period; and followed (3) by a series of surveys as flows are progressively increased:

- after releases of 25ML/day from Glebe and Gyranda Weir for 2 weeks
- after increasing flows to 50ML/day for 2 weeks
- after increasing flows to 100ML/day for 2 weeks
- after the normal irrigation releases had been applied for 3-4 weeks.

However the survey strategy planned around the releases in September 1997 had to be abandoned because the 'pre-watering' releases for cotton were made over a month earlier in 1997, commencing in August rather than September. We were not notified in sufficient time to respond to this release, and in any case it was considered to be too early in the season (in the middle of winter) to observe the effect of the low flow stoppages. It was expected that the effects of the flow stoppages would be worse in summer than in winter due to the greater chemical and biological demand for oxygen and the greater potential for developing temperature stratification with the higher temperatures of the summer months.

A second strategy was therefore developed. Surveys would be conducted at the end of the high flow period in September, then in October, four weeks after the flows had ceased, and finally after the initial period of smaller releases during November.

The first two surveys were completed and the flow conditions were as planned except for minor storm generated flows during September. However the surveys during November had to be abandoned after two days due to heavy rain which made all the access tracks impassable. The only surveys that would be completed were at sites immediately upstream and downstream of Glebe and Theodore weirs. An additional site was surveyed at 'Junction Park' in the Theodore weir pool.

This meant that we were unable to survey the sites during low flows of about the size thought to be sufficient to break down the temperature stratification in most of the areas affected. Nevertheless, the current study does define the problem by comparing high flows and low flow conditions. But follow-up surveys will be needed to define the minimum releases needed to overcome the problems identified.

The survey conducted during October 1996 (Refer IAS Aquatic Fauna Report) provides additional information. That survey was undertaken about 2 weeks after high flow releases for irrigation had ceased and provided some information on how quickly the stratification and deoxygenation problems develop once the flows stop.

2.2. Cross-Section Measurements and Sediment Particle Size Composition

Cross-sections were taken at a number of riffle and run habitats to examine the sediment types available in the shallow areas and the variation in depth with flow. Unfortunately the cancellation of the surveys during moderate flows meant that we were unable to measure how the wetted perimeter, depth and velocity was related to discharge. The cross-sections were only surveyed during the high flow period in September 1997. Several cross-section surveys taken during the 1996 study have also been included. The cross sections were measured by stretching a tape across the stream from left to right bank (facing downstream) and then taking a series of width and depth measurements from the surface. At most measurement locations the particle size composition of the bed sediments was estimated using a 'visual volumetric' estimation technique. After collecting a sediment sample, the percentage contribution of each of a series of particle size categories to the total sample volume was estimated visually and expressed as a percentage of the total sample volume.

2.3. Water Quality

Water quality surveys were conducted at a total of 25 sites for this study and for the previous study in 1996. The focus of the survey was on the area between Glebe and Theodore Weirs, though several sites were sampled upstream of Glebe Weir and one site (935) downstream of Theodore. The location of the sites is shown in Appendices MAP 1-3. Details of discharges from Glebe, Gyranda and Theodore weir before, and at the time of sampling, for the various survey trips are shown in Table 1. A summary of the sampling dates and times for each of the surveys, listed in a downstream direction, is shown in Table 2.

Trip 2 (September 1997) occurred during a relatively high flow period with sustained releases of 172ML/day from Glebe weir, 360ML/day from Gyranda Weir and 110ML/day from Theodore Weir for 3-4 weeks prior to the survey. These releases continued through the sampling period and ceased on 30 September 1997. The only flows during October were from isolated storm runoff. Irrigation releases recommenced on 1 November 1997.

Trip 3, conducted during the last week of October 1997, therefore represented a period of very low flow, preceded by a long period of very low or zero flow. A flow of 100 ML/day was made from Gyranda Weir from 25-31 October 1997, however this did not affect the surveys which were completed before the flows increased.

Trip 4, in early November 1997, was planned to represent a period of low to moderate flow at what may be expected as a possible environmental flow (around 50-100 ML/day). However this trip had to be abandoned due to heavy rain on 10 November which made the local roads and tracks impassable. It was only possible to survey Theodore and Glebe weir pools.

Water quality sampling conducted for the previous study in October 1996 occurred after releases had been stopped for about 9-17 days. Flows prior to the shut-down had been relatively high for several weeks (330ML/day at Glebe and Gyranda Weirs and 180 ML/day at Theodore weir). This survey therefore shows how quickly water quality problems re-establish once the flow stops.

The flow patterns that occurred during the sampling period are typical of the normal pattern of releases in the spring/early summer period. There are usually early releases during August/September, with a draw-down of the weirs. This is followed by a period of 4-6 weeks when no releases are made, and then the watering period for the cotton begins generally in November. There are some changes to this pattern from year to year depending on seasonal weather patterns and water demand. Given the uncertainty in predicting the weather and the water demand, the sampling represents a reasonable range of flow conditions to meet the objectives of the study.

The water quality measurements were made in-situ using a multiple probe instrument. Measurements were made as profiles through the water column at 0.5-1.0m intervals. The meters were calibrated prior to each trip and checked during and after the surveys. The calibrations were maintained within acceptable ranges throughout the study.

Table 1.Flow details for water quality surveys

TRIP	DATES	FLOW DETAILS	COMMENT
Trip 1	10-18th Oct. 1996	Releases Glebe Weir 330 ML/day from 23/09/97 Gyranda Weir 330 ML/day from 23/09/97 Theodore Weir 180 ML/day from 23/09/97 Ceased 01/10/1997	High flows preceded surveys, but releases had ceased 9 days prior to survey
Trip 2	17-20th Sept. 1997	Releases at time of survey Glebe Weir 172 ML/day Gyranda Weir 350 ML/day Theodore Weir 110 ML/day Ceased 30 September	These higher flows occurred for 3-4 weeks prior to the surveys and were established during the survey period
Trip 3	27-30th Oct. 1997	Releases had ceased on 1 October 1997 and there were only minor flows associated with storm runoff A release of 100ML/day was made from Gyranda Weir during 25-31 October 1997	No flow for 3 weeks prior to survey. Also no observable flow in the river between Glebe Weir and Theodore at the time of the surveys.
Trip 4	10th Nov. 1997	Releases Glebe Weir 70 ML/day from 4/11/97 Gyranda Weir 50 ML/day from 1/11/97 Theodore Weir 2 ML/day from 1/11/97	Moderate flows established for 7-10 days prior to survey Rainfall from 10/10/97 prevented access to other sites (trip aborted)

Table 2. Sample site locations and survey dates.

SITE NUMBER	LOCATION	TRIP 1 OCT 96	TRIP 2	TRIP 3	TRIP 4
616	Bridge at Taroom	21/9/96			
919	Upstream of Glebe Weir (10km downstream of Taroom)	16/10/96			
133	Glebe Weir pool -just upstream of weir	20/09/96		30/10/97	10/11/97
1133	Just downstream Glebe Weir		20/09/97		10/11/97
915	5 km downstream Glebe Weir	16/10/96			
907	just downstream Price Creek junction	11/10/96		28/10/97	
914	1996 dam site				
989	historic dam site	14/10/96			
988	'Round water Hole' - 5km downstream Price Creek junct.		19/09/97	/10/97	
903	'Nathan Gorge' - Cabbagetree	14/10/96	19/09/97	28/10/97	

SITE NUMBER	LOCATION	TRIP 1 OCT 96	TRIP 2	TRIP 3	TRIP 4
616	Bridge at Taroom	21/9/96			
	Creek junction				
2609	Gyranda Weir pool - about 23 km upstream of weir		19/09/97	28/10/97	
2605	Gyranda Weir pool - at end of track, about 20 km upstream of weir		19/09/97		
260	Gyranda Weir pool - just upstream of weir		19/09/97	28/10/97	
2601	just downstream Gyranda Weir		19/09/97	28/10/97	
1200	Orange Creek Weir pool - just upstream of weir		20/09/97	27/10/97	
1201	just downstream Orange Creek weir			27/10/97	
950	about 5km upstream Delusion Creek junction	18/10/96	18/09/97	27/10/97	
249	at Delusion Creek junction		17/09/97	27/10/97	
921	5km upstream Oxtrack Creek	17/10/96	18/09/97	28/10/97	
1246	just upstream Boam Creek		18/09/97	27/10/97	
246	1km downstream Boam Creek			27/10/97	
1244	Theodore Weir Pool 'Junction Park'			27/10/97	10/11/97
243	Theodore Weir Pool -just upstream of weir		19/09/97	27/10/97	10/11/97
1243	just downstream Theodore weir			27/10/97	10/11/97
935	downstream of Theodore - 10km upstream Banana Creek	14/10/96			

2.4. Surveys of Fish and other Aquatic Fauna

Surveys of fish and other aquatic fauna were conducted during Trips 2 and 3, during September 1997 (high flow) and October 1997 (low flow), respectively. The methods and techniques used were identical to those used in the previous study (Anderson and Howland, 1997). The focus was on the shallow riffle and run sections using back-pack electrofishing techniques. In October 1997 the riffle and run sections were mostly dry and the sampling was directed at the shallow pool margins in areas immediately upstream and downstream of the riffle and run areas. The range of gear types and amount set at each site varied depending on the habitat type and size available, and also access. The gear had to be carried into some of the more difficult sites such as the areas in the vicinity of the 1996 dam site.

The catch was standardised in terms of catch per unit effort. The unit used for this standardisation varied with gear type. Each single set represented a single unit for fyke nets (single wing 6m long), bait traps and gill nets (30m long 2m deep). The catch for the back-pack electrofisher was standardised as a catch per square metre of bed fished. Fork lengths were measured for the larger fish. The size range caught by each gear type has been presented in the catch summary (Appendix CATCH). All fish caught during the surveys were released after counting and measurement.

3. RESULTS

3.1. Cross Section Measurements and Sediment Particle Size Composition

The cross sections and sediment particle size composition estimates are shown in Appendix CROSS. Many of the cross sections were shallow despite the high flow during September 1997. The sites sampled are representative of the shallow riffle and run sections in the regulated Dawson River. There are a series of riffle and run sections with gravel, cobble and rock substrates in the area from Price Creek junction to Cabbage Tree Creek junction. Just downstream of Price Creek junction, (in the vicinity of sites 907, 914, 989) there are a series of shallow riffle and run sections. These areas are inundated when Gyranda Weir is full, but flow when the weir level is lowered and releases are being made from Glebe weir (or during natural flow events). Local springs maintain some flow during low flow periods, but depths are less than 0.2m and widths less than 1m. Fish passage is inhibited at times of low flow and most of the wetted perimeter is lost

There is also a series of 'drowned' riffle and run areas between the pools in the upper end of Gyranda weir pool between the old 313.9 km AMTD dam site and Cabbagetree Creek junction ('Nathan Gorge'). These areas are mostly inundated, but do function as riffle and run areas when water is passed through Gyranda Weir when the weir level is kept low (i.e. during drawdown periods when there is some discharge upstream).

Sites 914 and 989 (Appendix CROSS 3 and 4, respectively) provide good examples of the riffles and runs in this area. These sites had cobble (60-300mm) and gravel (2-60mm) sediments. Important riffle areas were also surveyed near Boam Creek junction, downstream of Orange Creek weir, (site 246; Appendix CROSS 5), 5km downstream of Oxtrack Creek junction (site 1921;Appendices CROSS 6&7), and at Delusion Creek junction (site 249; Appendices 1&2). These sites were generally less than 1m deep at high flow in September 1997, and had predominantly coarse sand (0.5-2mm) and gravel sediments (5-60mm). In late October 1997 (Trip 3) flow had reduced to a trickle though these sites. For example, at site 246, depth in the riffle areas was only <0.1m and with a wetted perimeter width of 0.5m. This area had a maximum depth of 1.4m during the high flows in September, and a wetted perimeter width of 26m (Appendix CROSS 5).

The riffle areas at the Delusion Creek junction (site 249; Appendix CROSS 2) was completely dry during October. In September, the maximum depth though this 50m long riffle was 0.3m, and the width 7.5m. The riffle area 5km upstream of Oxtrack Creek junction (site 1921; Appendix CROSS 7) was also completely dry in October, but had a maximum depth of 1.2m and a width of 31m during September 1997. Sediments at site 1921 were predominantly moderate to coarse gravels (5-60mm).

These areas are very important as they provide habitat diversity and represent remnants of many riffle and run areas which are now permanently inundated in the Gyranda, Orange Creek and Theodore weirs.

3.2. Fish and Other Aquatic Fauna Surveys

Catch summaries for the fish and aquatic fauna surveys are shown in Appendix CATCH. A total of 17 species of fish were taken during the surveys in the riffle and run areas and pool areas adjacent to these habitats. The only species not caught in these areas which were taken during the previous surveys were Dawson Saratoga, Silver perch and purple-spotted gudgeon(Appendix CATCH 1). Shrimp and macrobrachium were also very abundant. Tadpoles and yabbies were also caught. Two Platypus were also caught in shallow run areas, and turtles were also abundant. Significantly many of the fish taken were juveniles. Large numbers of carp gudgeon juveniles (10mm long) were also caught, emphasising the importance of these areas as feeding and rearing habitats.

The most abundant larger species of fish were Golden perch, long-finned eels and eel-tailed catfish. Bony bream (juveniles), banded grunter, and spangled perch were also reasonably abundant and widespread. Carp gudgeon were the most abundant and widespread of the smaller species. Empire gudgeon, ambassid, hardyhead, rainbowfish, flat-headed gudgeon and blue-eye were also taken in lower numbers. There were no major differences in the fish species caught at the upper end of the Gyranda weir pool (914, 907) with sites downstream of Orange Creek weir (249, 246, 1921)(Appendix CATCH).

Catch rates at site 246 (downstream of Boam Creek junction) were similar for the larger species in the September and October samples, though catch rates for the smaller species were generally higher in October, and ambassid and rainbowfish were only caught in October (Appendices CATCH 3&5). The catches in September and October at site 249 were very similar. Carp gudgeons were more abundant in September. The large number of turtles taken in October was due to the fyke nets being set in the pool perimeter areas immediately upstream of the riffle area which was dry in October.(Appendices CATCH 4&6). The capture of platypus at site 1921 (upstream of Oxtrack Creek junction) and site 246 (downstream of the Boam Creek junction was particularly significant as it show that platypus also make used of the food supplies in these areas when they are deep enough.

The catch of fish during October remained high despite the water quality problems. This occurred because the area fished was the shallow, oxygenated pool margin and shallow run sections. It is conceivable that the fish are concentrated into these shallow margin areas as the deeper areas become deoxygenated and uninhabitable. The very high catch rates for shrimp and macrobrachium was also significant as it emphasises the importance of these areas as feeding habitats.

3.3. Water Quality

The water quality survey results are shown in Appendix WQUAL for the 26 sites surveyed. The data are presented as profiles of temperature and dissolved oxygen concentration versus depth for each set of measurements. Depth data are presented as depth below the water surface at the time of sampling.

3.3.1. High flow conditions during Spring and early Summer

The sampling conducted for Trip 2 (September 1997) showed that the higher flows are sufficient to break down the temperature stratification, and associated deoxygenation below the thermocline, at most shallow sites, but stratification persists in the weir pools, particularly at the upstream end of Gyranda weir pool.

No stratification was evident at site 1133 just below Glebe Weir and oxygen levels (4ppm) did not change with depth (Appendix WQUAL 5). Similarly there was no temperature stratification or changes on oxygen concentrations with depth at site 2601 (just downstream of Gyranda Weir; Appendix WQUAL 15), site 249 (at Delusion Creek junction; Appendix WQUAL 19.), site 921 (5 km upstream of Oxtrack Creek junction; Appendix WQUAL 20.), and at site 1246 (just upstream of Boam Creek junction; Appendix WQUAL 21). Oxygen concentrations at all of these sites, except 1133, were close to saturation. Site 1246 was 5 m deep and sites 921, and 249 were about 3 m deep.

Minor stratification with oxygen concentrations generally greater than 3.0 ppm, except for the first reading above the bottom, occurred downstream in the weir pools and at a number of other sites. At site 260 (Gyranda weir pool, just upstream of the weir; Appendix WQUAL 14) there was a gradual decline in temperature from 22 degrees C at the surface to 18 degrees C at a depth of 4 m. Temperatures at the bottom (depth of 5 m) were 14 degrees C. Oxygen concentrations fell from 9ppm at the surface to about 4ppm at 4m, then fell to 0.3ppm at 5m deep.

There was a similar pattern just upstream of Orange Creek weir (Appendix WQUAL 16) with temperatures declining gradually from 20.4° C at the surface to 15°C just above the bottom at a depth of 6m. Oxygen concentrations declined from 6.5 to 3ppm. A similar pattern also occurred just upstream of Glebe Weir (Appendix WQUAL 4) with a gradual decline in temperature from 19 to 17°C, and oxygen from 6 to 3ppm between the surface and the bottom at 4.5m deep. A more pronounced temperature stratification occurred at site 950 (5km upstream Delusion Creek junction; Appendix WQUAL 18.), with a clear thermocline at 5-6m deep, and temperatures in the bottom layer to 10m deep at about 15°C. Oxygen concentrations fell gradually from 8ppm at the surface to 7ppm at 4.5m, then declined rapidly through the thermocline, but only to a minimum of 4.7ppm. Oxygen concentrations at all of these sites was greater than 3ppm except for the layer just above the bottom.

Significant temperature stratification and associated severe deoxygenation, were found upstream in the Gyranda weir pool, despite the high flows passing through the weir pool at the time. At 'Round Water Hole' (site 988; Appendix WQUAL 10) temperatures declined gradually from 22°C at the surface to 18.3°C at 3m, then dropped to 15°C at 4m deep and reaching 14°C at the bottom (9m deep). Dissolved oxygen concentrations declined from 7ppm to 6ppm at 3m deep, then declined to1.9ppm at 4m, declining steadily to 0.48 ppm at the bottom.

Site 903 (Nathan Gorge, at Cabbagetree Creek junction; Appendix WQUAL 11) showed a similar pattern with a pronounced thermocline and deoxygenation to <2ppm from 4m deep to the bottom at 7.5m. At sites 2609 and 2605 (Appendix WQUAL 11 &12), there was a more gradual decline in temperatures from 22-23°C at the surface to a minimum of about 14°C which applied to the 6m of the water column deeper than 5m. Dissolved oxygen concentrations showed a similar pattern, declining in the first 4m of water and then remaining relatively constant between 1.5 and 2.5ppm. Theodore weir pool showed a pronounced thermocline and deoxygenation similar to sites 988 and 903. Oxygen levels in the bottom 2m of the water column 7.5 m deep were between 0.7 and 2.3ppm.

3.3.2. Prolonged flow stoppages (no releases) during spring and early summer

Trip 3 at the end of the no release period in October 1997 showed that major stratification and severe deoxygenation occurred at all sites between Glebe and Theodore weirs, extending to within 1.5-2m, even in shallow water. The deoxygenation below the thermocline reached levels of 0.5ppm at most sites. Significantly a site sampled at the bridge in Taroom, not subject to the flow stoppage, showed only minor deoxygenation with depth from 8.3ppm at the surface to 6.7ppm at a depth of 4.5m (Site 166; Appendix WQUAL 2). The temperature stratification and deoxygenation were minor in the Glebe Weir (site 133; Appendix WQUAL 4). Also only minor deoxygenation occurred at site 1201 (just downstream Orange Creek weir; Appendix WQUAL 17) despite a pronounced decline in temperature from 27°C at the surface to 17°C at 4.5m depth.

At the shallower sites at the upstream end of the Gyranda weir there was very severe deoxygenation. At site 907 (just downstream of Price Creek junction; Appendix WQUAL 7), dissolved oxygen concentrations were only 5ppm at the surface and declined rapidly to 0.5ppm at 1.5m deep, and remained very low to the bottom at 3m. This deoxygenation was linked with a temperature decline from 24 to 21°C between 0.5 and 1.5m deep. Oxygen levels declined rapidly below 1m at site 914 (just downstream of the 1996 dam site; Appendix WQUAL 8) to <0.1ppm at 2.5m deep.

Similar patterns occurred in the deeper sites of Gyranda and Orange Creek weir pools. Oxygen levels fell below 0.1ppm at 2.5m deep at site 2505 (Gyranda weir pool; Appendix WQUAL 13). Temperatures fell from 26°C at the surface to 15°C at 4.5m and remained at this concentration to the bottom at 9.5m. Downstream of Gyranda Weir (site 2601; Appendix WQUAL 15) oxygen concentrations fell from 7.7ppm at the surface to 1.3ppm at 1.5m deep and to 0.6ppm at 2m deep. In the Orange Creek weir pool, oxygen levels declined from 6.2ppm at 1.5m deep, to < 0.1ppm in the bottom layer from 3.5-5m deep. At site 950 (downstream of Orange Creek weir; Appendix WQUAL 18) oxygen levels declined from 7.5ppm at the surface to <1.7ppm at 5m deep, associated with a fall in temperature from 27.5 to 17.5°C. In the shallow waters at the Delusion Creek junction oxygen levels fell from 7.6 at the surface to 2.2ppm at 2m deep and temperatures from 30.3 to 22oC., in a run only 3m deep. Similarly at site 921 (5km upstream of the Oxtrack Creek junction; Appendix WQUAL 20), oxygen levels fell to 2ppm at 1.5m.and <0.5ppm below 2m deep in a pool only 2.5m deep. Also at site 1246 just upstream of the Boam Creek junction (Appendix WQUAL21), oxygen levels fell from 7ppm at the surface to 2ppm at 1m deep and to <0.5ppm in the rest of the 4m water column below 1.5m deep.

In the Theodore weir pool (site 1244 at 'Junction Park'; Appendix WQUAL 23) the decline in oxygen levels was more gradual, from only 5ppm at the surface to 1.7 at a depth of 3.5m and 0.6 at 5m, and then virtually zero to the bottom at 8.5m. Just upstream of the weir the decline was more rapid, reaching 1.3ppm at 1m deep, 0.7 at 2m and <0.1ppm at 3m, in a 6m deep pool. Downstream of the weir pool, oxygen levels reached 0.9ppm at 1m, and <0.1 at 2m deep

3.3.3. Short-term flow stoppages (no releases) during Spring and early Summer (1996)

Upstream of Glebe Weir in the unregulated section (site 919; Appendix WQUAL 3) only minor stratification occurred and moderate deoxygenation, with oxygen levels falling to 2.5ppm at a depth of 2m and zero on the bottom at 2.5m deep. The deoxygenation was much more severe at site 915 (5km downstream of Glebe Weir, declining from 2.3ppm at the surface to 1.5 at 1.5m deep and 0.3 at 2.0m deep. Similarly oxygen levels were low at site 907 just downstream Price Creek junction being 1.9ppm at 1m deep and 0.4ppm at 2m deep, and also at 989 where oxygen levels fell to 3ppm at 1.5m and 0.1 at 2m deep.

These surveys suggest that the deoxygenation tends to develop more rapidly in shallower than deeper sites, but is also likely to be broken down more easily and rapidly by increased flows.

Deoxygenation was less severe in the deeper sites that were sampled. For example, at site 950, in excess of 6m deep oxygen levels were 7.3ppm at the surface and reached a minimum of 3ppm at 5-6m depth. At the shallower site 921, about 2-3m deep, oxygen levels fell below 5ppm at 1.5m depth.

3.3.4. Low flow conditions (50-100ML/day)

The limited sampling conducted in November 1997 showed that deoxygenation persisted just upstream of the weirs. At Glebe weir the stratification occurred at 2.5m depth, and oxygen levels declined to 1.5ppm below 3.5m depth. No stratification occurred downstream of the weir.

4. DISCUSSION

4.1. Fish and Aquatic Fauna

Runs and riffles are important habitats for fish and other aquatic fauna in the Dawson River. They are:

> '....vital habitats in the breeding cycle of potamodromous fish such as Golden Perch and possibly Black Bream. Theses fish are stimulated to migrate by increases in water temperature and water level rises associated with floods. It is known that these areas provide a highly oxygenated environment for eggs to hatch and floods stimulate the growth of planktonic food for larvae to feed once hatched'(Berghuis & Long 1995; page 11).

These authors also place emphasis elsewhere on the oxygenated nature of these habitats:

> 'Runs and glides are also important habitats (as) several species of fish in the Dawson River system prefer areas with some flow. These areas are often rich in oxygen, with large numbers of insects and other invertebrates colonising such habitats for part of their life-cycle.'(Berghuis & Long 1995; page 11).

This is why the finding that the shallow run and riffle areas become rapidly deoxygenated at low flows is so important. The value of these areas is lost if flows are too low to maintain a reasonable proportion of the available area under water, with a reasonable depth and with oxygen levels sufficient to maintain their function.

A large proportion of run and riffle has already been lost through inundation in the weir pools, and their will be further losses in the area inundated under the new dam. This emphasises the need to keep the remnant areas working at maximum capacity. At least seven species of fish are known to require rocks or gravel areas as breeding habitat (Eel-tailed catfish, jewfish, Firetail Gudgeon, Fly-speckled Hardyhead, Flat-headed gudgeon, Long Tom, and Empire gudgeon).

4.2: Water Quality

The water quality surveys showed that severe deoxygenation associated with temperature stratification occurs in the regulated section of the Dawson River downstream of Glebe Weir in Spring and early Summer. A major finding of the four surveys is that:

Prolonged flow stoppages and low flows cause severe deoxygenation to within 1-2m of the surface, even in the shallow run and pool sections, rendering most of the water column anoxic (unable to support aerobic life).

Surveys conducted four weeks after releases ceased on 1 October 1997 showed the severity of the water quality problem. In the deeper weir pool sections oxygen levels were generally less than 0.5ppm, in all areas below a depth of 1.5-2m from the surface. In most of the shallower sites oxygen levels less than 1ppm were found below depths of 1-2m. Most species of fish can resist oxygen levels of 2ppm for only 1 hour before dying, while 0.5ppm concentration is toxic to all aquatic vertebrates (Anderson 1975). Even carp can only tolerate 0.2ppm for 3 hours at 20°C (Anderson 1997). Oxygen levels of around 4-5ppm are generally regarded as being required to sustain aerobic organisms and communities. The occurrence of this severe deoxygenation, therefore, renders most of the water column toxic, particularly as the reducing conditions lead to a build up of toxic levels of hydrogen sulphide.

The deoxygenation is linked to the temperature stratification that develops under low flow conditions. The surface layers are warmed by the sun. Warm water is less dense than colder water. The warm water therefore floats on the cold layers underneath and the density difference effectively prevents the layers mixing through convection. Why does this lead to a decline in oxygen levels? The separation of the layers and the prevention of mixing cuts off the major source of oxygen which is the surface and replenishment from the air. Under normal circumstances in a lake or river the surface water is being constantly replenished with oxygen. The oxygenated surface waters are being mixed with the bottom water layers through turbulence induced by river flow, wind and wave action and convection. For the oxygen to be replenished the water must move or be moved, as oxygen diffuses only slowly though water.

What about photosynthesis? This process can generate oxygen during daylight hours, but the water has to be very clear for the light to penetrate. However, the Dawson River is generally very turbid and photosynthesis, therefore, is insignificant in the river. The density stratification acts as a barrier preventing the normal mixing through the water column, so, with the oxygen supply cut off, the oxygen levels below the thermocline drop as more and more oxygen is consumed by aerobic organisms, etc. (biological and chemical oxygen demand). In effect, the water in the bottom of the pools stagnates, just as the water in a drum or bathtub in the backyard stagnates if it is not mixed. It is a question of supply and demand for oxygen. The greater the demand the more rapidly the oxygen levels will fall.

Once the flows in the river stop, the aerobic organisms (fish, crustaceans, bacteria, etc.) in the bottom waters consume oxygen through respiration. The surface waters absorb sunlight and heat up. If the flows are insufficient to prevent the stratification from forming, or to break it down, the oxygen supply is cut off and the oxygen will be depleted to very low and toxic concentrations. Even with low or moderate flows the mixing may be restricted, that is only occur down to a certain depth. The surface flow may simply pass over the stagnant, cold, bottom layers. The water in the bottom layers may remain there undisturbed for many months until there is a flow large enough to generate the turbulence needed to break down the stratification.

Wind and wave action can effectively create turbulence to mix the surface layers, but only generally down to 2-3m, depending on the fetch and the size of the waves that are produced. The long narrow shape of the Gyranda weir pool within the confines of a narrow gorge effectively minimises the potential mixing effects of wind and wave action in the middle to upper ends of the weir pool.

Such severe deoxygenations associated with temperature stratification can cause major fish kills, but generally only when the stagnant lower toxic waters are moved downstream in a way that the fish have 'no where to go' to avoid it. Normally fish and other aerobic organisms can survive by simply avoiding the bottom toxic layers. Fish may make short excursions into the bottom layers but quickly move out once they sense the toxic conditions. Under certain circumstances the mass of toxic bottom waters may be picked up and moved downstream. This generally occurs through a 'first-flush' event of a moderate size.

If the new flows are insufficient to completely mix the water column, but are large enough not to pass over the top of the stagnant bottom layers, the deoxygenated water may be picked up and moved downstream *en masse* with the flow front. Under these circumstances fish in shallow pools downstream may suddenly be met by a minor flood of toxic stagnant water. Temperatures in this first flush may be 10°C lower than the water in which they have been living. The toxic conditions may extend right through the water column and the combination of a sudden decline in temperature and oxygen levels may be lethal, as the fish can not escape.

Local residents in the Gyranda Weir area have reported a strong smell of 'rotten eggs' during the later stages of draw-down in the weir. A possible explanation for this is that, during draw-down, water is taken from the surface. This may effectively remove all 'good' oxygenated water, eventually lowering the water level down to the 'foul' deoxygenated waters below the original thermocline. The bottom layers are highly reduced and have high concentrations of hydrogen sulphide.

This causes a major loss of water column volume that is available for use by aerobic organisms. It generates the potential for fish-kills with first flush events. It dramatically reduces the effective production of the system by switching off detrital food supplies. It may also may prevent breeding or recruitment and generate a chemical barrier inhibiting fish passage.

Initially it may seem that the loss of usable water column depth may not represent a major problem, because the fish and other organisms can avoid the toxic bottom layers and live quite happily in the upper aerated zone. Indeed fish have been shown to avoid the bottom layers. When surveying fish in the Dawson with gill nets set at right angles to the shore, the number of fish caught suddenly falls to zero as the net passes into the deeper water below the thermocline. Fish are only caught in the shallow margin areas at the outside of the deeper pools. Occasionally fish were caught in traps below the thermocline. When the nets were recovered these fish were dead - they had moved into the deoxygenated area, become trapped and had been unable to return to the oxygenated water again.

The previous construction of weirs on the Dawson has led to a general deepening of the water column. It has created new large deep pools. Perhaps the extra habitat created more than offsets the loss of the deeper areas through deoxygenation? This is true to some extent, but the habitat created is different from the original habitat and there are other more profound problems associated with the deoxygenation shown in Figure 1.

This figure illustrates the effect of the stratification on detrital production. When the pool shown becomes stratified, the bottom 7m of the 9m water column becomes anoxic. Associated with this is a loss of about 70% of the water column. The fish and other aerobic organisms are confined to the upper 2m of the water column and to the shallow pool edges around the perimeter down to a depth of about 2m. However, more significantly, about 95% of the bottom substrate of the pool is excluded from use, and 95% of the detritus (coarse organic matter) is also made unavailable as it is covered by toxic anoxic water.

This is significant because the food webs and energy production systems of rivers and reservoirs, particularly turbid ones, are driven by the break down of detritus, which is coarse organic matter such as leaves, twigs and macrophyte debris. Importantly, the processing of this detritus occurs mostly on the bottom. The leaves and twigs and other organic debris accumulate on the bed where they are broken down by shrimp, yabbies and various macroinvertebrates. These are termed benthic organisms, that is, they occur on the bed or bottom of the river. The stratification and deoxygenation therefore means that the aerobic processing of this detritus, and the food-webs that it supports, is effectively switched off. This may affect about 95% of that production (Fig.1), and in turn will affect food supply to juvenile fish and other aquatic fauna.

Many of the native fish in the Dawson breed during spring and early summer. The water quality conditions also force aerobic animals into the restricted shallow margins of the pool where many species may be more prone to predation, and where breeding habitats may not be available. Deoxygenation therefore has the potential to dramatically reduce detrital production and to affect fish and other aerobic organisms.

The deoxygenation of shallow run areas that occurred at the end of October just downstream of the dam site, and in the area between Orange Creek weir and Theodore, also has the potential to interfere with breeding and rearing of juvenile fish. The breeding and rearing of many species of fish in the Dawson River is linked to the run and riffle areas. The deoxygenation makes these areas unsuitable. It may also provide a chemical barrier preventing or restricting fish migration. Reducing or stopping the flow removes the stimulus to initiate these migrations, and the fish may not be able to move through the shallow run sections if they contain deoxygenated toxic water. Stopping the flow may also mean the riffle areas are too shallow for fish passage. For example, at the end of October the riffle areas at site 989 (downstream of the 1996 dam site) and at the, Delusion Creek junction were only a few centimetres deep.

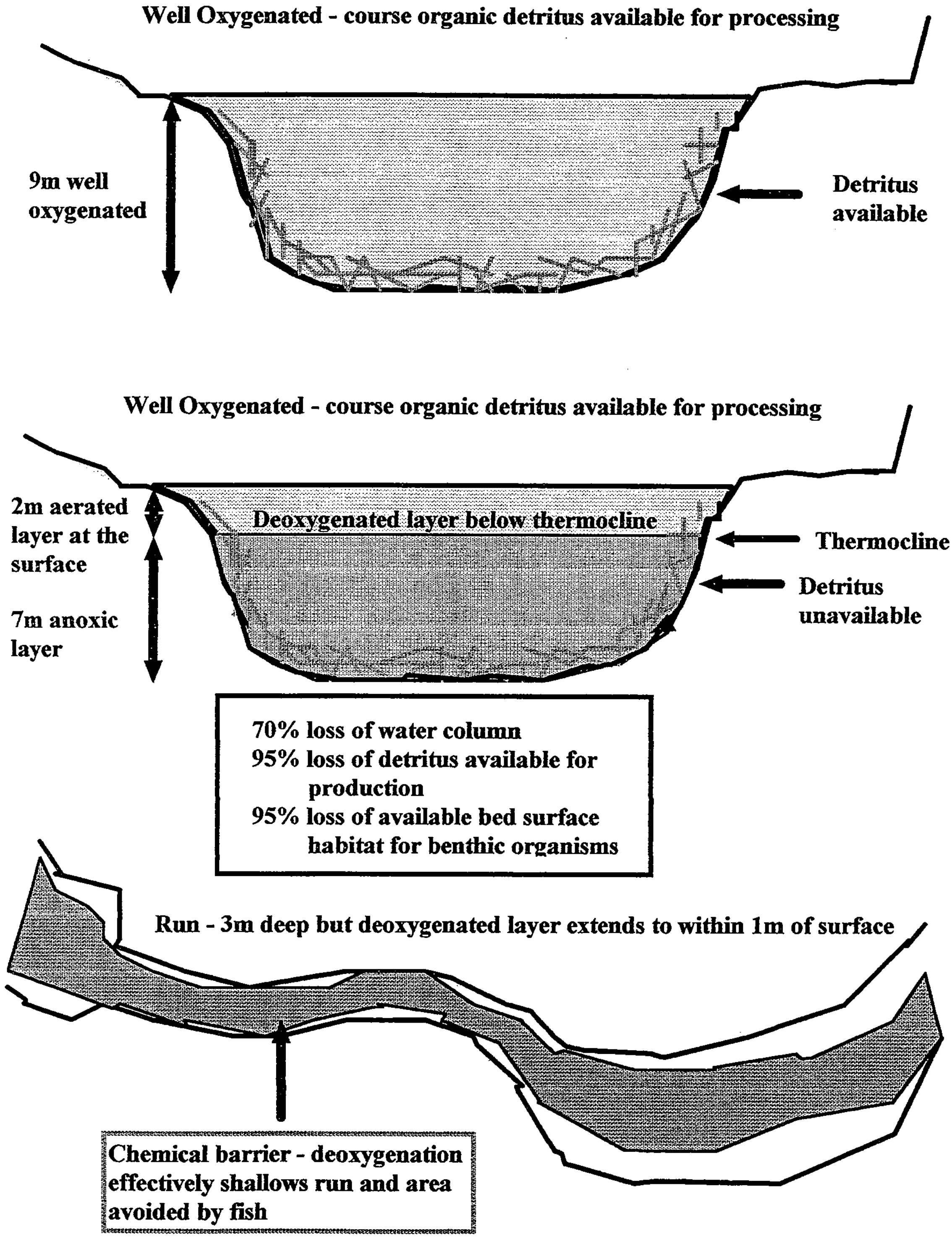


Figure 1. Effects of deoxygenation below the thermocline on aquatic habitats (cross-section and longitudinal section)

How Quickly does the Deoxygenation Develop once the Flow Stops?

The sampling undertaken from 10-18 October 1996 provides some insight as it occurred about 9 days after high-flow releases had ceased. Although only a small number of sites were sampled the results suggest that the deoxygenation develops rapidly, especially in the shallow areas. At sites 907 and 989, downstream of the dam site, oxygen levels were <2ppm at depths of 1.0 and 1.5m, respectively, in run areas 2-3 m deep. Likewise at site 921 oxygen levels were <1ppm below 1.5m in a 3m deep pool.

The deoxygenation was generally less severe in the deeper pools occurring at greater depths and not declining to such low concentrations. For example at site 950, a natural pool below Orange Creek weir, oxygen levels only declined to a minimum of 3ppm at a depth of 5m. Also at 903, in the Gyranda weir pool at 'Nathan Gorge', oxygen levels were above 2ppm even at a depth of 2.5m.

These results suggest that the deoxygenation develops rapidly once the flow stops, perhaps within 1-2 weeks. This confirms similar results for other studies that have shown that these deoxygenations may develop rapidly once flows are reduced (Anderson and Morison 1989). The rapid development of the deoxygenation, especially in shallow run areas where it has the most impact, indicates that continuous releases may be required to prevent the problem developing. It also indicates that the release of periodic 'flushing flows' to break down the stratification is likely to be less effective than continuous releases of smaller volumes of water(Anderson and Morison 1989).

Are the deoxygenation and temperature stratification in spring and summer natural phenomena?

The answer to this is definitely yes, especially in streams that have natural intermittent flow patterns. The September/ October period is the natural low flow period for the Dawson. It would be expected that naturally occurring low flows and flow stoppages at this time would cause temperature stratification and deoxygenation.

Site 950 is a natural deep long pool downstream of Orange Creek weir. Stratification patterns at this site were similar to those found in Orange Creek weir in September and October 1997 (Appendix 16&18). Site 921 is located in a natural pool about 3.5m deep, between Orange Creek and Theodore Weir pools. This site is unaffected by weir pool inundation. The pattern of deoxygenation and temperature stratification seen at this site in late October 1997 was virtually identical with that seen at site 907 in the upper reaches of the Gyranda weir pool. Similarly the pattern at site 921 in October 1996 was very similar to that seen at site 989, another site of similar depth in the upper Gyranda weir pool.

However, the issue is not whether the phenomenon is natural or not, but rather whether human impact has exacerbated the problem in terms of space and time. Clearly the construction of the weirs and the flow regulation have made the situation worse. The weir pools are long and narrow, the area inundated in the weir pools is deeper than the natural bed, and the water is retained for longer periods. There would have been natural deoxygenation in the deeper pools in the original river channel in the weir pool areas. However, the inundation by the weirs means that virtually the entire length of the weir pools(Gyranda 30km, Orange Creek 14 km, Theodore 15km) are now affected. The area and length of stream affected by deoxygenation has therefore been substantially increased.

The proposed new dam will substantially reduce the remaining extent of natural river bed between Glebe Weir and Theodore. Most of the new reservoir will be relatively shallow and wide, and should remain well oxygenated except for the deeper areas in the original river channel and valley. Therefore

doubtful given that other shallow areas don't the new dam will not substantially increase the area affected, although the reservoir areas will be of a different habitat type to those in the natural river bed. The construction of the weirs has therefore substantially increased the area of river bed and length of river that is affected by these deoxygenation events, by at least one or two orders of magnitude.

Has the construction of the weirs and the flow regulation substantially increased the time during which these deoxygenation events affect the river?

The answer to this is also yes. The weirs are designed to capture the small and medium flows and to retain them for release at other times according to seasonal demands. The capture of the small discharges is of major significance, particularly that from storms during Spring and Early summer in the upper catchment (above Glebe Weir), and reduced the incidence of flushing flows which would have periodically broken down the stratification. More significantly, holding water in the weir pools for long periods has kept major lengths of river channel under deoxygenated water for long periods of time. Under natural conditions the river would have been shallower and therefore the area affected by the deoxygenation would have been substantially less. Clearly the construction of the weirs and the retention of water in them and the flow regulation have increased the time the river bed is covered with deoxygenated water.

The releases of water do offset this to some extent, especially as the releases are unseasonable compared with the natural flow regime. The releases in August/September and again in November do generate flows sufficient to break down the stratification in most of the pools, at times when it would be rare to have such flows under natural conditions. These unseasonable natural flows have both negative and positive impacts. and may be detrimental to the environment in other ways.

Have the land use practices, river management and other human impact in the catchment contributed to the problem?

Again the answer to this is probably yes. The temperature stratification and deoxygenation are natural phenomena that would have occurred before European man entered the area. But would it have been as severe as it is now, and how have the river and land use changes in the catchment and other human impacts affected the situation? It has already been mentioned that the deoxygenation develops after the re-supply pathways from the surface and mixing in the water column have been stopped by the temperature stratification. It is, however, a rate phenomenon. It depends on the size of the chemical and biological oxygen demand. It is probable that these demands have been increased by human impact via higher nutrient and organic matter loads. If this is true, then the problem is exacerbated because the deoxygenation will develop more rapidly once river flow stops.

Other changes in the catchment may also have had an effect. Runoff patterns and river flow patterns now are certainly considered to be different from the patterns prior to European colonisation. Where land has been cleared of trees, surface runoff is faster and of shorter duration than in the uncleared state. Thus the rivers would probably have been more persistent in their flows then than they are now, ignoring the river regulation. With more persistent flows, deoxygenation would be expected to be less severe and occur less frequently than is the case today.

4.3. Environmental Flow Issues

The following issues are relevant in terms of environmental flow requirements to maintain the value of the riffle and run sections in the regulated Dawson River between Glebe and Theodore weirs:

- The total area of riffle and run sections, and shallow pool areas have been considerably reduced because of the construction of the weirs and they will be further reduced by the construction of the new dam.

- The shallow riffle and run habitats are unique and valuable for aquatic fauna, particularly as spawning sites and as rearing and feeding sites for juvenile fish and other aquatic vertebrates.

- These habitats are particularly vulnerable to deoxygenation due to temperature stratification during times of low flow and flow stoppages. The surveys in October 1996 showed that severe instances of deoxygenation developed below a depth of about 1-2m, some 9 days after high releases had ceased.

Can environmental flows be beneficial in maintaining the value of these riffle, run and shallow pool habitats? The answer is yes. Previous studies have shown that establishing minimum flows of 50ML/day in the Wimmera River in Western Victoria, a river quite similar to the Dawson River in many respects, were adequate to break down the temperature stratification and to keep it from re-establishing (Anderson and Morison 1989). This study also concluded that continuous low flow was likely to be more beneficial than a series of larger periodic releases because the stratifications develop so quickly once the flow stops. Such flows were shown to break down the stratifications in the surface waters of large natural pools, 500m long, 30m wide and up to 9m deep. These pools are similar to those in the Dawson River. Smaller releases are likely to be effective at least in the shallower areas.

What flows are required to break down the stratifications at least in the riffles, runs and shallow pool areas?

Unfortunately there is insufficient information to determine this. The restricted surveys in November 1997 were inconclusive because the surveys had to be abandoned due to rain. However, from previous studies it would appear that releases of 25-50ML/day would break down the stratification. Experimental releases using automatic recorders would be required to determine precisely the size of the release required. The present study demonstrated the frustration of trying to monitor natural flow events. The critical time for these releases is during the Spring and Early Summer period, when many of the fish and other aquatic vertebrates breed and rear their young.

4.4. River Management Considerations

The issue here is to discuss how such an environmental flow could be established at minimum cost in terms of water demand and use, and with maximum benefit to the environment. The following issues are relevant:-

- The release of an environmental flow through the various areas may not require a specific purpose release and it may not necessarily represent an exclusive consumption or loss from the system. It may be simply a matter of changing the way the water is delivered. Once the new dam is constructed it may be possible to lower Theodore and Gyranda weirs in winter. It may then be possible to gradually fill them during periods when there would be no releases, by establishing a flow of 25-50ML/day as a release from the new weir. Initially Gyranda could be kept at a low level, allowing the water to pass all the way downstream to Theodore weir, maintaining a flow all the way from the new dam through the Gyranda weir to Theodore.

- It is important that the new dam has a multiple level offtake, otherwise the release water will be anaerobic and toxic. Multiple offtakes are now standard engineering practice.

- Serious consideration should be given to removing Orange Creek weir and restoring the bed to its original condition, thereby removing a major barrier and a source of deoxygenation problems.

- Destratification devices using aerators, etc., are unlikely to be successful because the weir pools are long and narrow.

- Ideally the weirs should be kept at low to moderate depth during such environmental releases. This would reactivate some of the riffle areas in the tailwater regions of the weir pools. Also the reduced depth of the weir pools would maximise the benefits of the flow in terms of breaking down the temperature stratification.

- It may be necessary to release flows higher than that required to break down the stratification in order to maintain depths and flow through the riffle areas. A considerable number of water users have been allowed to construct low level weirs in the Dawson River to generate a head for pumping and to increase water levels in tributaries. These low level weirs act as barriers to fish movement. It is important that if these barriers are to remain that the releases are sufficient to drown them out.

4.5. Outcome and Future Monitoring

The project has clearly established the severe water quality problems and loss of important riffle and run habitat that occurs during low flows and flow stoppages. There is a need for follow-up surveys to establish the size of the flow needed to break down the stratification in most of the areas. The present study showed that some stratification remains even during high flows in the deeper pools at the upstream end of the Gyranda weir pool. Ideally this showed be determined using experimental releases.

The experimental releases could perhaps be organised during the September/October period when no releases are made. The ideal arrangement would be to establish a set of monitoring sites preferably using automatic oxygen and temperature measurement equipment during the release period. The releases would be stopped for a period of one to two weeks and the water quality monitored to determine how quickly the stratification and deoxygenation takes to develop. The next step would be to start experimental releases, initially at a low flow of about 20Ml/day. This would be continued for 1 week and then increased to 40Ml/day. This would ideally be stepped up to 60 and 80 ML/day, monitoring water quality continuously through the entire release period. This would provide the best way of determining the minimum environmental flow required to overcome the deoxygenation problem.

Ideally several sites downstream of the release point would be monitored simultaneously with the flow at the monitoring sites. At the completion of the study, the results could then be translated into an environmental flow recommendation that took account of transmission losses and local variation in site responses. The possible increase in consumptive water use during an environmental flow release also needs to be considered with additional releases being required to maintain the designated flow in the river.

The environmental flow should be designated as a target discharge at several key locations, not simply as daily release volume, because of transmission losses and extra usage that may occur when the river is flowing.

5. REFERENCES

Anderson, J.R. and A.K. Morison (1988) Primary and Secondary environmental problems caused by saline groundwater intrusions into the Wimmera River, Victoria. Ext. Abs. BMR, Division of Continental Geology Groundwater Series No. 12. p 3-6.

Anderson, J.R. and A.K. Morison (1989) Environmental Flow Studies for the Wimmera River, Victoria -Part C Water Quality and the Effects of an Experimental Release of Water. Arthur Rylah Institute for Environmental Research Tech. Rep. Series No. 75.

Anderson, J.R. and M. Howland (1997) Impact Assessment Study for Proposed Dawson Dam : Aquatic Fauna. A Report prepared for Hyder International.

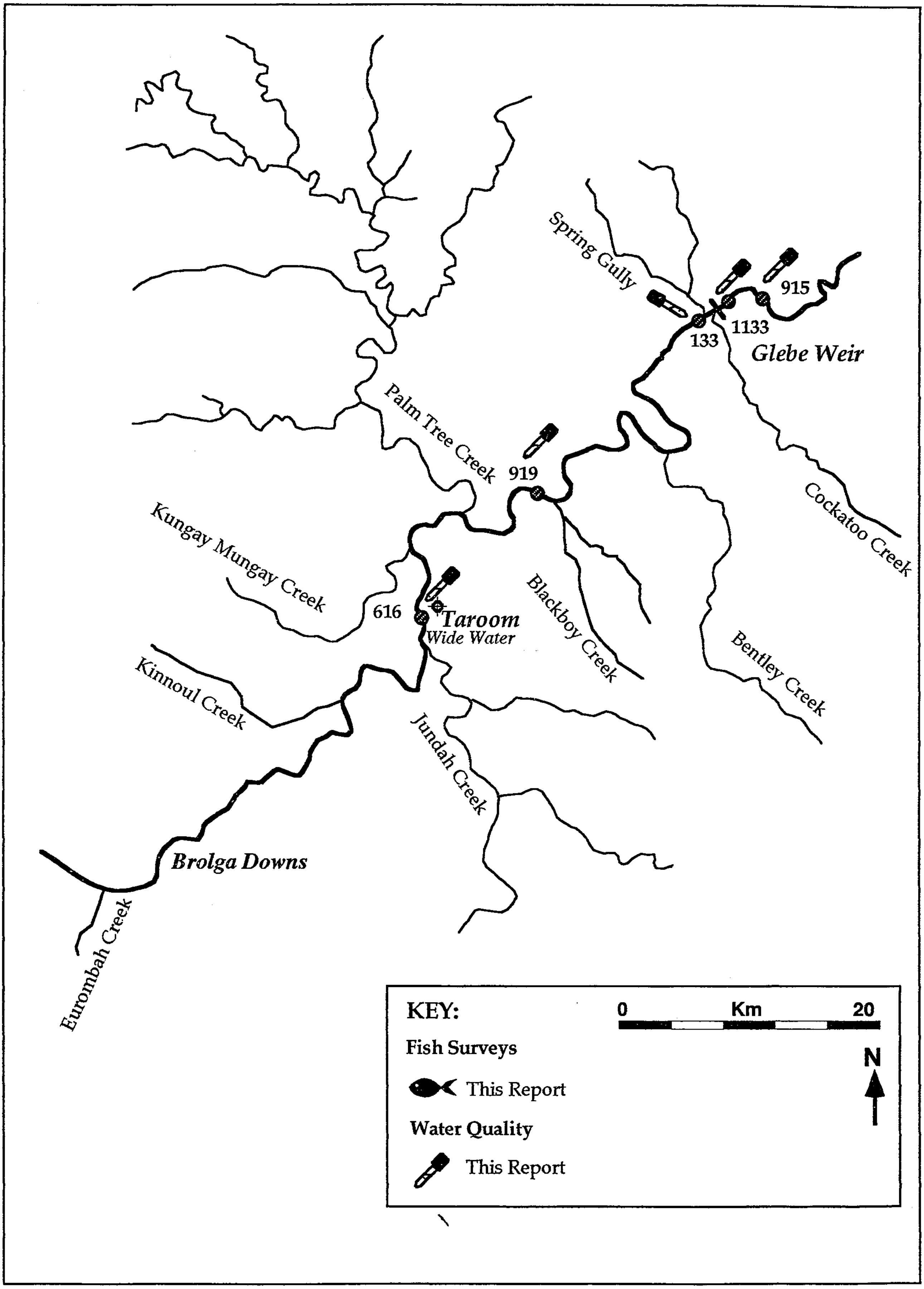
Berghuis, A. and P. Long (1995) Dawson River Fisheries Document, Central Queensland. QDPI.

Telfer, D (1995) State of the Rivers - Dawson River and Major Tributaries. An Ecological and Physical Assessment of the Condition of Streams and Rivers in the Dawson River Catchment. Department of Primary Industries, Brisbane, Queensland.

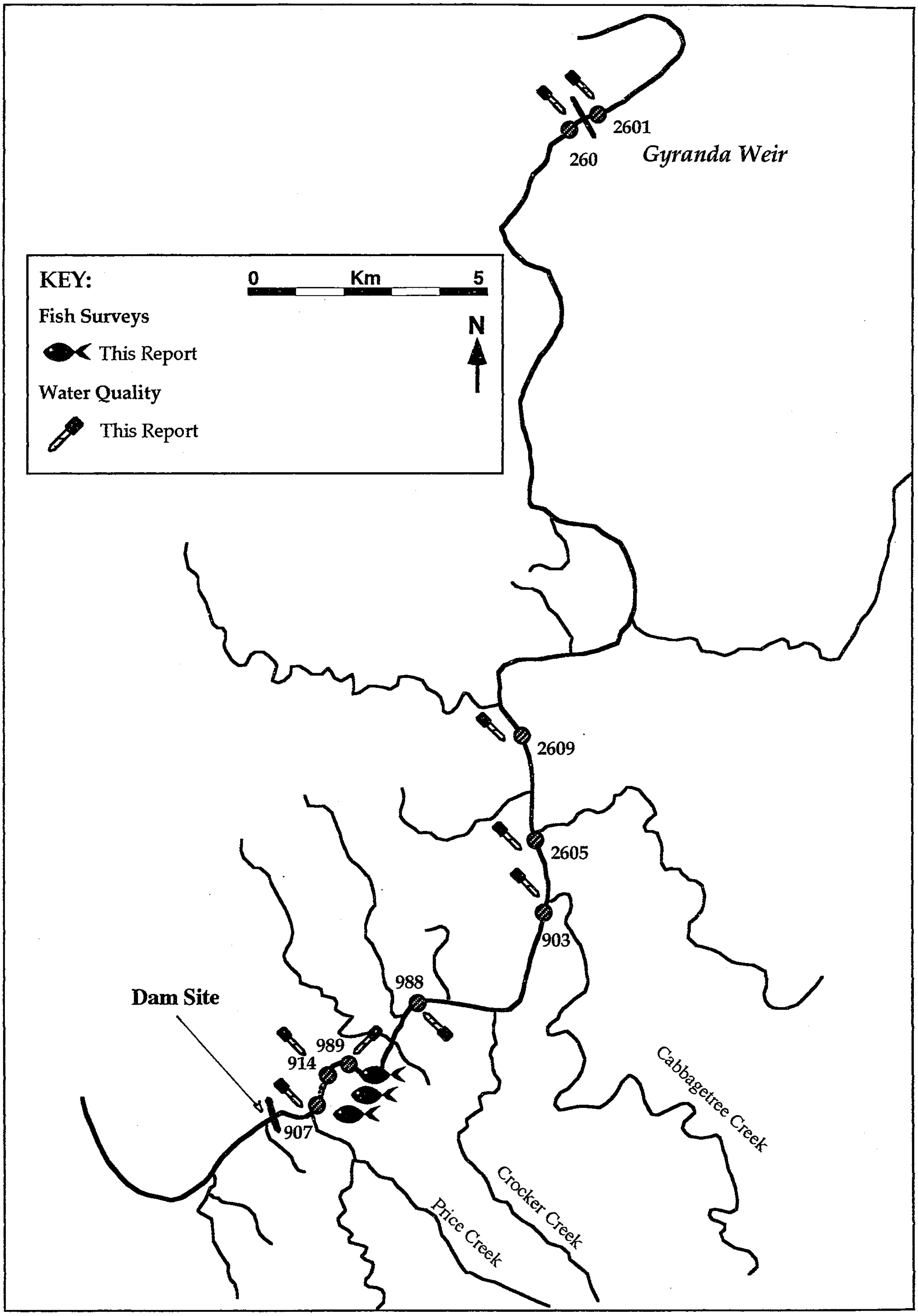
6. ACKNOWLEDGEMENTS

We thank Bruce and Melba Clothier, Burnett Joyce, and all the other land owners along the river who gave us permission to get access to the river through their properties and for their helpful advice and comments.

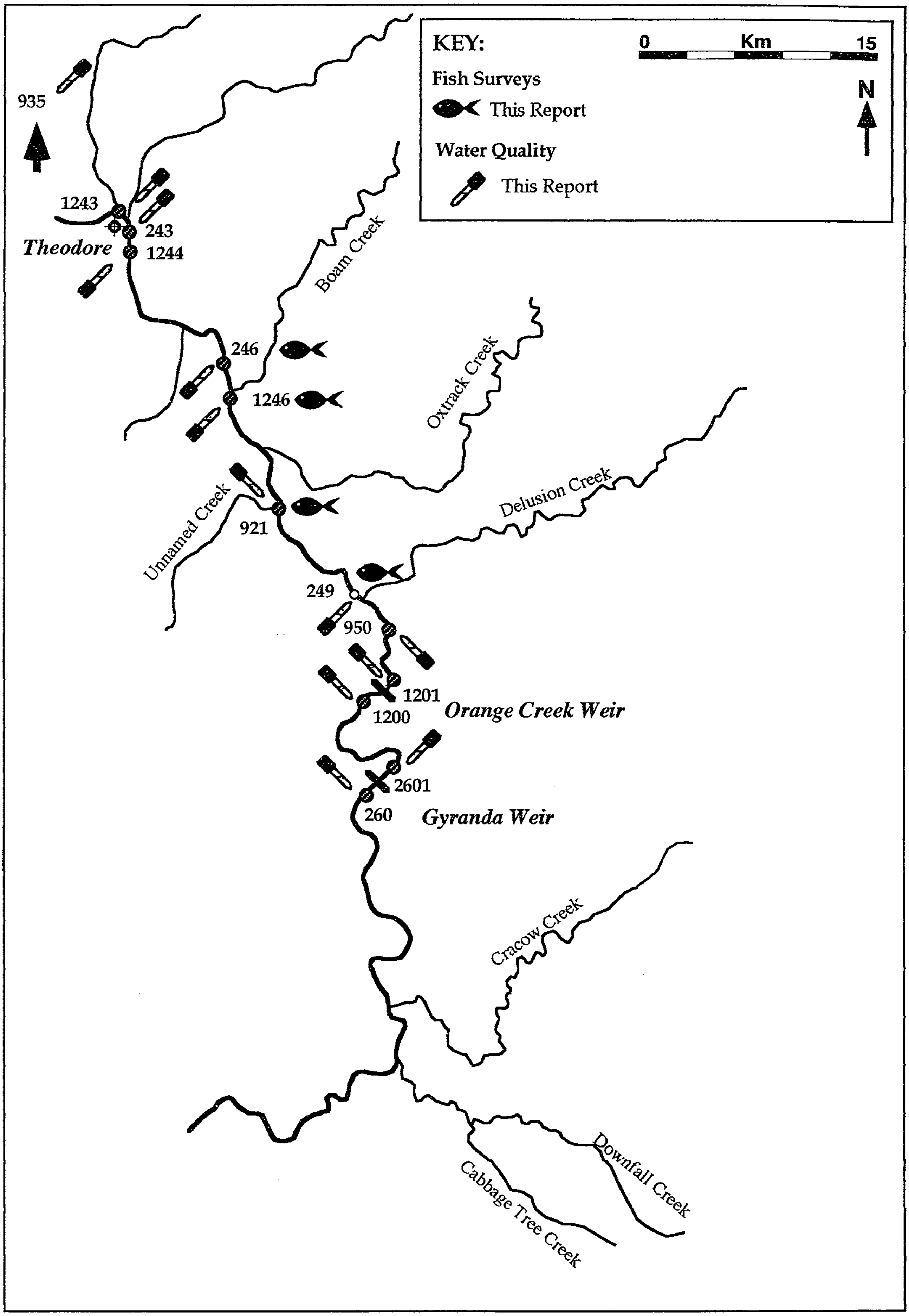
We also thank Mick Patterson and other Departmental staff for information on the flow in the rivers and historical releases from the weirs.



Appendix MAP 1. Upstream survey sites

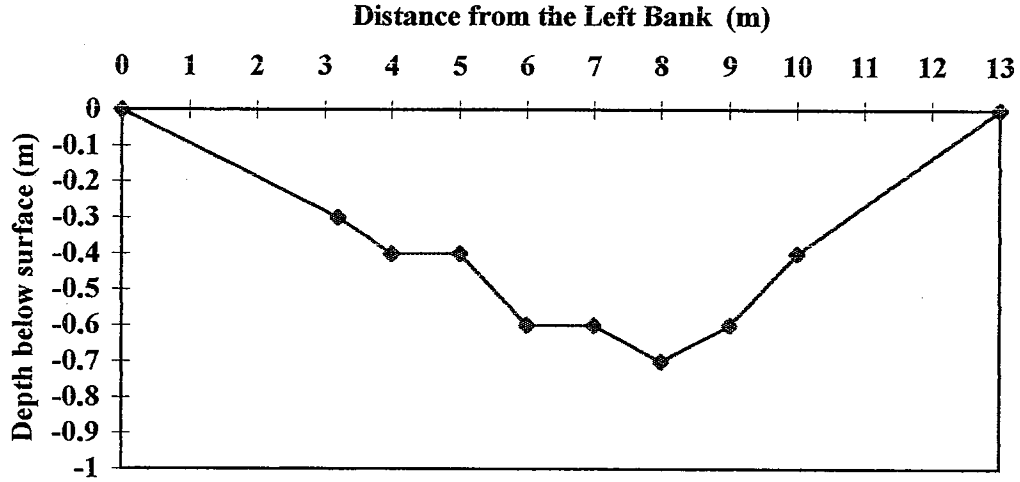


Appendix MAP 2. Upstream survey sites

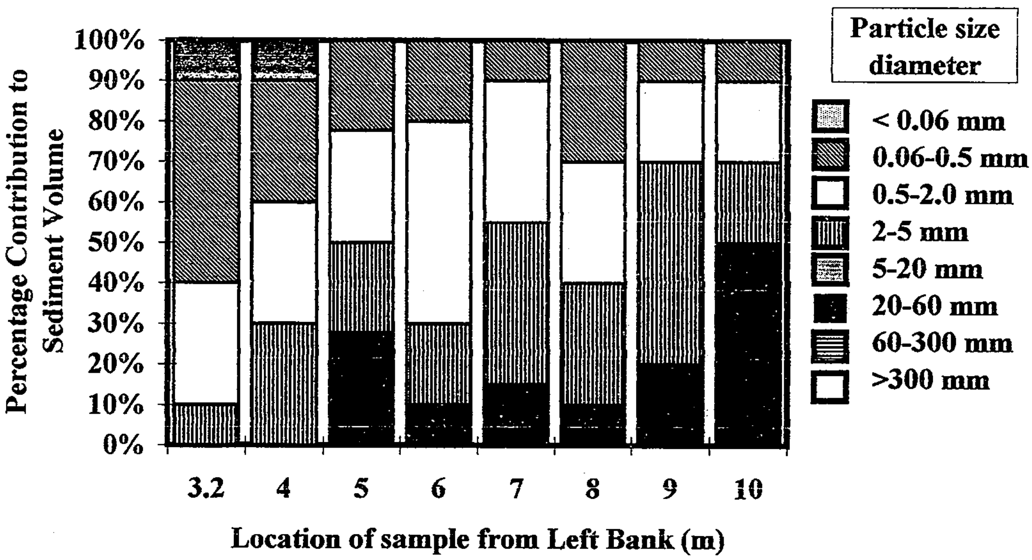

KEY:
0 Km 15
Fish Surveys
This Report
Water Quality
This Report
N
935
1243
243
Theodore
1244
Boam Creek
246
1246
Oxtrack Creek
Unnamed Creek
921
Delusion Creek
249
950
1201
1200
Orange Creek Weir
2601
260
Gyranda Weir
Cracow Creek
Downfall Creek
Cabbage Tree Creek

Site Number 249 19/09/97
- Main Channel

Cross-section Profile

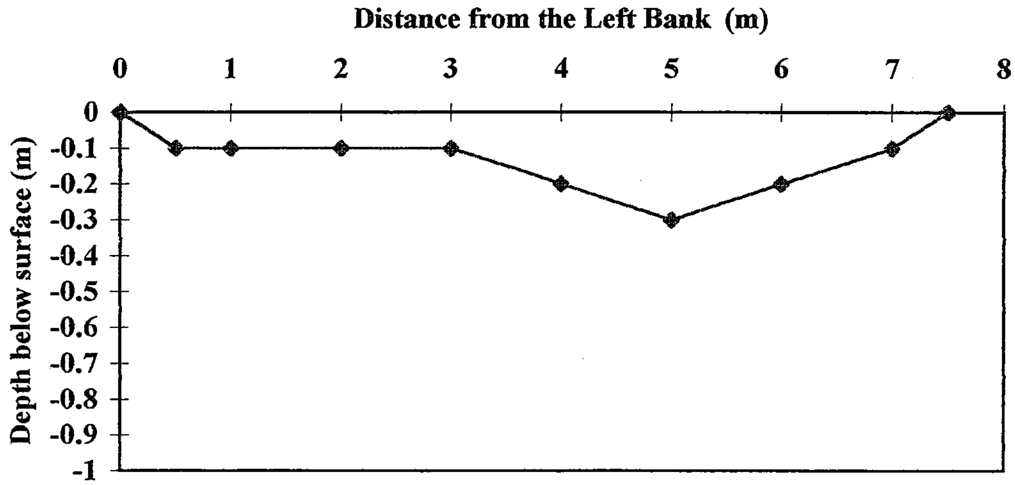


Sediment Particle Size Composition

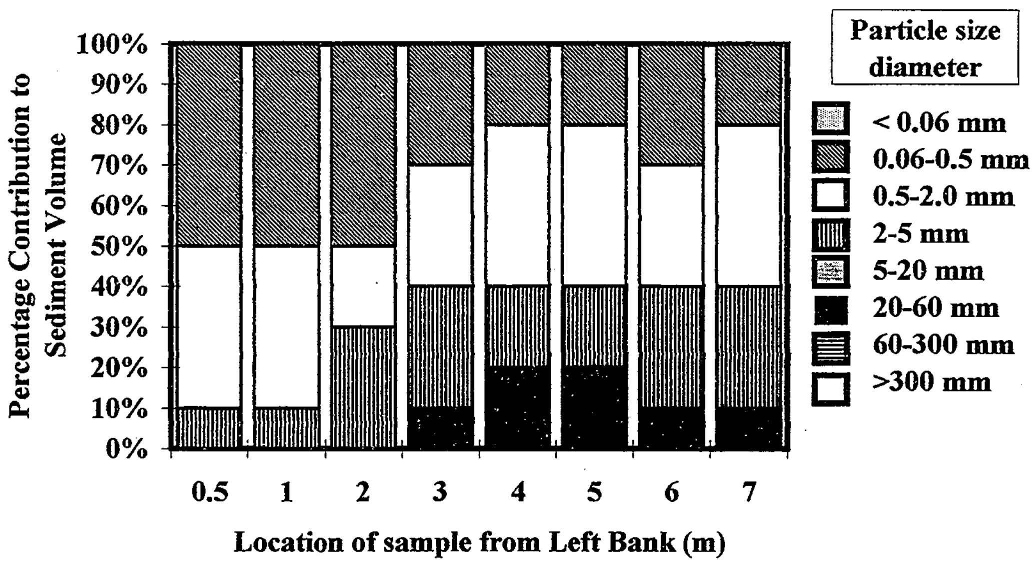


Site Number 249 19/09/97
- Riffle in by-pass channel

Cross-section Profile

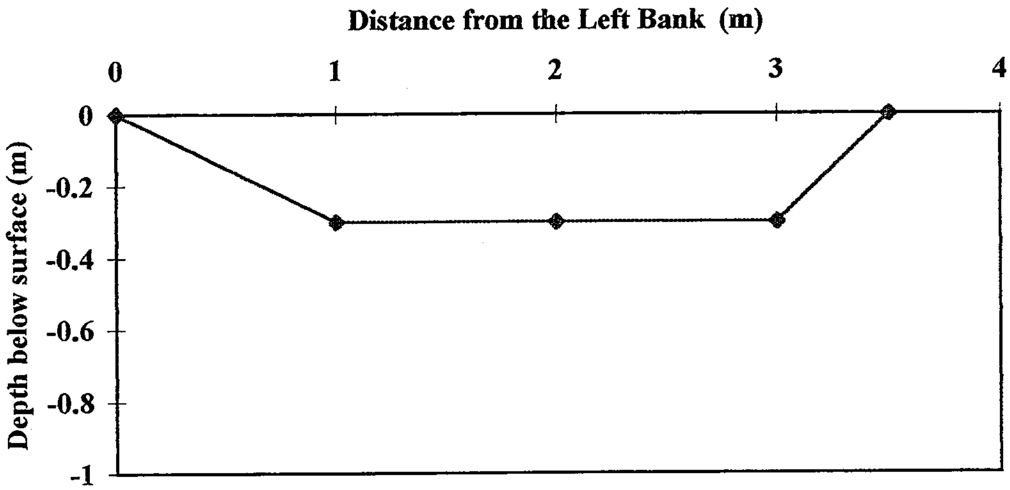


Sediment Particle Size Composition

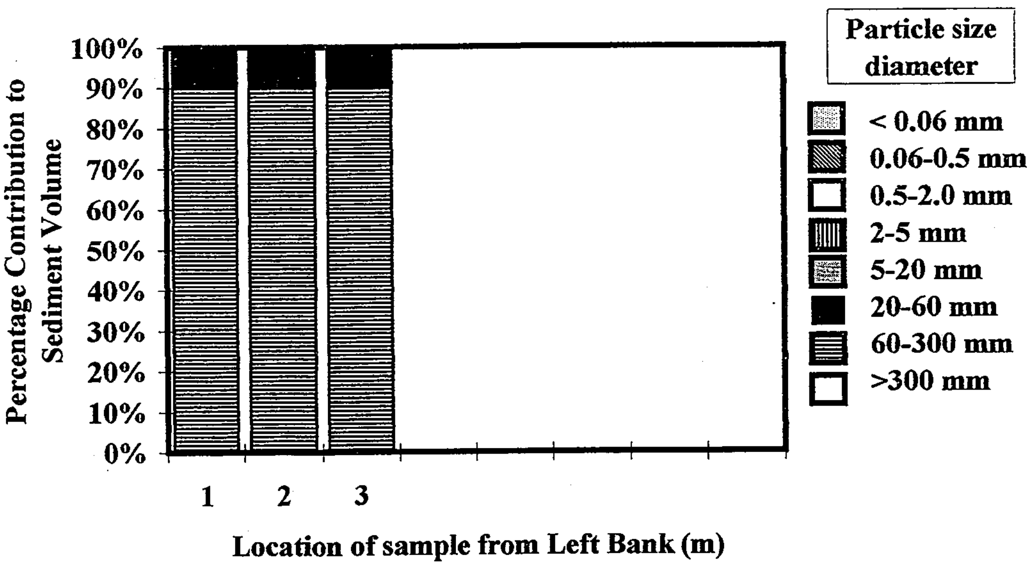


Site Number 914 1996 surveys
 - just downstream 1996 dam site

Cross-section Profile

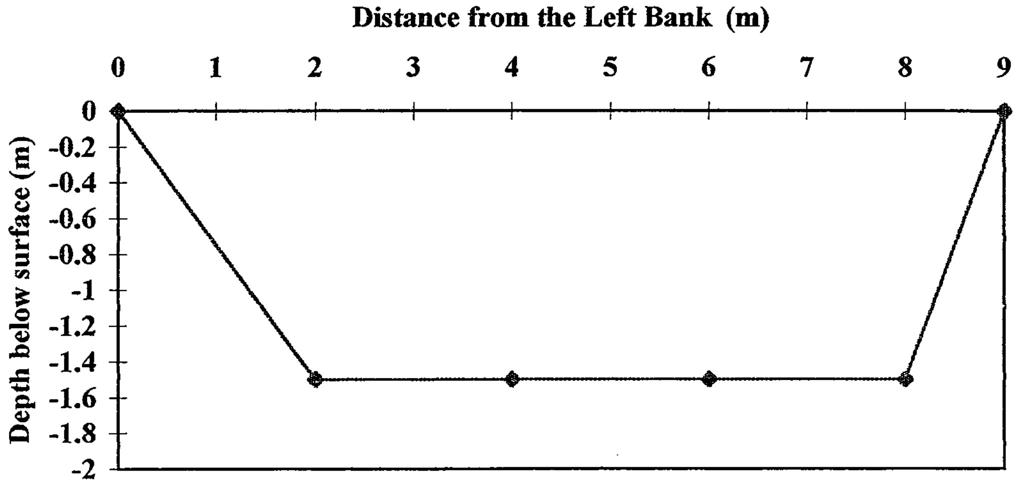


Sediment Particle Size Composition

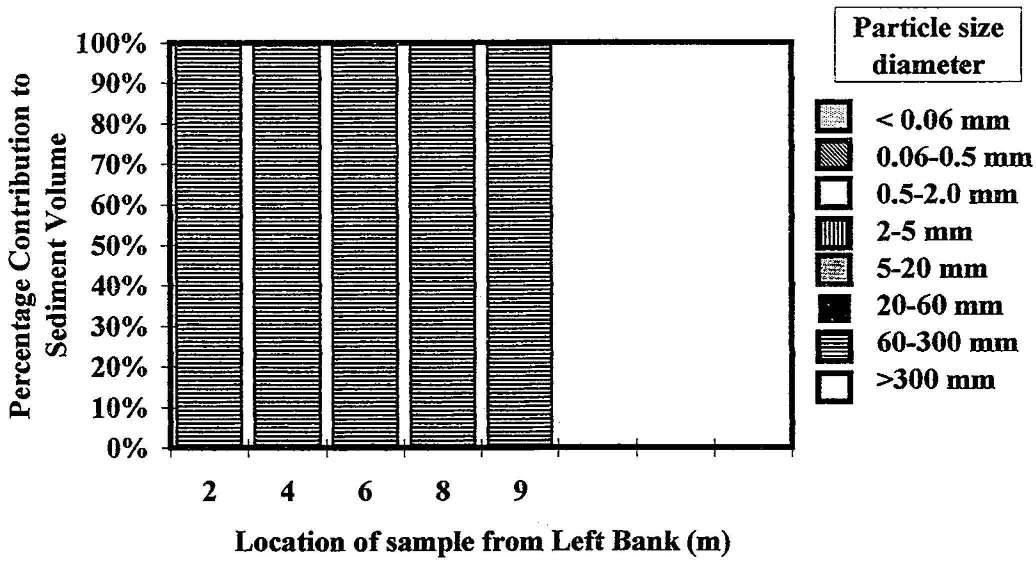


Site Number 989 1996 surveys
- just downstream old dam site

Cross-section Profile

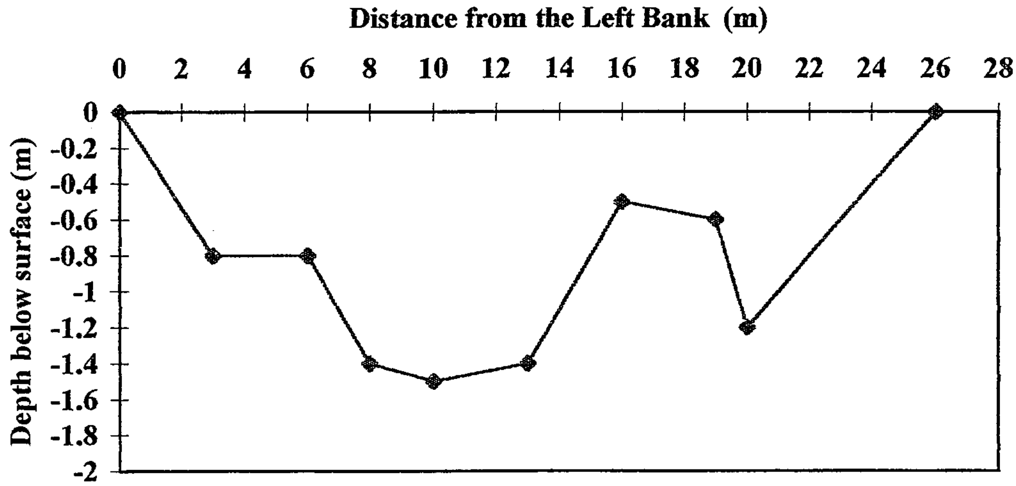


Sediment Particle Size Composition

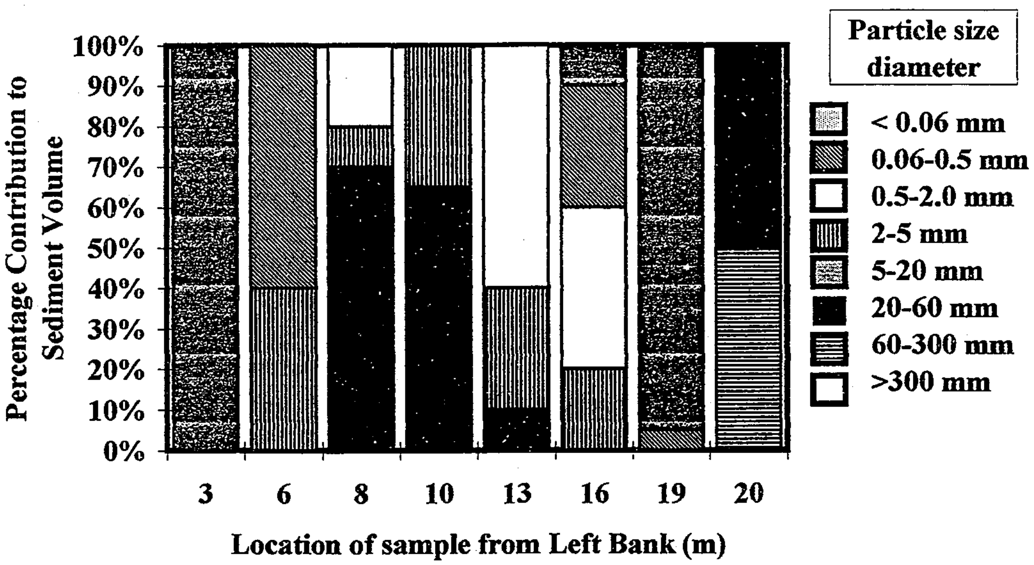


Site Number 246 18/9/97
- Riffle area 1km downstream Boam Creek junction

Cross-section Profile

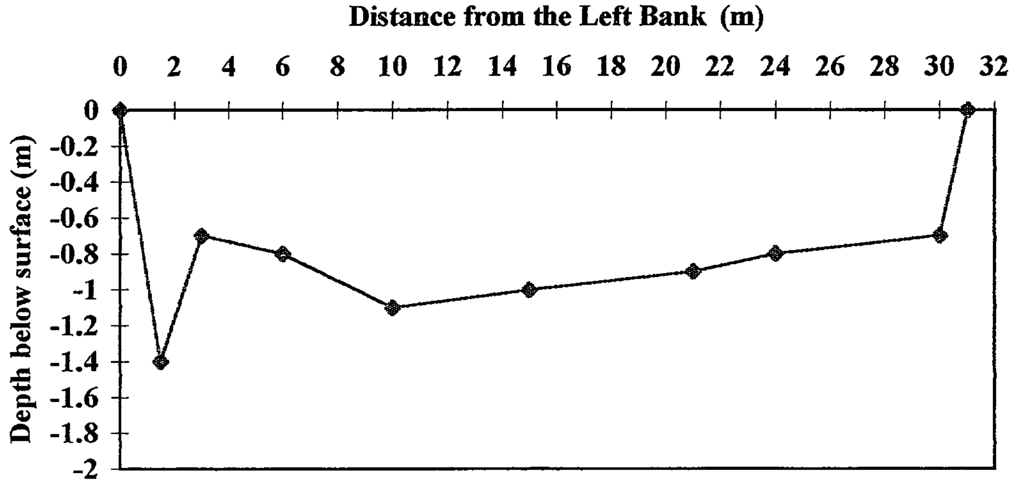


Sediment Particle Size Composition

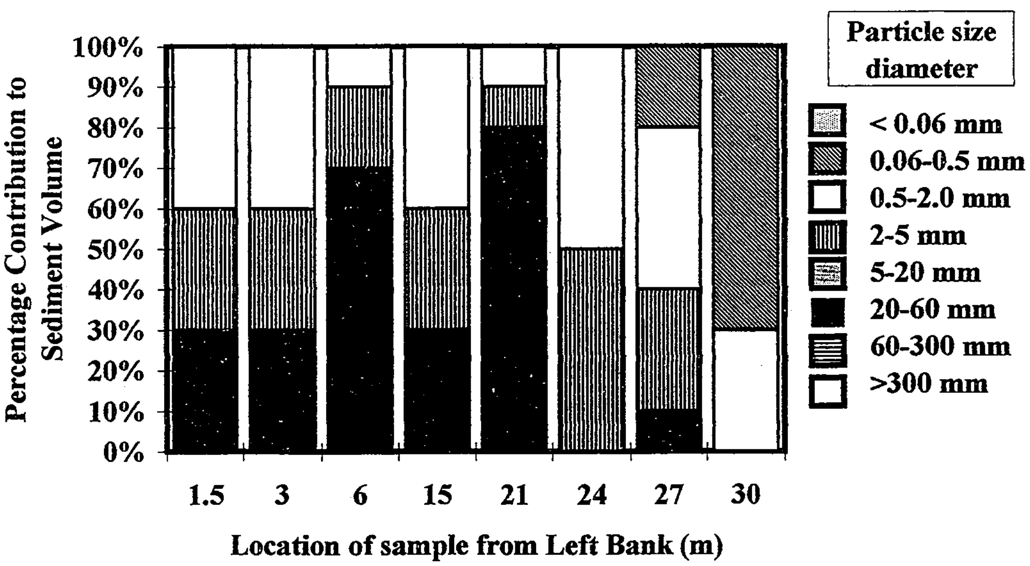


Site Number 1921 18/9/97
- Riffle area 5km upstream Oxtrack Creek junction — upstream area

Cross-section Profile



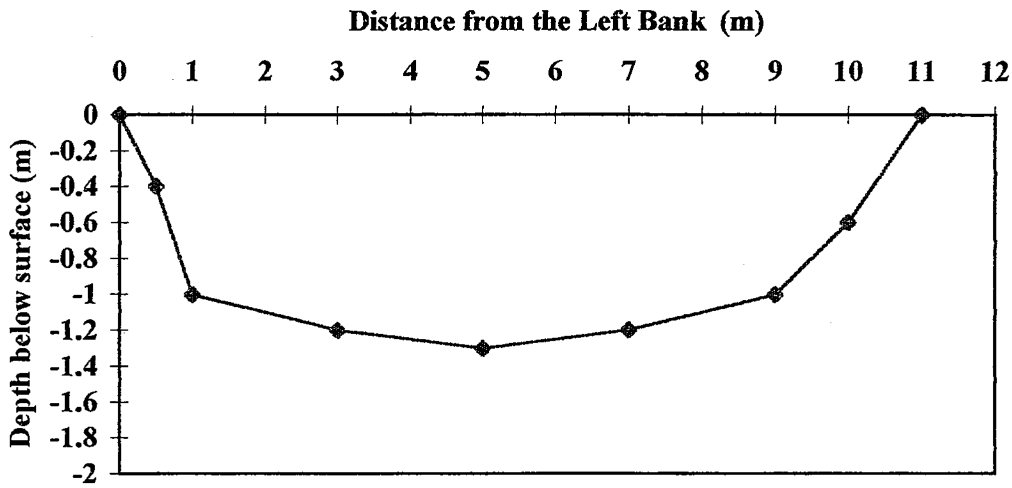
Sediment Particle Size Composition



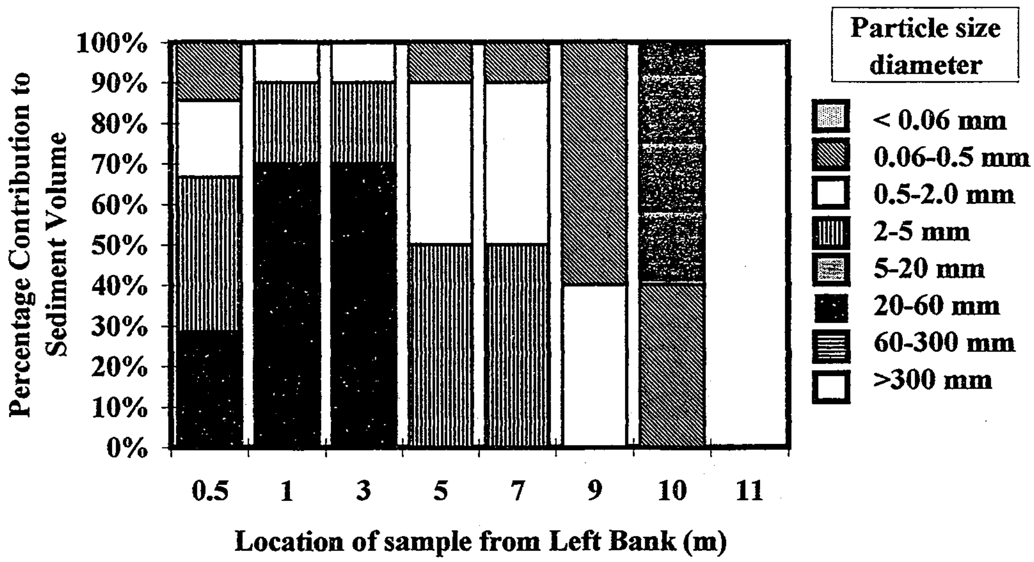
Site Number 1921 18/9/97

- Riffle area 5km upstream Oxtrack Creek junction — downstream area

Cross-section Profile



Sediment Particle Size Composition



Appendix CATCH 1. Catch summaries for 1996 and 1997 surveys for all gear types

COMMON NAME	*SCIENTIFIC NAME*	TOTAL CATCH 1997 SURVEYS	TOTAL CATCH 1996 SURVEYS
Golden perch	***Macquaria ambigua***	**17**	**143**
Long finned eel	***Anguilla reinhardti***	**4**	**10**
Banded Grunter	***Amniataba percoides***	**7**	**3**
Eel tailed Catfish (Tandanus)	***Tandanus tandanus***	**41**	**79**
Hurtl's Catfish	***Neosilurus hyrtlii***	**4**	**9**
Forktailed catfish	***Arius graeffei***	**2**	**46**
Bony bream	***Nematalosa erebi***	**39**	**725**
Spangled perch	***Leiopotherapon unicolor***	**7**	**129**
Gambusia	***Gambusia holbrooki***	**3**	
Carp gudgeon (unid)	***Hyseleotris spp (unidentified)***	**251**	**80**
Empire gudgeon	***Hypseleotris compressa***	**5**	**317**
Midgeley's Carp gudgeon	***Hypseleotris sp. 2***	**30**	**22**
Flat-headed gudgeon	***Philypnodon grandiceps***	**1**	**18**
Fly-speckled hardyhead	***Cratarocephalus stercusmuscarum***	**11**	**9**
Ambassid	***Ambassis agassizii***	**7**	**19**
Eastern rainbowfish	***Melanotaenia splendida splendida***	**17**	**24**
Pacific Blue-eye	***Pseudomugil signifer***	**3**	
Macrobrachium shrimp	***Macrobrachium***	**505**	**32**
Other shrimp		**814**	**107**
Tadpole		**43**	
Yabbies		**13**	
Platypus		**2**	**6**
Eyestripe turtle	***Emydura krefftii***	**47**	**86**
Saw-shelled turtle	***Elseya latisternum***	**2**	**9**
Species only taken 1996			
Dawson Saratoga	***Scleropages leichardti guntheri***		**40**
Purple-spotted Gudgeon	***Mogurnda adspersa***		**7**
Silver Perch	***Bidyanus bidyanus***		**4**

Appendix CATCH 2. Catch summary for site 1921 18/09/1997
Location: 4km upstream Oxtrack Creek junction

Note
1. Numbers in brackets (()) are the average catch per unit effort
2. Numbers in square brackets ([]) are the size range (mm) caught by each gear type.

GEAR	ELECT-FISHER	BAIT TRAPS	FYKE NETS	GILL NETS	TOTAL
EFFORT	35 sq.m.	8 unit	6 units		
SPECIES					
Golden perch			3(0.5) [235-360]		3
Long finned eel			2(0.3) [750-850]		2
Banded Grunter			2(0.3) [50-100]		2
Eel tailed Catfish (Tandanus)			11(1.9) [290-400]		11
Hurtl's Catfish					
Forktailed catfish					
Bony bream					
Spangled perch					
Gambusia					
Carp gudgeon (unid)	80(2.28)				80
Empire gudgeon	3(0.08)	1(0.13)			4
Midgeley's Carp gudgeon	17(0.48)				17
Flatheaded gudgeon					
Freshwater hardyhead					
Ambassid	1(0.03)				1
Eastern rainbowfish					
Blue-eye					
Macrobrachium shrimp	16(0.46)	16(2.0)			32
Other shrimp	107(3.05				107
Tadpole					
Yabbies					
Platypus			1(0.17)		1
Eyestripe turtle					
Saw-shelled turtle					

Appendix CATCH 3. Catch summary for site 246 18/09/1997
Location : Riffle area 1 km downstream Boam Creek junction

Note 1. Numbers in brackets (()) are the average catch per unit effort
2. Numbers in square brackets ([]) are the size range (mm) caught by each gear type

GEAR	ELECT-FISHER	BAIT TRAPS	FYKE NETS	GILL NETS	TOTAL
EFFORT	50 sq.m.	7 unit	6 units		
SPECIES					
Golden perch			2(0.3) [200-380]		2
Long finned eel			2(0.3) [1250]		2
Banded Grunter			2(0.3) [90]		2
Eel tailed Catfish (Tandanus)			4(0.67) [300-410]		4
Hurtl's Catfish					
Forktailed catfish					
Bony bream			2(0.3) [80-110]		2
Spangled perch					
Gambusia					
Carp gudgeon (unid)	6(0.03)	6(0.18)			12
Empire gudgeon					
Midgeley's Carp gudgeon	1(0.01)				1
Flatheaded gudgeon					
Freshwater hardyhead	2(0.01)				2
Ambassid					
Eastern rainbowfish					
Blue-eye					
Macrobrachium shrimp	6(0.03)	19(2.7)			25
Other shrimp	12(0.06)				12
Tadpole					
Yabbies					
Platypus					
Eyestripe turtle					
Saw-shelled turtle					

Appendix CATCH 4. Catch summary for site 249 17/09/1997
Location: At Delusion Creek junction

Note 1. Numbers in brackets (()) are the average catch per unit effort
2. Numbers in square brackets ([]) are the size range (mm) caught by each gear type

GEAR	ELECT-FISHER	BAIT TRAPS	FYKE NETS	GILL NETS	TOTAL
EFFORT	240 sq.m.	6 unit	6 units		
SPECIES					
Golden perch			2(0.3) [210-255]		2
Long finned eel					
Banded Grunter					
Eel tailed Catfish (Tandanus)	1(0.004) [100]		6(1.0) [100-400]		7
Hurtl's Catfish			1(0.1) [210]		1
Forktailed catfish					
Bony bream	11(0.046) [60-250]				11
Spangled perch	1(0.004) [100]				1
Gambusia					
Carp gudgeon (unid)	88(0.367)				88
Empire gudgeon					
Midgeley's Carp gudgeon	9(0.038)				9
Flatheaded gudgeon					
Freshwater hardyhead	7(0.029)				7
Ambassid	2(0.008)				2
Eastern rainbowfish	4(0.017)				4
Blue-eye	1(0.004)				1
Macrobrachium shrimp	16(0.067)	3(0.5)			19
Other shrimp	134(0.56)	7(0.85)			141
Tadpole					
Yabbies					
Platypus					
Eyestripe turtle					
Saw-shelled turtle					

Appendix CATCH 5. Catch summary for site 246 27/10/1997
Location : Riffle area 1 km downstream Boam Creek junction

Note 1. Numbers in brackets (()) are the average catch per unit effort
2. Numbers in square brackets ([]) are the size range (mm) caught by each gear type

GEAR	ELECT-FISHER	BAIT TRAPS	FYKE NETS	GILL NETS	TOTAL
EFFORT	250 sq.m.	11 unit	5 units		
SPECIES					
Golden perch			1(0.2) [400]		1
Long finned eel					
Banded Grunter			1(0.2) [30]		1
Eel tailed Catfish (Tandanus)			2(0.4) [100-430]		2
Hurtl's Catfish			2(0.40) [150-180]		2
Forktailed catfish					
Bony bream			3(0.6) [80-90]		3
Spangled perch					
Gambusia					
Carp gudgeon (unid)		6(0.54)			6
Empire gudgeon					
Midgeley's Carp gudgeon	2(0.008)	1(0.09)			3
Flatheaded gudgeon					
Freshwater hardyhead					
Ambassid		1(0.09)			1
Eastern rainbowfish		3(0.27)	1(0.2)		4
Blue-eye					
Macrobrachium shrimp	8(0.03)	28(2.54)			36
Other shrimp	10(0.04)	3(0.27)			13
Tadpole					
Yabbies	2(0.008)	1(0.09)			3
Platypus			1(0.2)		1
Eyestripe turtle					
Saw-shelled turtle					

Appendix CATCH 6. Catch summary for site 249 27/10/1997
Location: At Delusion Creek junction
Note riffle dry - survey in shallow run and pool margin areas upstream and downstream

Note 1. Numbers in brackets (()) are the average catch per unit effort
2. Numbers in square brackets ([]) are the size range (mm) caught by each gear type

GEAR	ELECT-FISHER	BAIT TRAPS	FYKE NETS	GILL NETS	TOTAL
EFFORT	100 sq.m.	19 unit	9 units		
SPECIES					
Golden perch			4(0.444) [160-330]		4
Long finned eel					
Banded Grunter			2(0.222) [120]		2
Eel tailed Catfish (Tandanus)			8(0.89) [230-430]		8
Hurtl's Catfish			1(0.11) [360]		1
Forktailed catfish			2(0.222) [230]		2
Bony bream	10(0.1)				10
Spangled perch					
Gambusia	3(0.03)				3
Carp gudgeon (unid)	12(0.12)	31(1.63)			43
Empire gudgeon					
Midgeley's Carp gudgeon					
Flatheaded gudgeon					
Freshwater hardyhead	2(0.02)				2
Ambassid	2(0.02)				2
Eastern rainbowfish	7(0.07)				7
Blue-eye					
Macrobrachium shrimp	5(0.05)	27(1.42)			32
Other shrimp	3(0.03)	6(0.31)			9
Tadpole	30(0.3)	13(0.68)			43
Yabbies	2(0.02)	4(0.21)			6
Platypus					
Eyestripe turtle			47(5.22)		47
Saw-shelled turtle			7(0.77)		7

Appendix CATCH 7. Catch summary for site 914 29/10/1997
Location: Just downstream 1996 dam site

Note 1. Numbers in brackets (()) are the average catch per unit effort
2. Numbers in square brackets ([]) are the size range (mm) caught by each gear type

GEAR	ELECT-FISHER	BAIT TRAPS	FYKE NETS	GILL NETS	TOTAL
EFFORT	240 sq.m.				
SPECIES					
Golden perch					
Long finned eel					
Banded Grunter					
Eel tailed Catfish (Tandanus)					
Hurtl's Catfish					
Forktailed catfish					
Bony bream	2(0.1) [35-50]				2
Spangled perch	3(0.013) [30-170]				3
Gambusia					
Carp gudgeon (unid)	15(0.063)				15
Empire gudgeon	1(0.004)				1
Midgeley's Carp gudgeon					
Flatheaded gudgeon					
Freshwater hardyhead					
Ambassid					
Eastern rainbowfish					
Blue-eye	3(0.125)				3
Macrobrachium shrimp	140(0.58)				140
Other shrimp					
Tadpole					
Yabbies					
Platypus					
Eyestripe turtle					
Saw-shelled turtle					

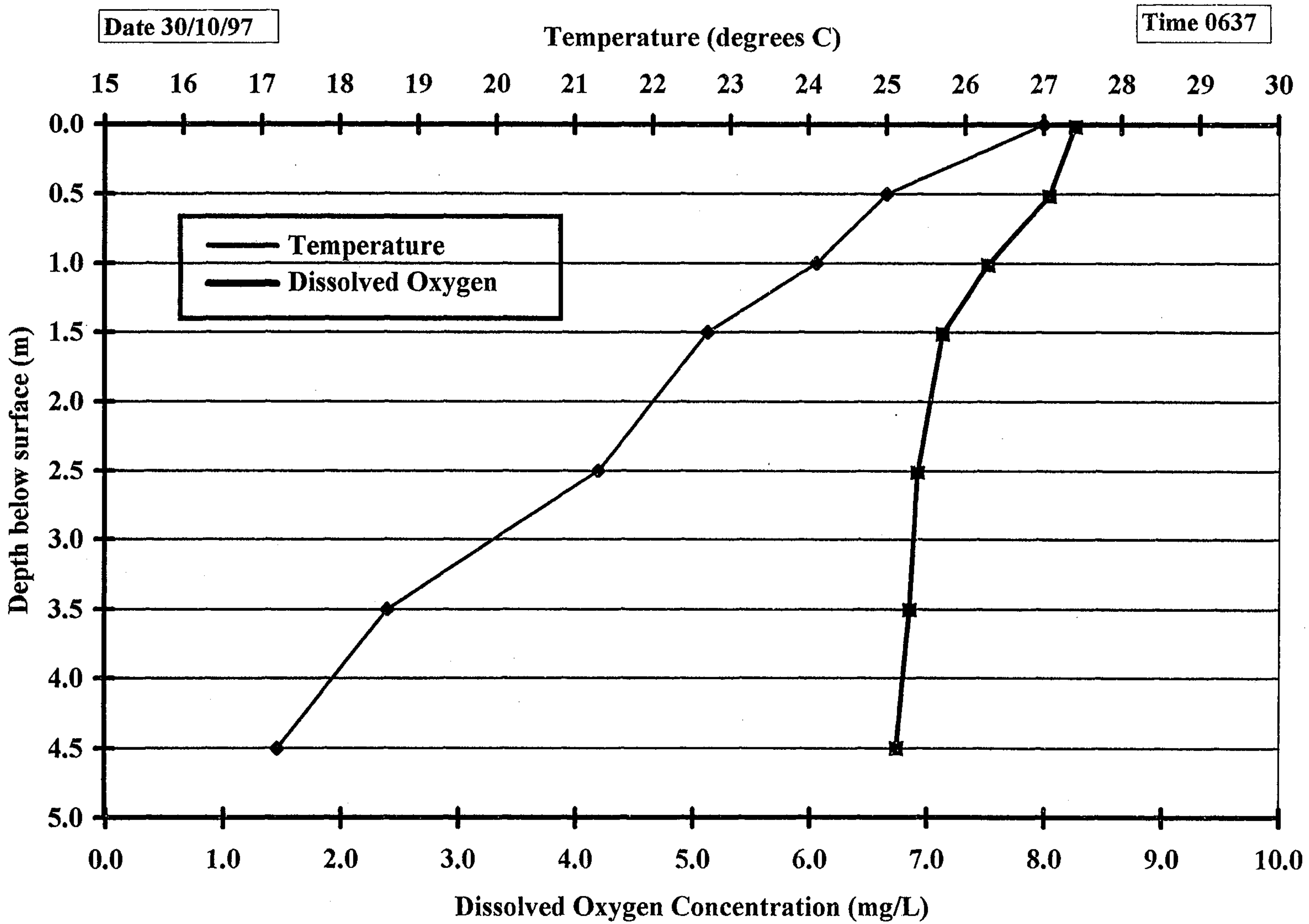
Appendix CATCH 8. Catch summary for site 907 29/10/1997
Just downstream of Price Creek junction

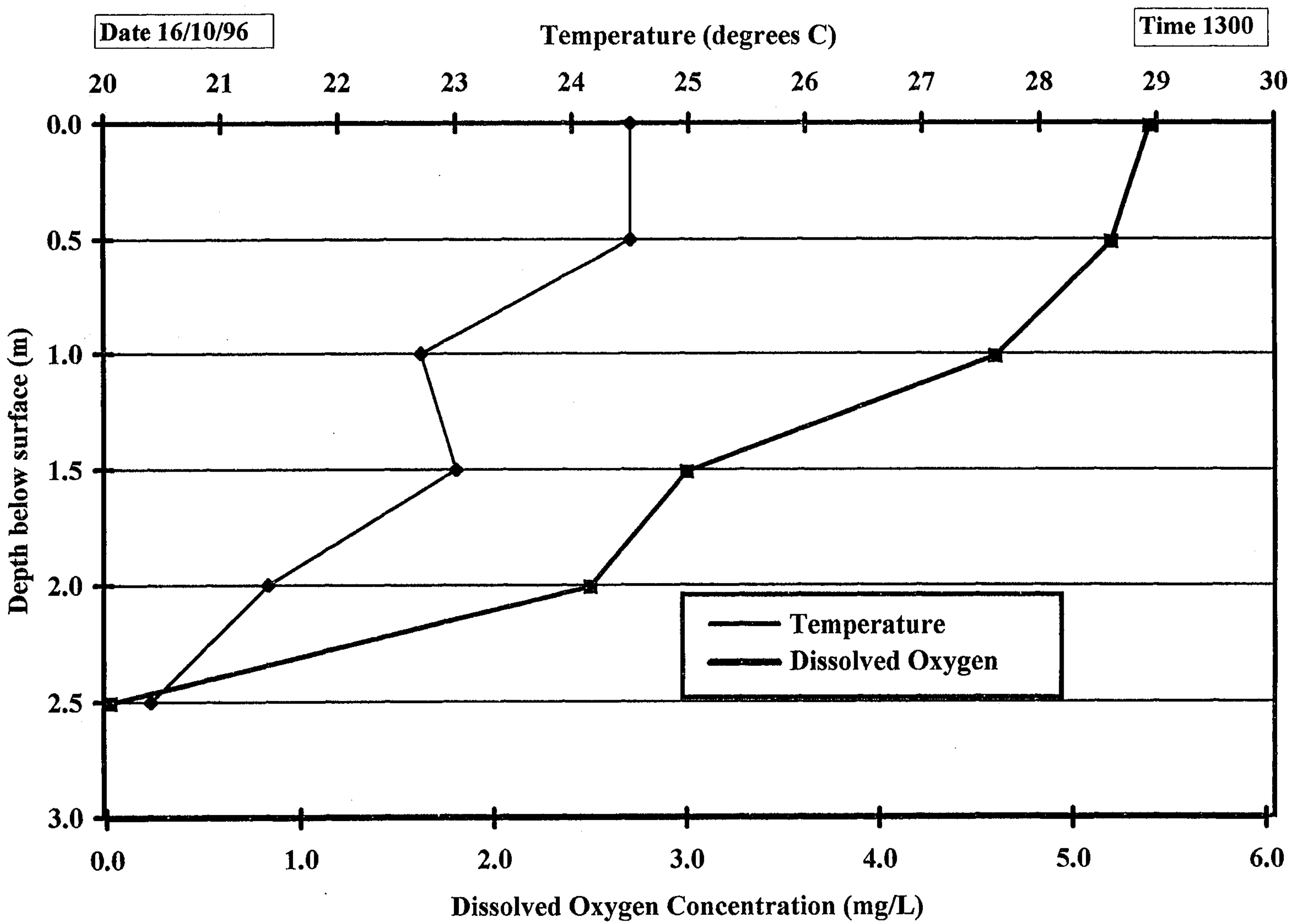
Note 1. Numbers in brackets (()) are the average catch per unit effort
2. Numbers in square brackets ([]) are the size range (mm) caught by each gear type

GEAR	ELECT-FISHER	BAIT TRAPS	FYKE NETS	GILL NETS	TOTAL
EFFORT		9 unit	7 units	4 (80-130mm)	
SPECIES					
Golden perch			1(0.14) [150]	4(1.0) [260-400]	5
Long finned eel					
Banded Grunter					
Eel tailed Catfish (Tandanus)			2(0.28) [400]	7(1.75) [390-430]	9
Hurtl's Catfish					
Forktailed catfish					
Bony bream			11(1.57) [35-180]		11
Spangled perch			3(0.42) [100-160]		3
Gambusia					
Carp gudgeon (unid)		7(0.78)			7
Empire gudgeon					
Midgeley's Carp gudgeon					
Flatheaded gudgeon					
Freshwater hardyhead					
Ambassid		1(0.11)			1
Eastern rainbowfish					
Blue-eye					
Macrobrachium shrimp		30(3.33)			30
Other shrimp		27(3.0)			27
Tadpole					
Yabbies		20(0.22)	2(0.28)		4
Platypus					
Eyestripe turtle					
Saw-shelled turtle			2(0.28)		2

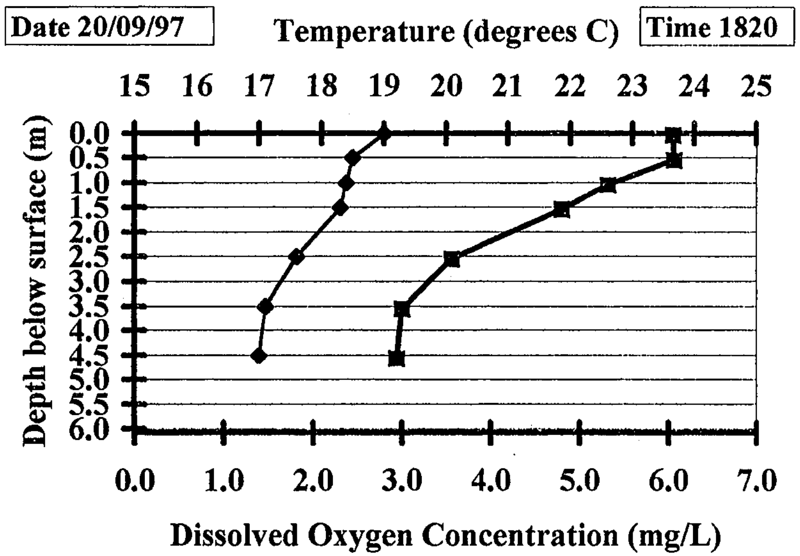
Appendix WQUAL.

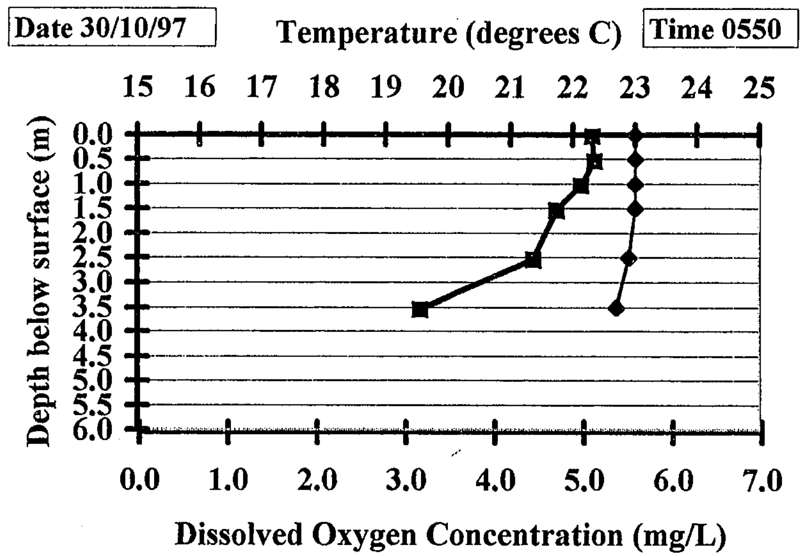
Water quality measurements were taken *in situ* at a series of depths from the surface, generally at 0.5-1m intervals. Readings were taken just under the surface. The deepest reading was taken 0.5m above the bottom. The time a date for each of the readings is shown on the following graphs. Trend lines have been added to help visualise the changes with depth. The depth changes between various sample dates was due to changes in the location, and hence depth, where the profile readings were taken rather than a change in depth of the water column.

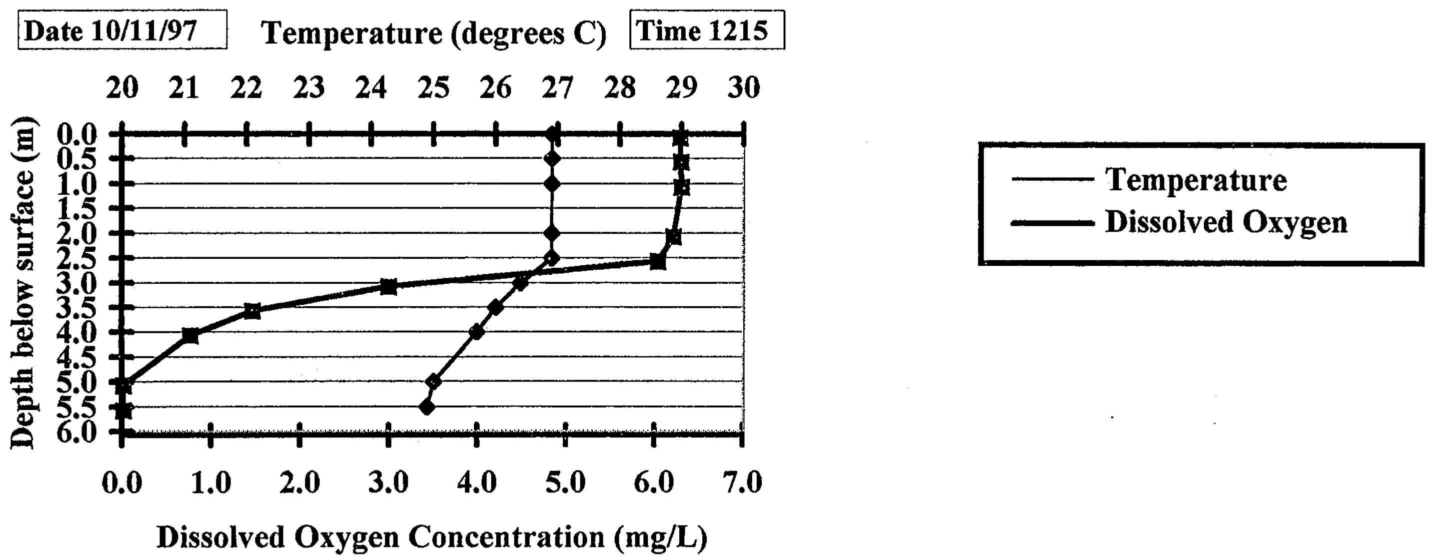

Date 30/10/97
Time 0637
Temperature (degrees C)
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
Temperature
Dissolved Oxygen
Depth below surface (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Dissolved Oxygen Concentration (mg/L)



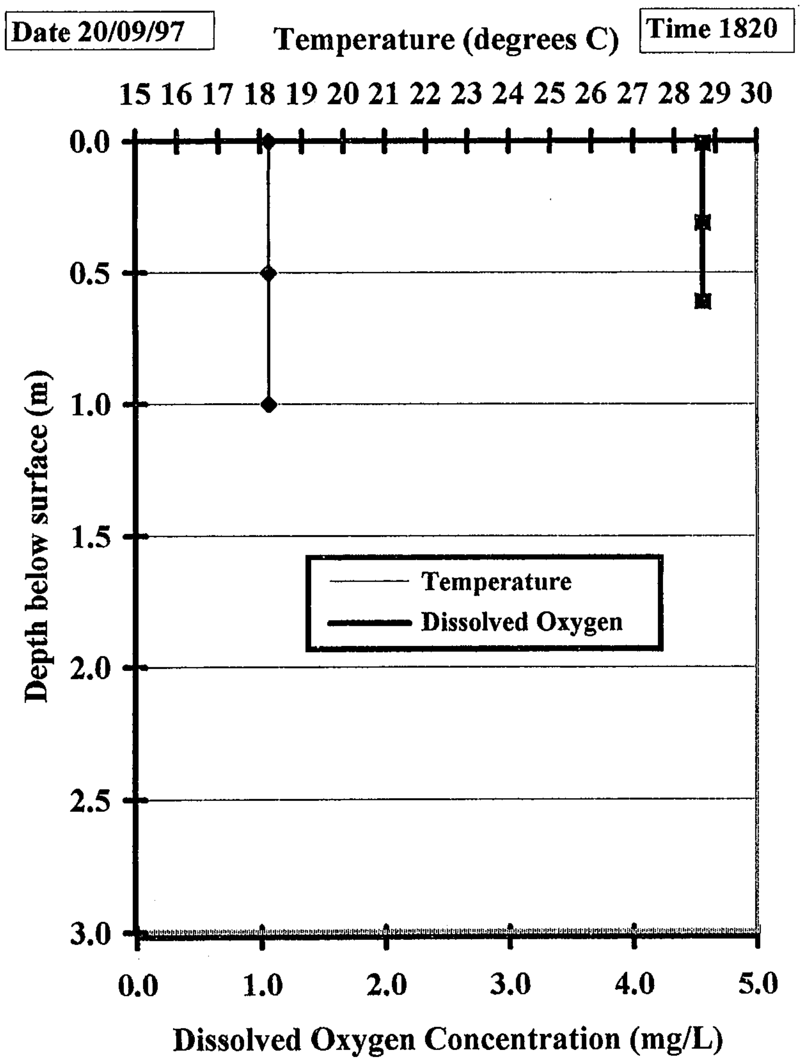
Date 16/10/96
Temperature (degrees C)
Time 1300
20
21
22
23
24
25
26
27
28
29
30
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Depth below surface (m)
Temperature
Dissolved Oxygen
0.0
1.0
2.0
3.0
4.0
5.0
6.0
Dissolved Oxygen Concentration (mg/L)



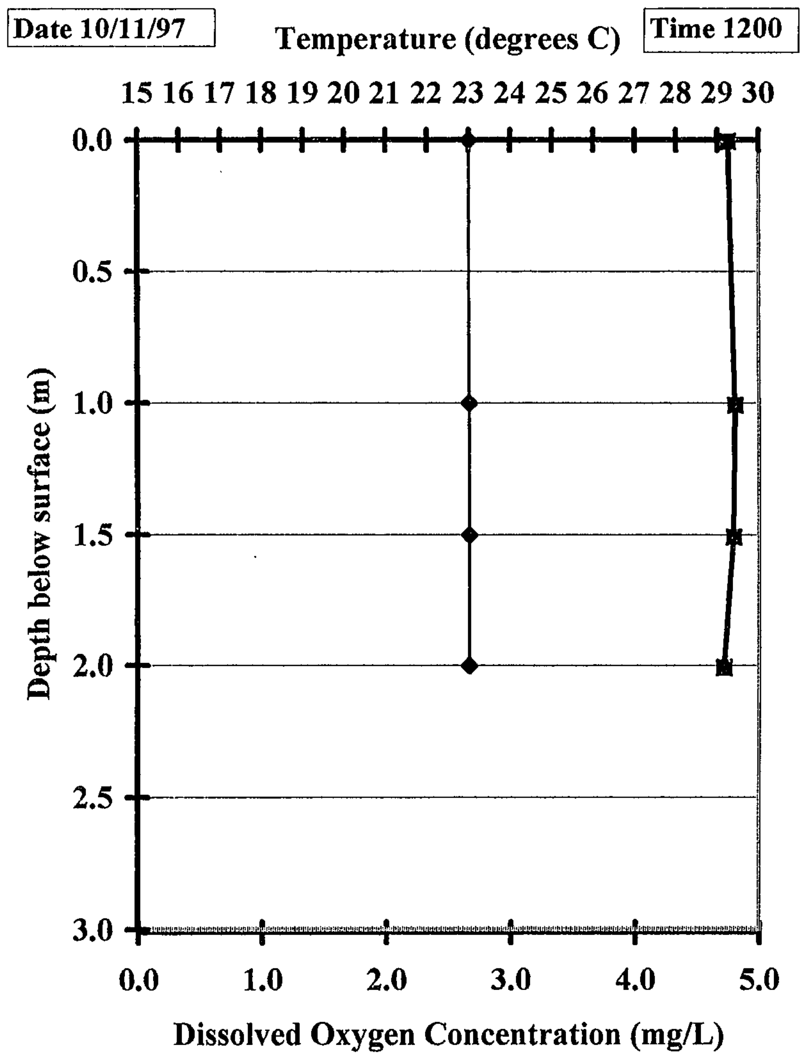




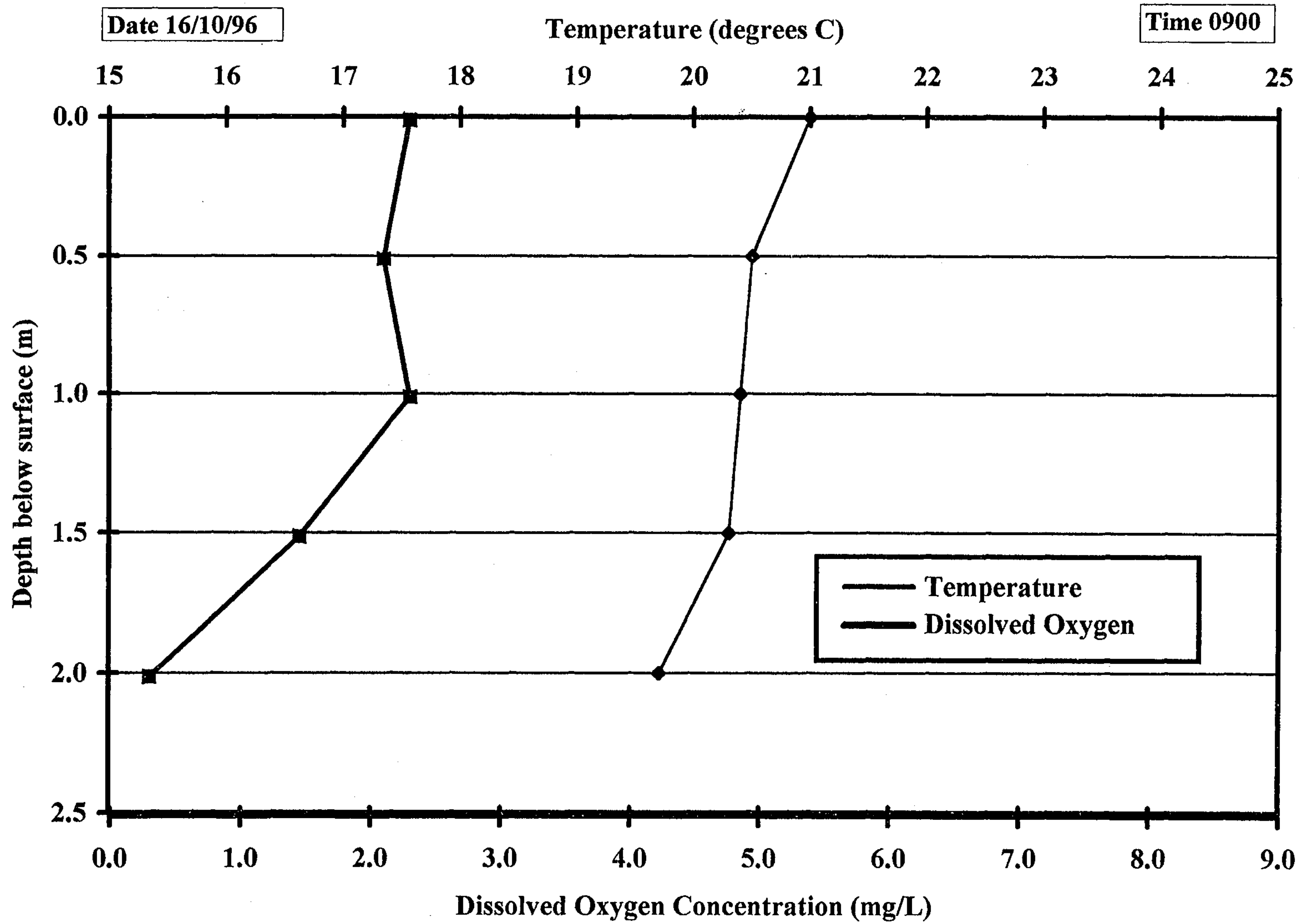
Site Number 133 -Glebe Weir (just upstream weir)



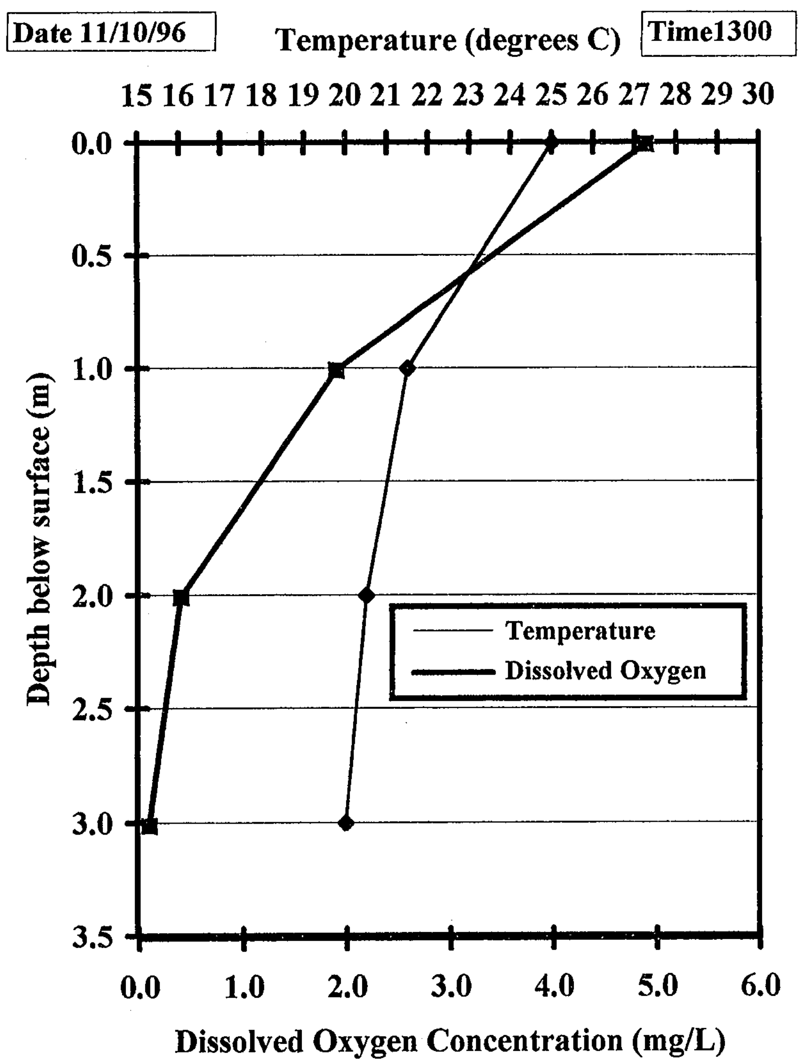
Date 20/09/97
Temperature (degrees C)
Time 1820
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Depth below surface (m)
Temperature
Dissolved Oxygen
0.0 1.0 2.0 3.0 4.0 5.0
Dissolved Oxygen Concentration (mg/L)



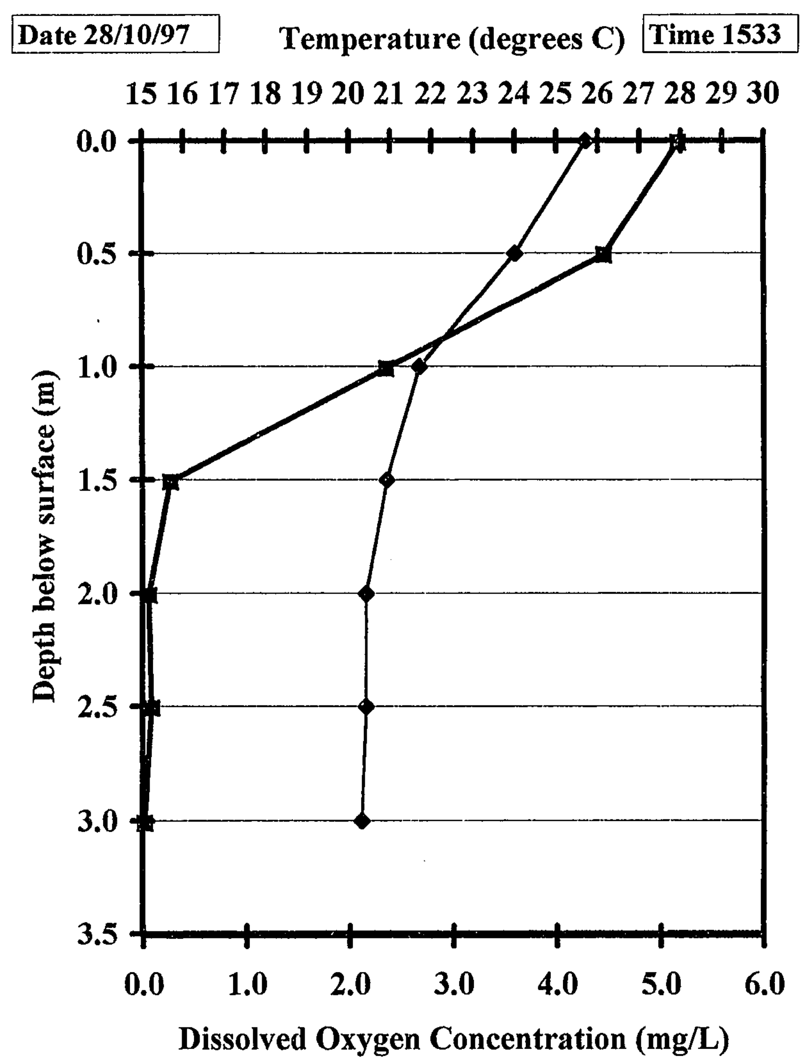
Date 10/11/97
Temperature (degrees C)
Time 1200
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Depth below surface (m)
0.0 1.0 2.0 3.0 4.0 5.0
Dissolved Oxygen Concentration (mg/L)



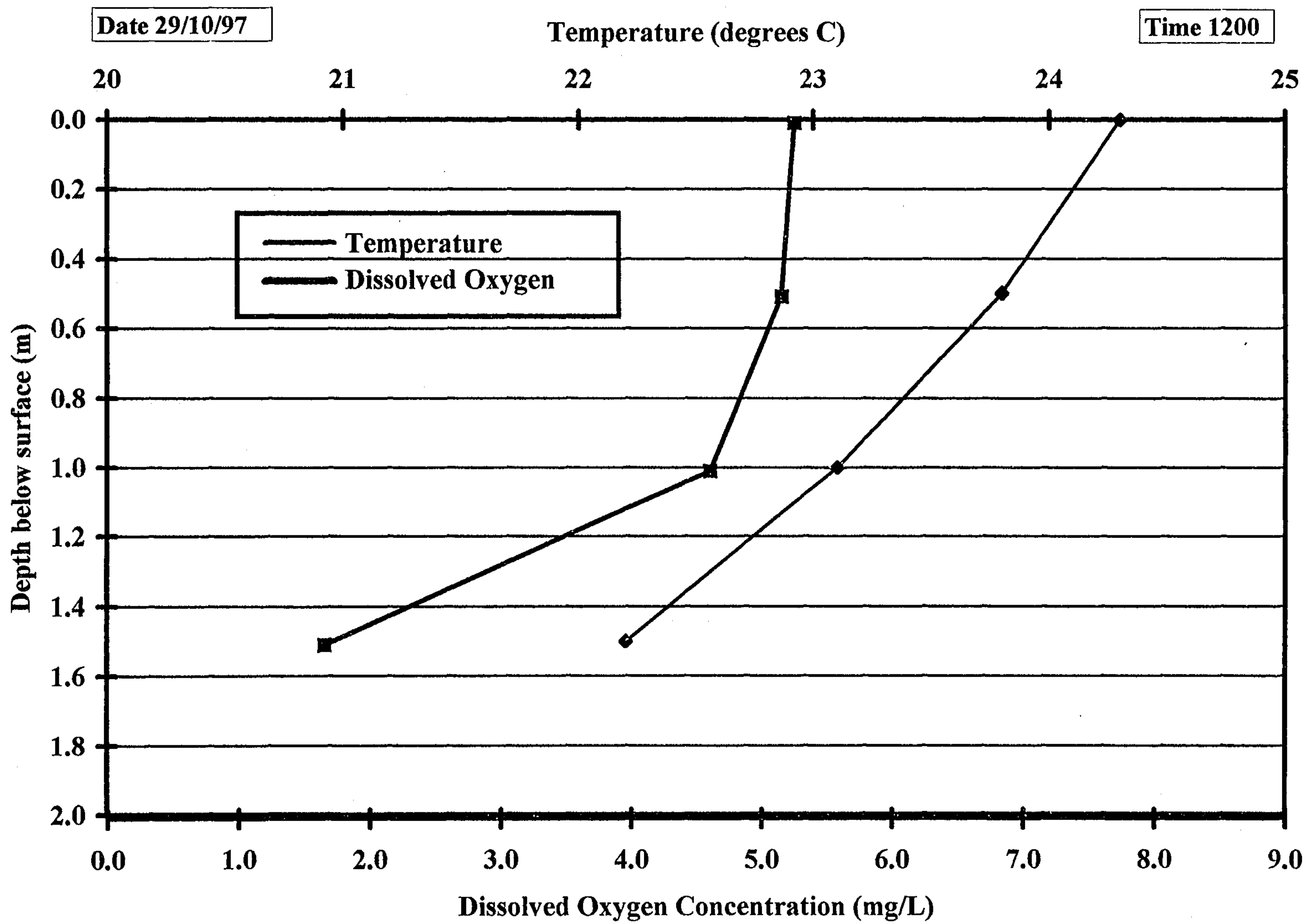
Site Number 915 -5km downstream Glebe Weir



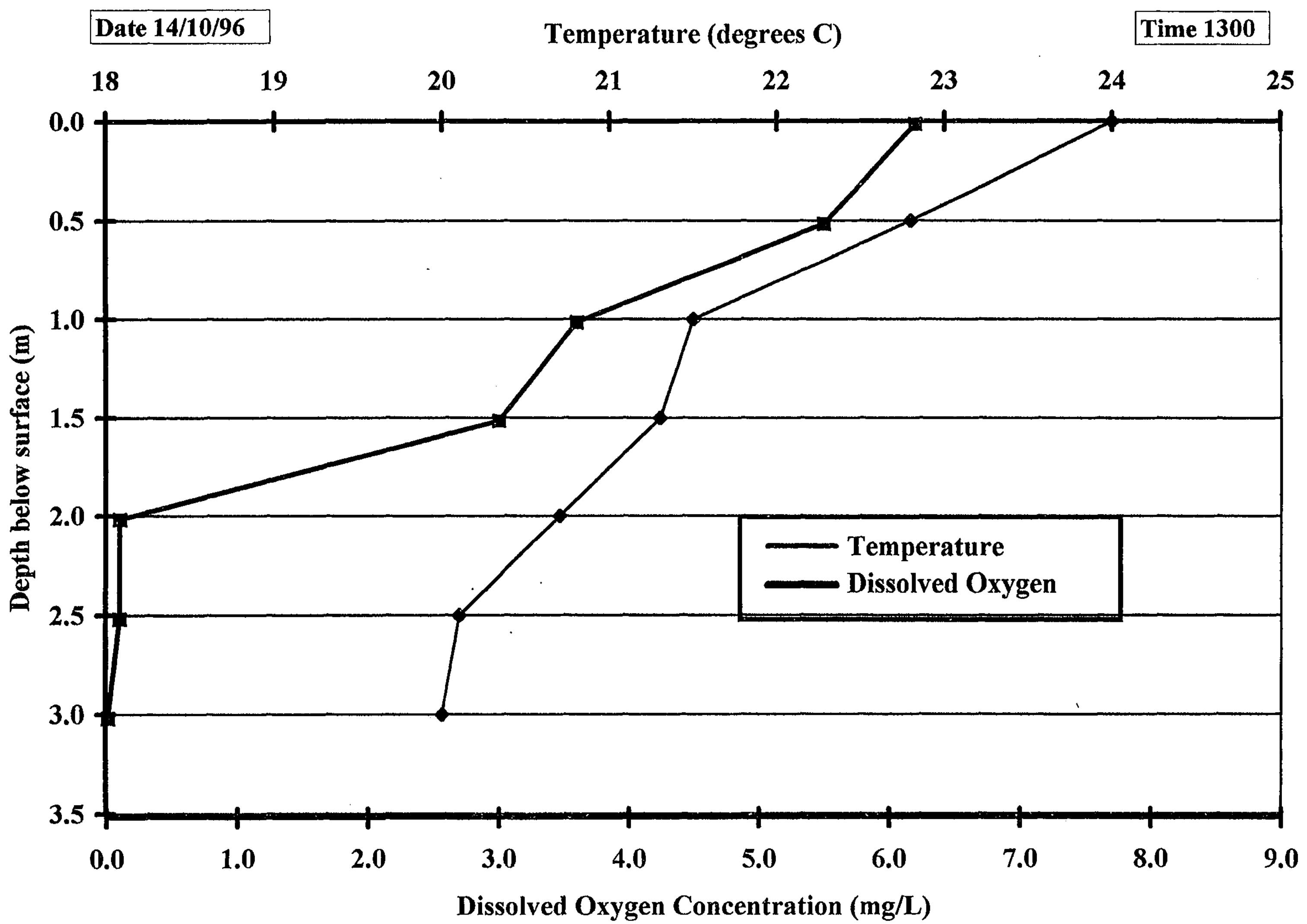
Date 11/10/96
Temperature (degrees C)
Time1300
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Depth below surface (m)
Temperature
Dissolved Oxygen
0.0 1.0 2.0 3.0 4.0 5.0 6.0
Dissolved Oxygen Concentration (mg/L)

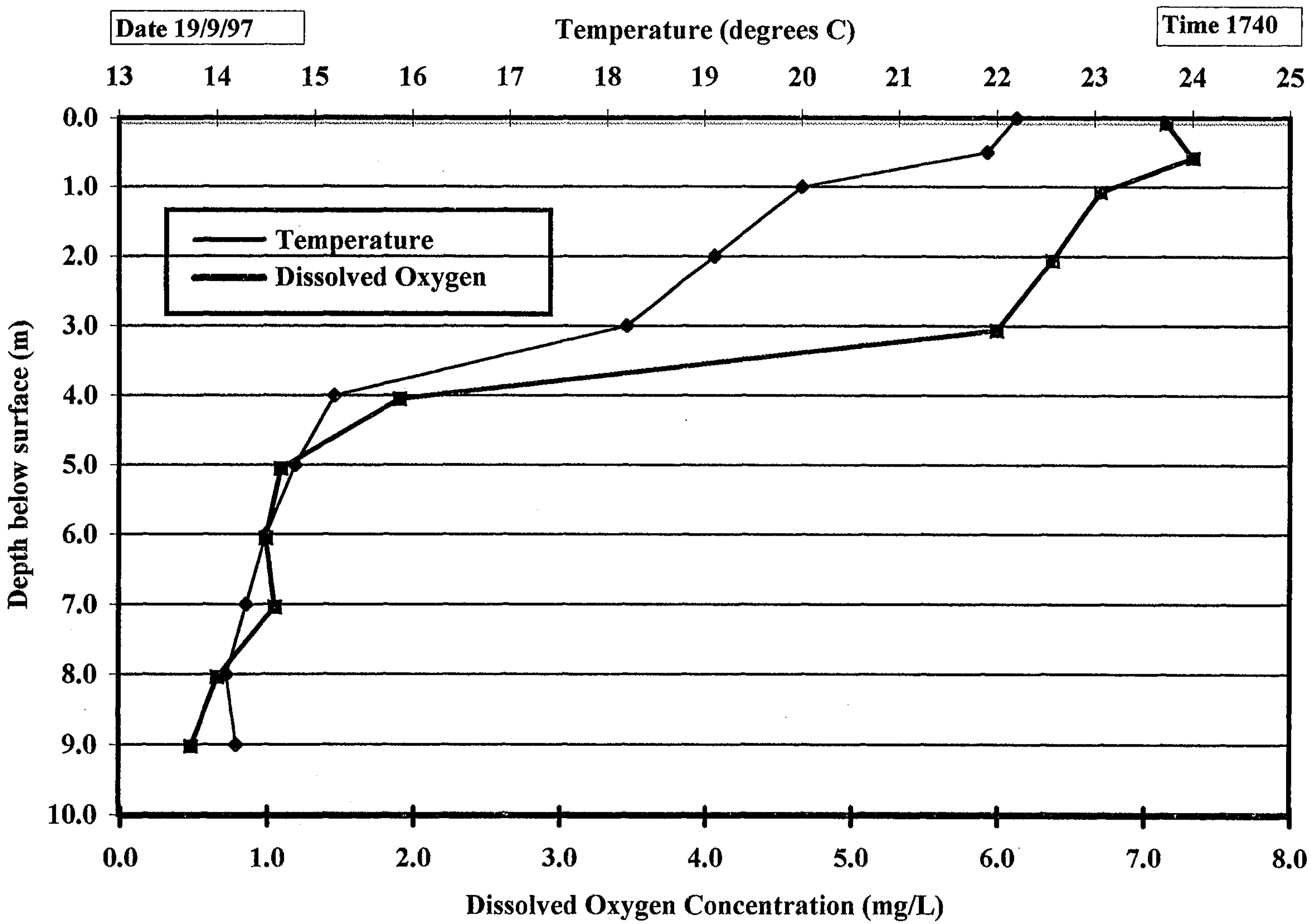


Date 28/10/97
Temperature (degrees C)
Time 1533
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Depth below surface (m)
0.0 1.0 2.0 3.0 4.0 5.0 6.0
Dissolved Oxygen Concentration (mg/L)

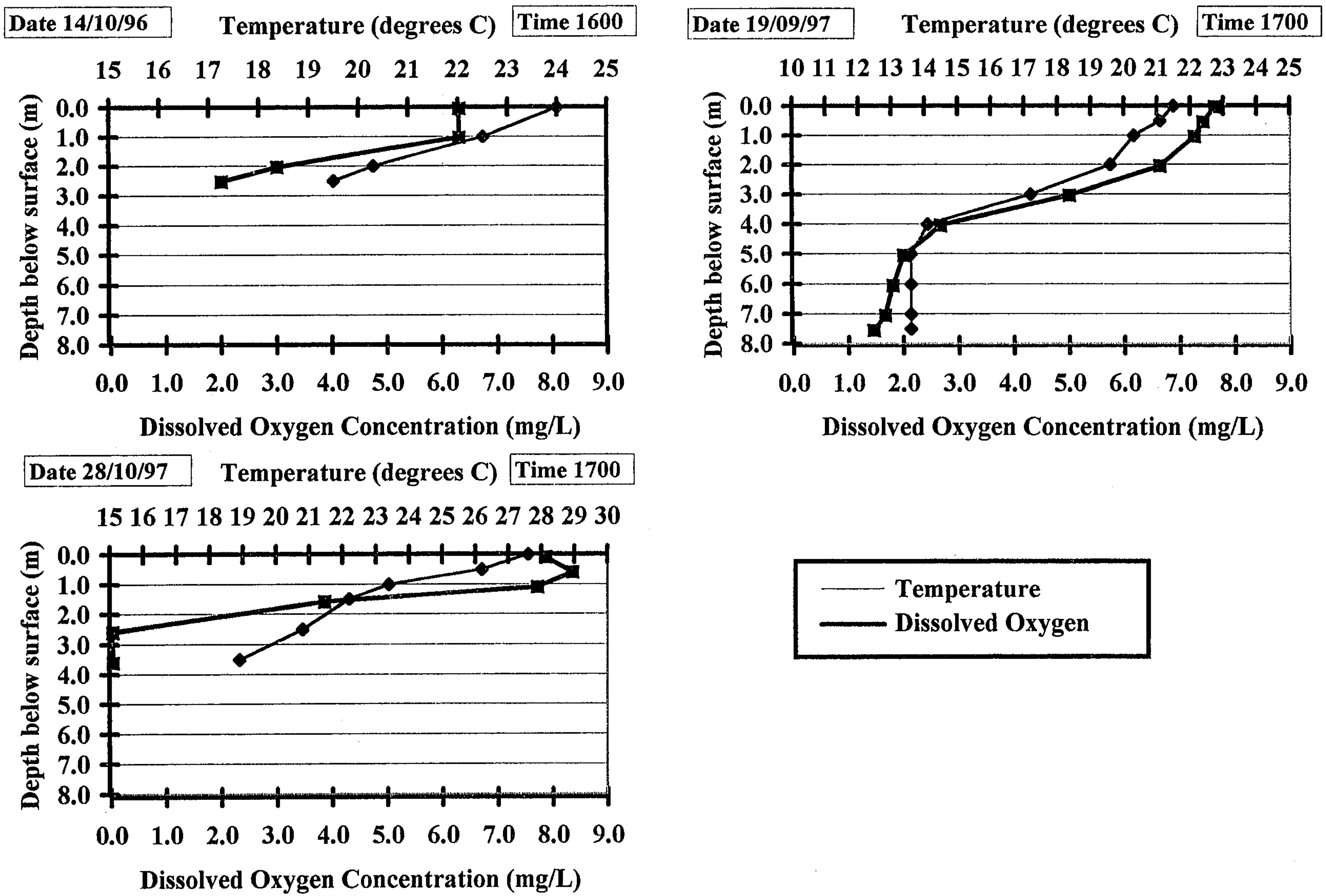


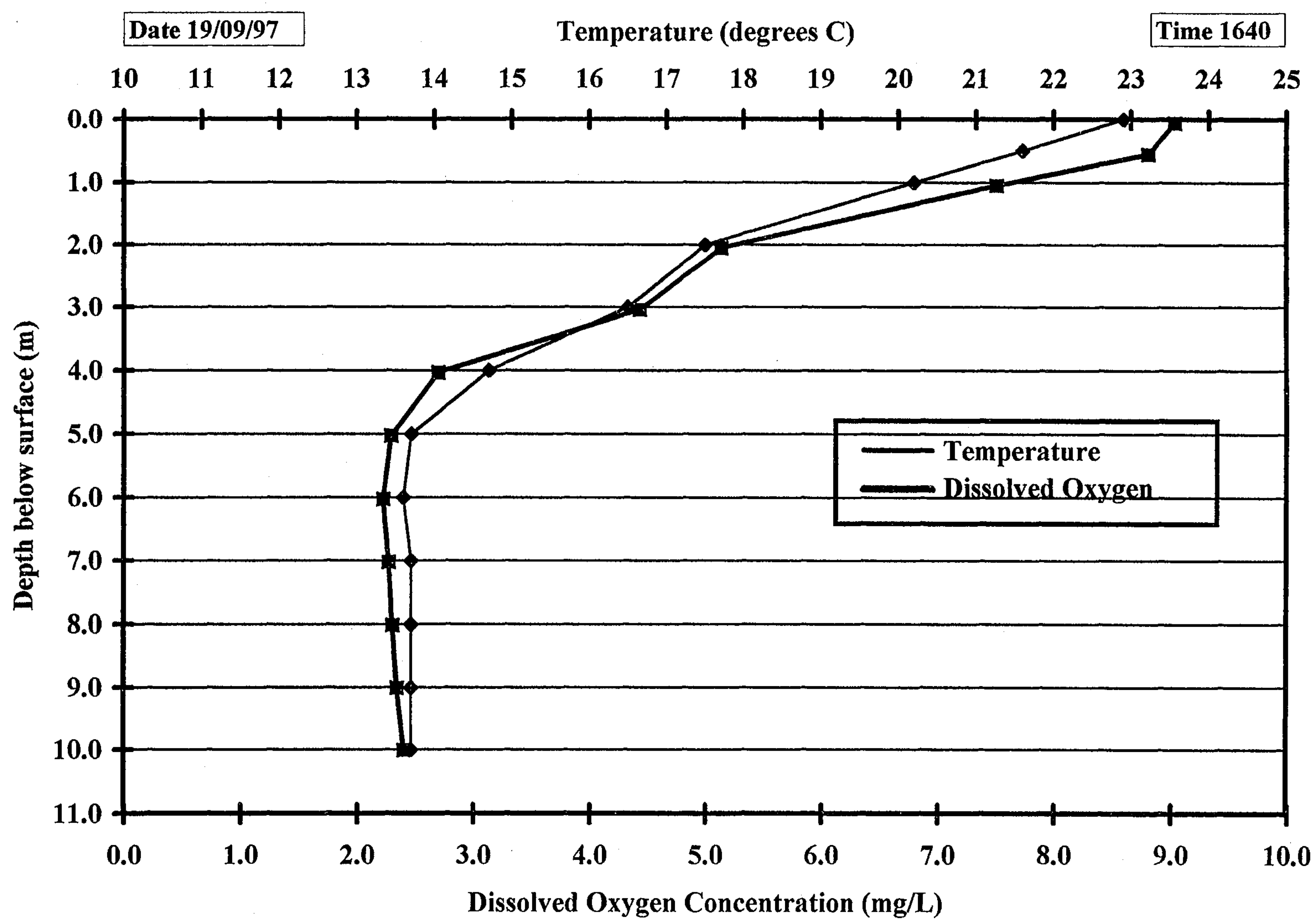
Site Number 914 -just downstream 1996 Dam site


Date 14/10/96
Temperature (degrees C)
Time 1300
18
19
20
21
22
23
24
25
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Depth below surface (m)
Temperature
Dissolved Oxygen
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
Dissolved Oxygen Concentration (mg/L)

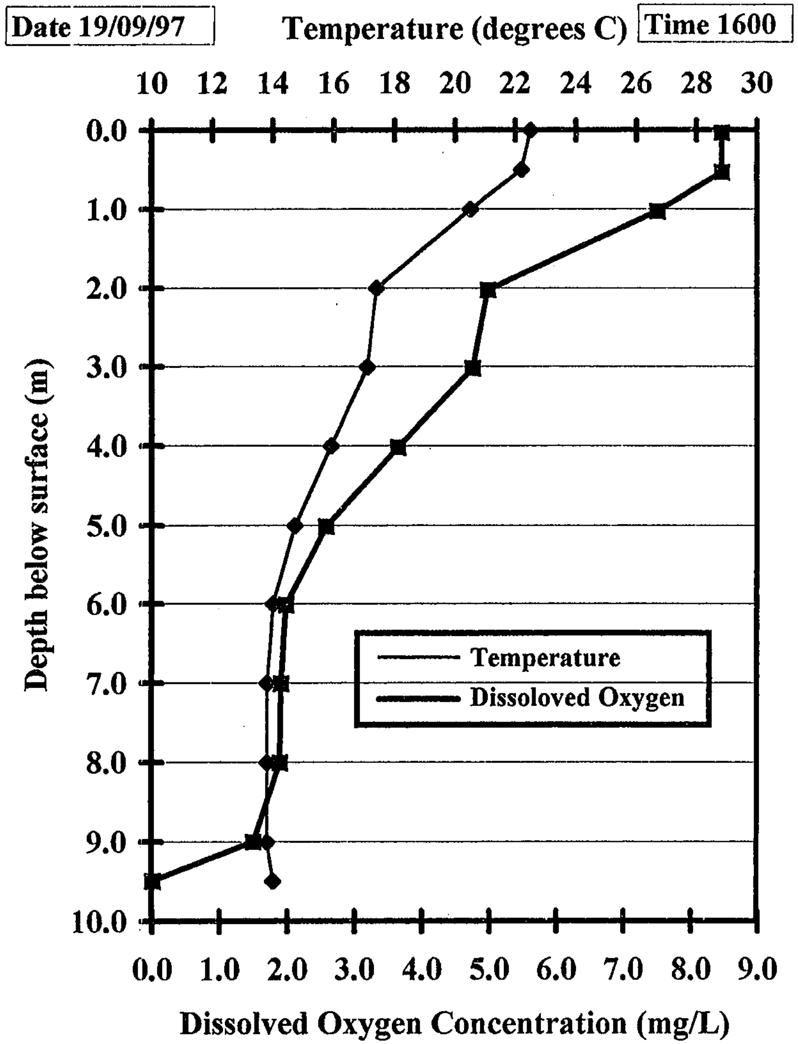


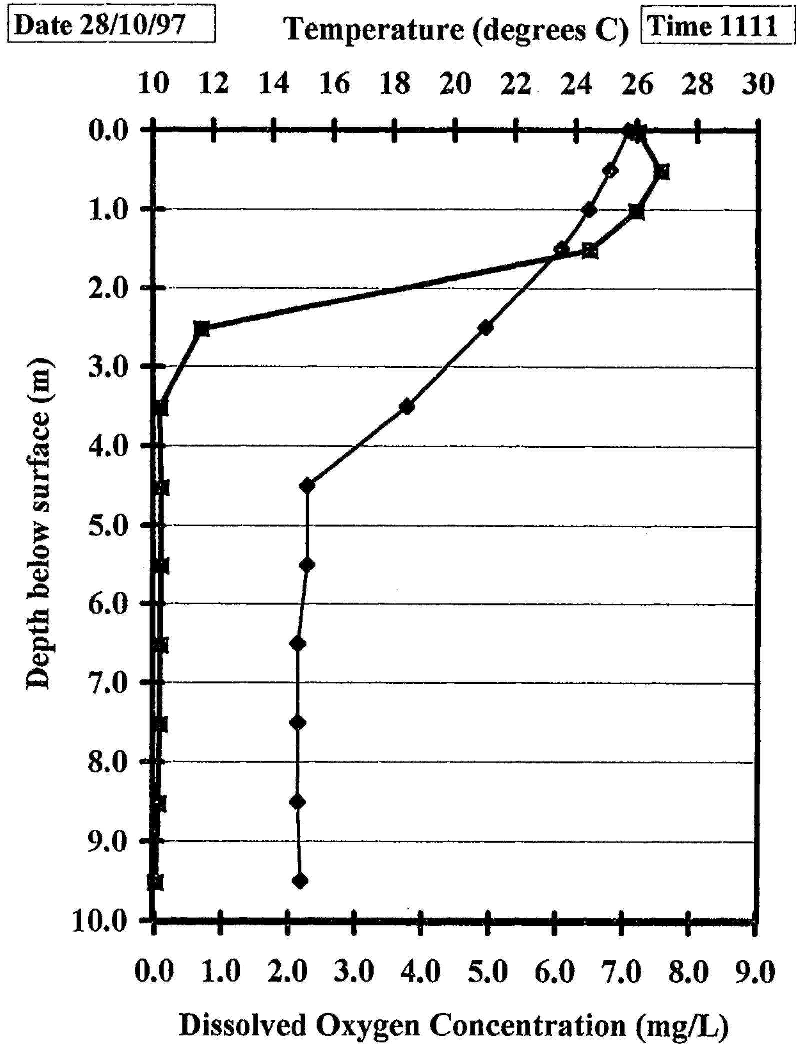
 Site Number 988 -'Round Water Hole' 5km downstream of Price Creek junction

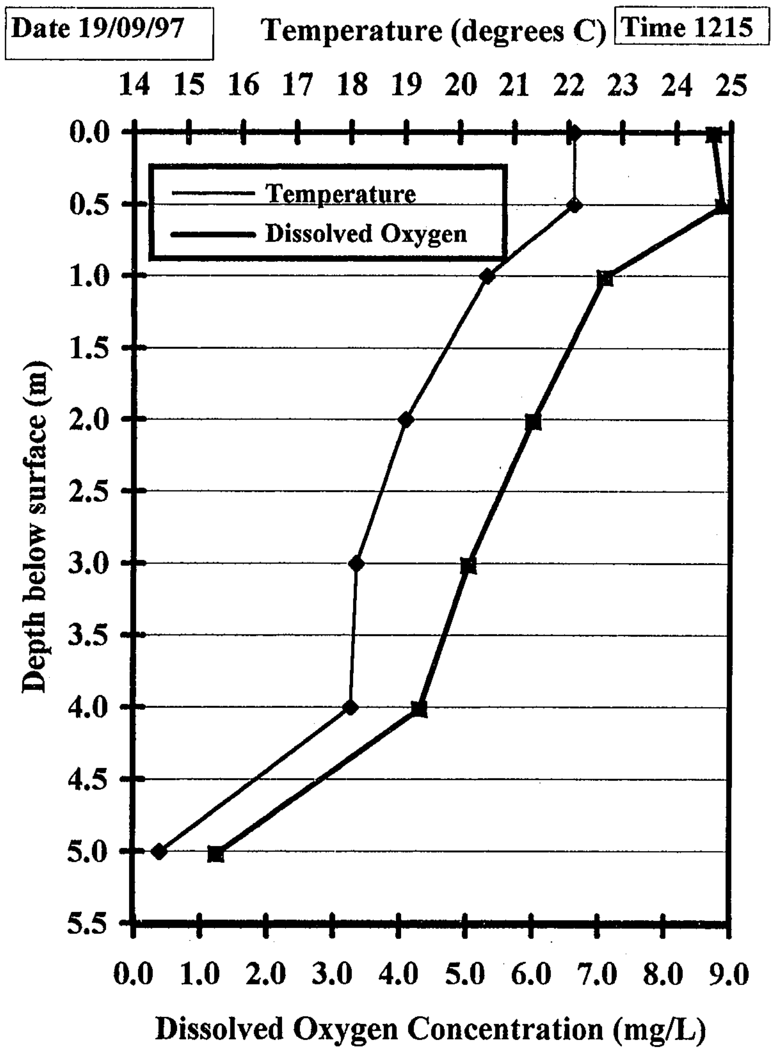

Date 14/10/96
Temperature (degrees C)
Time 1600
15 16 17 18 19 20 21 22 23 24 25
Depth below surface (m)
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0
Dissolved Oxygen Concentration (mg/L)
Date 19/09/97
Temperature (degrees C)
Time 1700
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Depth below surface (m)
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0
Dissolved Oxygen Concentration (mg/L)
Date 28/10/97
Temperature (degrees C)
Time 1700
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Depth below surface (m)
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0
Dissolved Oxygen Concentration (mg/L)
Temperature
Dissolved Oxygen

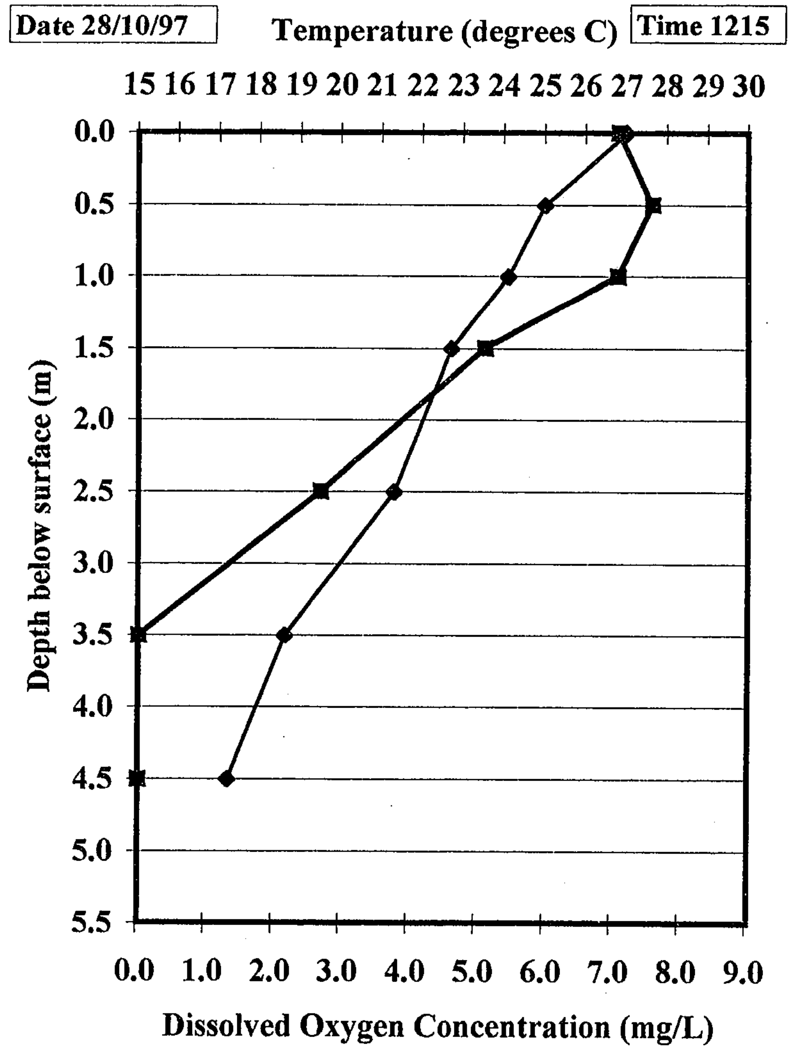


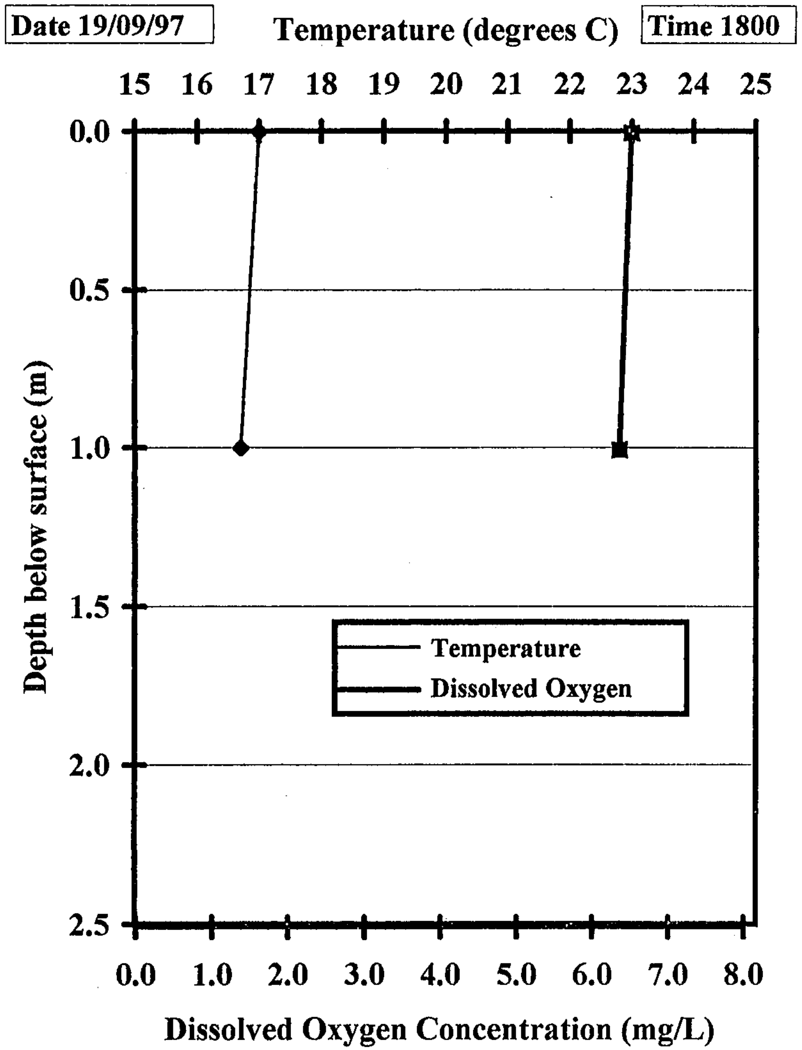
Site Number 2609 -Gyranda weir pool about 20 km upstream weir

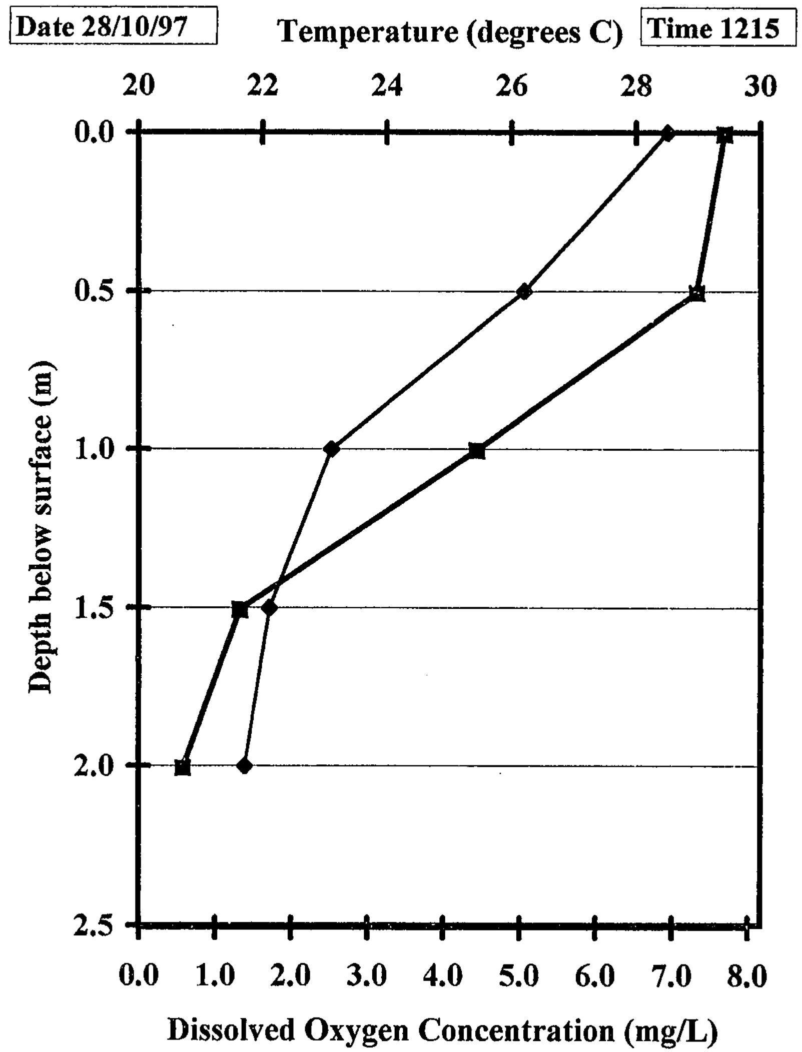

Date 19/09/97
Temperature (degrees C)
Time 1600
10 12 14 16 18 20 22 24 26 28 30
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Depth below surface (m)
Temperature
Dissoloved Oxygen
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0
Dissolved Oxygen Concentration (mg/L)

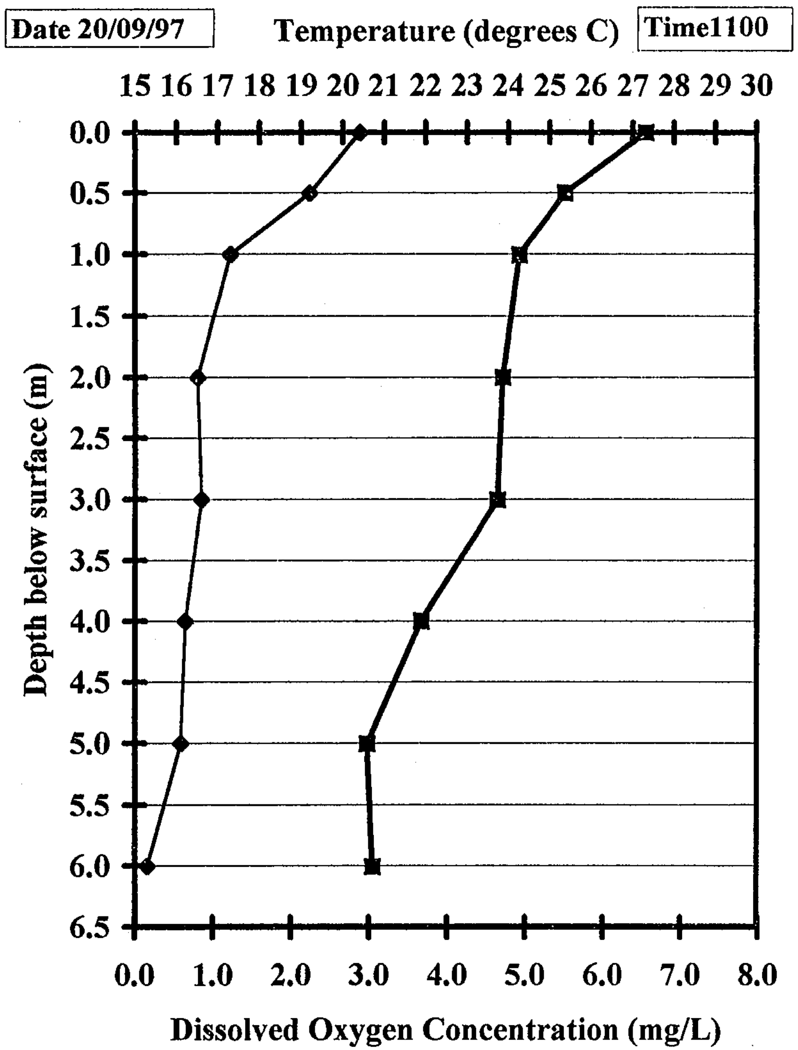

Date 28/10/97
Temperature (degrees C)
Time 1111
10 12 14 16 18 20 22 24 26 28 30
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Depth below surface (m)
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0
Dissolved Oxygen Concentration (mg/L)

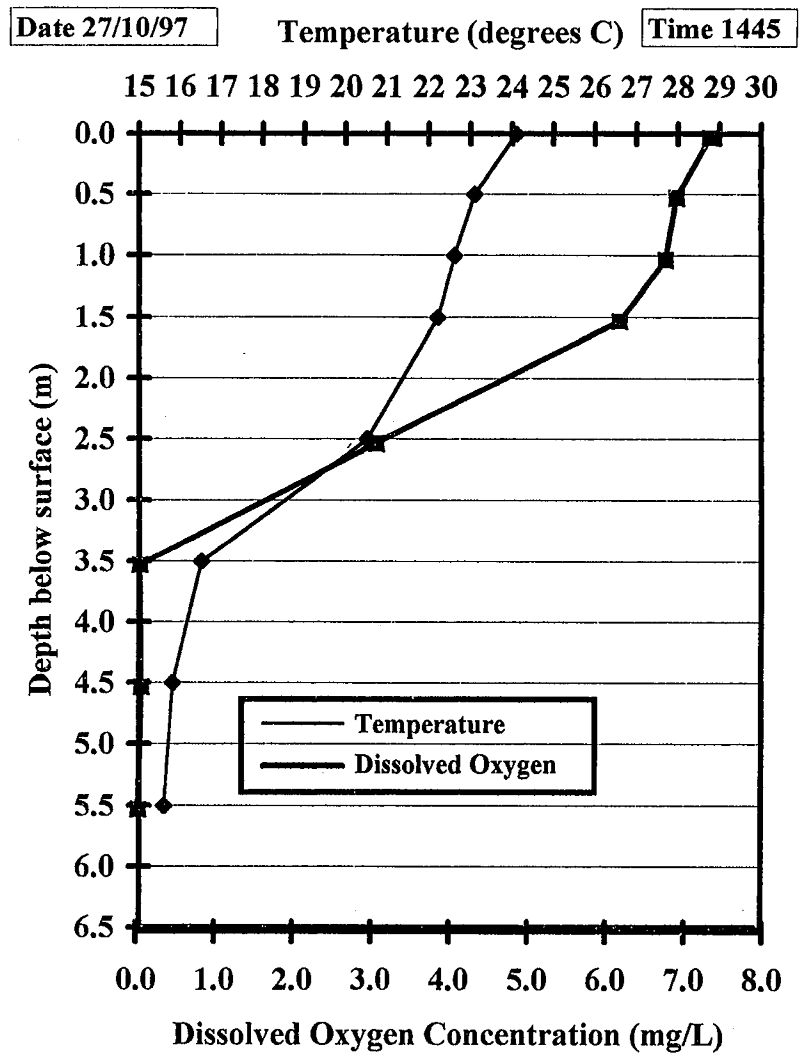

Date 19/09/97
Temperature (degrees C)
Time 1215
14 15 16 17 18 19 20 21 22 23 24 25
Temperature
Dissolved Oxygen
Depth below surface (m)
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0
Dissolved Oxygen Concentration (mg/L)


Date 28/10/97
Temperature (degrees C)
Time 1215
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Depth below surface (m)
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0
Dissolved Oxygen Concentration (mg/L)

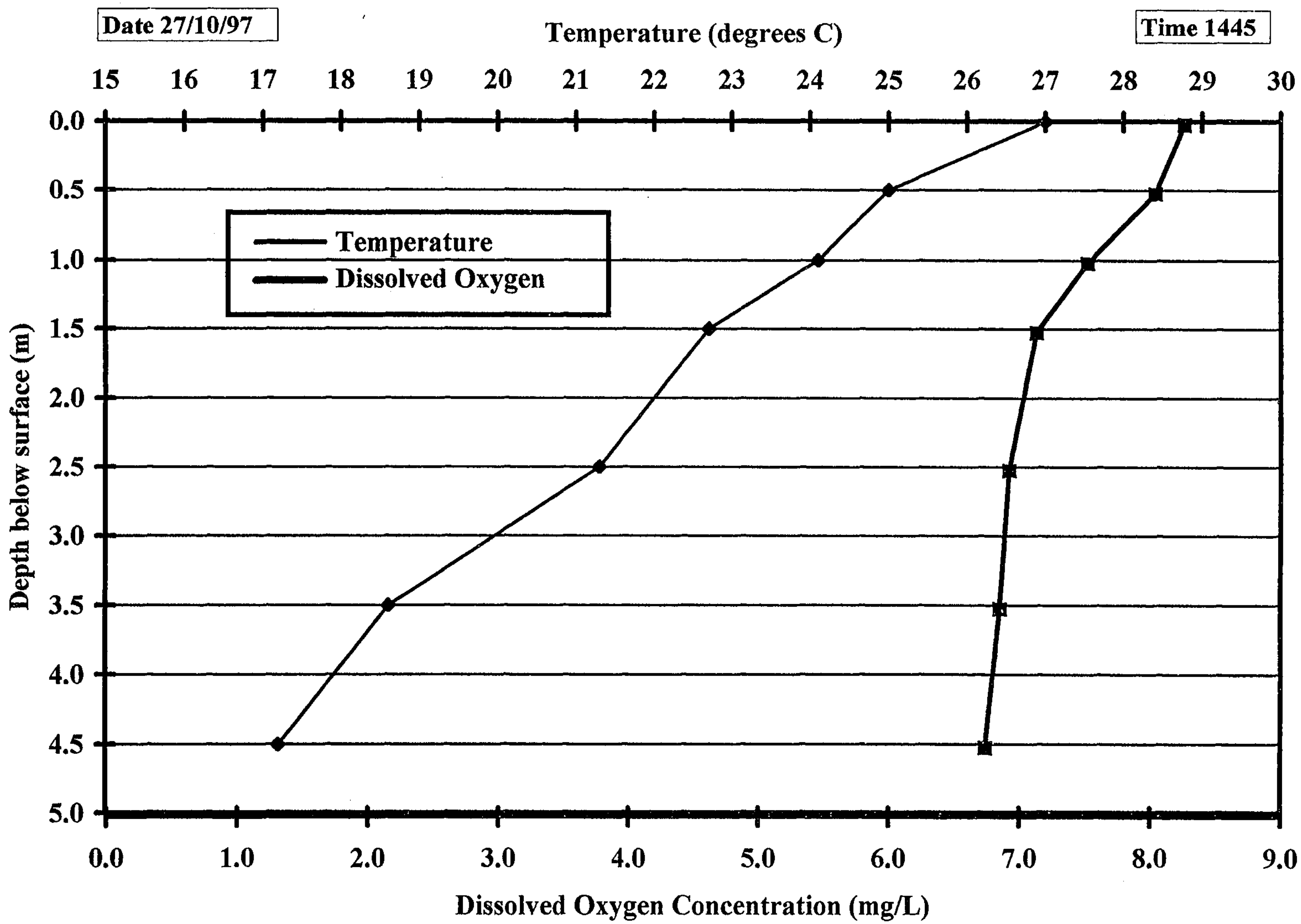

Date 19/09/97
Temperature (degrees C)
Time 1800
15
16
17
18
19
20
21
22
23
24
25
0.0
0.5
1.0
1.5
2.0
2.5
Depth below surface (m)
Temperature
Dissolved Oxygen
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
Dissolved Oxygen Concentration (mg/L)

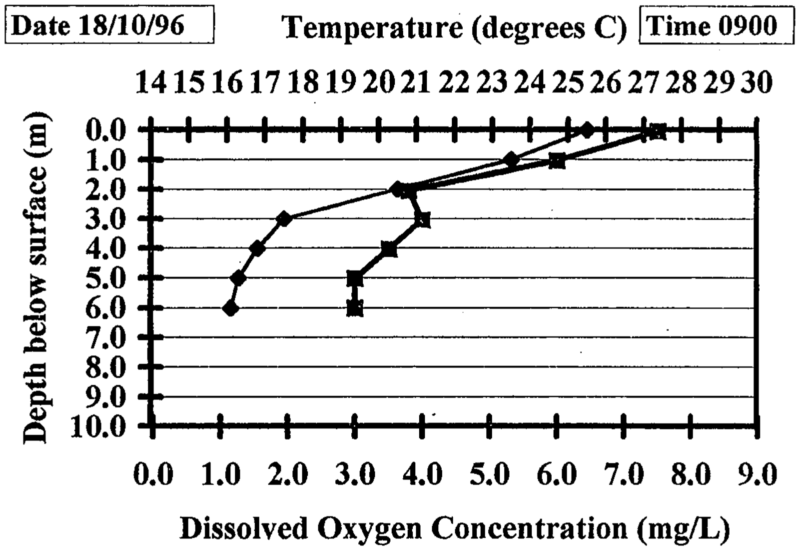

Date 28/10/97
Temperature (degrees C)
Time 1215
20
22
24
26
28
30
0.0
0.5
1.0
1.5
2.0
2.5
Depth below surface (m)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
Dissolved Oxygen Concentration (mg/L)

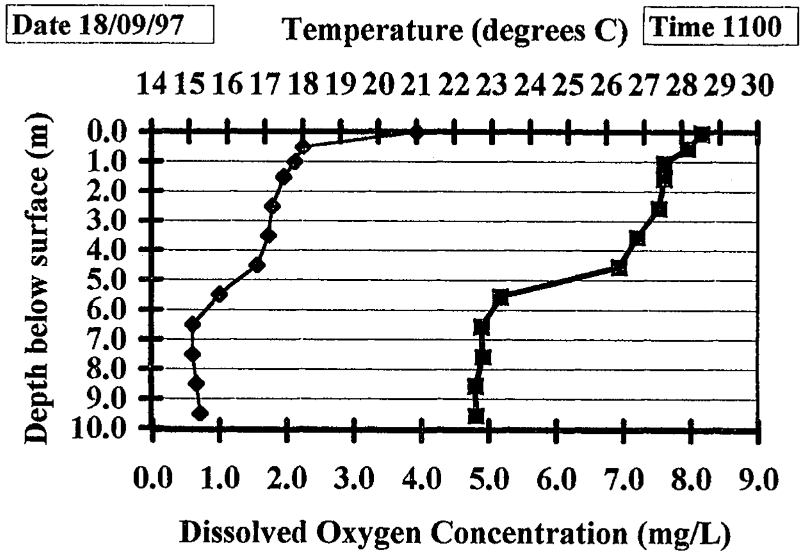


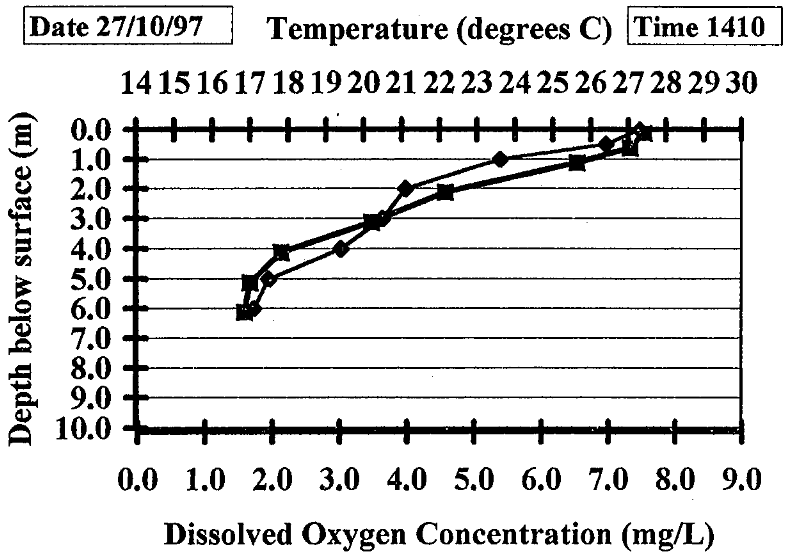


Site Number 1200 -just upstream Orange Creek Weir

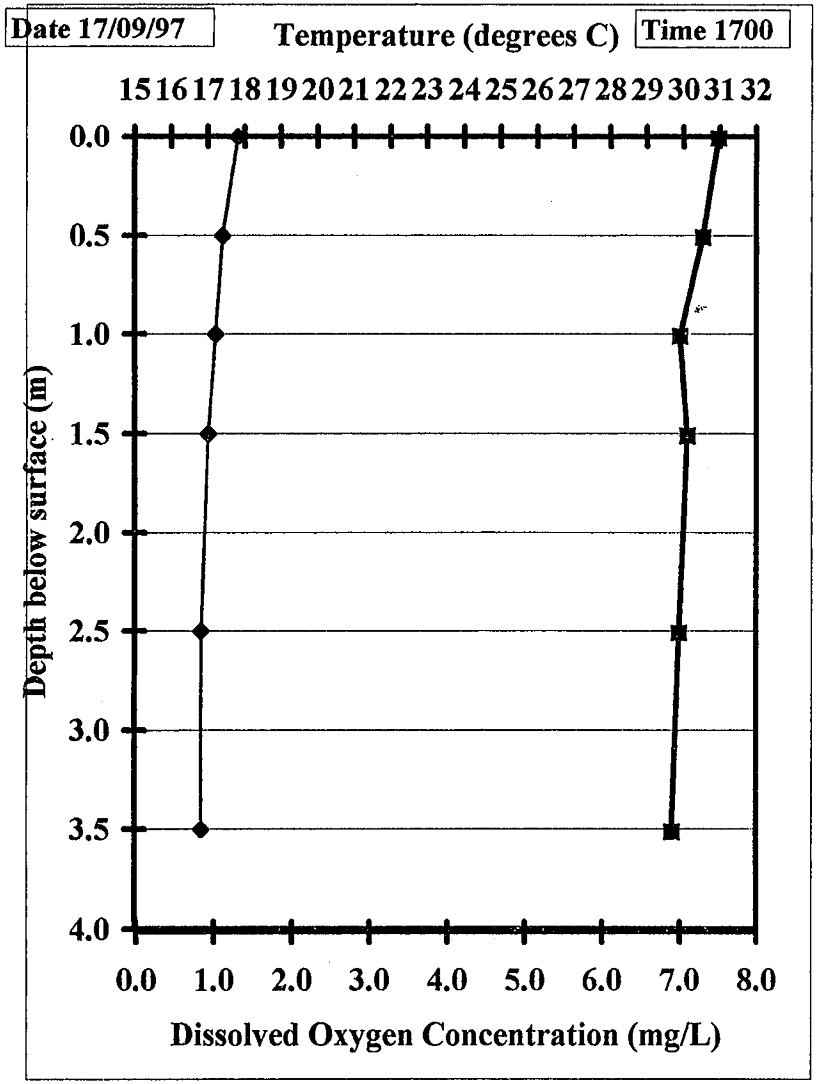

Date 27/10/97
Temperature (degrees C)
Time 1445
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Depth below surface (m)
Temperature
Dissolved Oxygen
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
Dissolved Oxygen Concentration (mg/L)



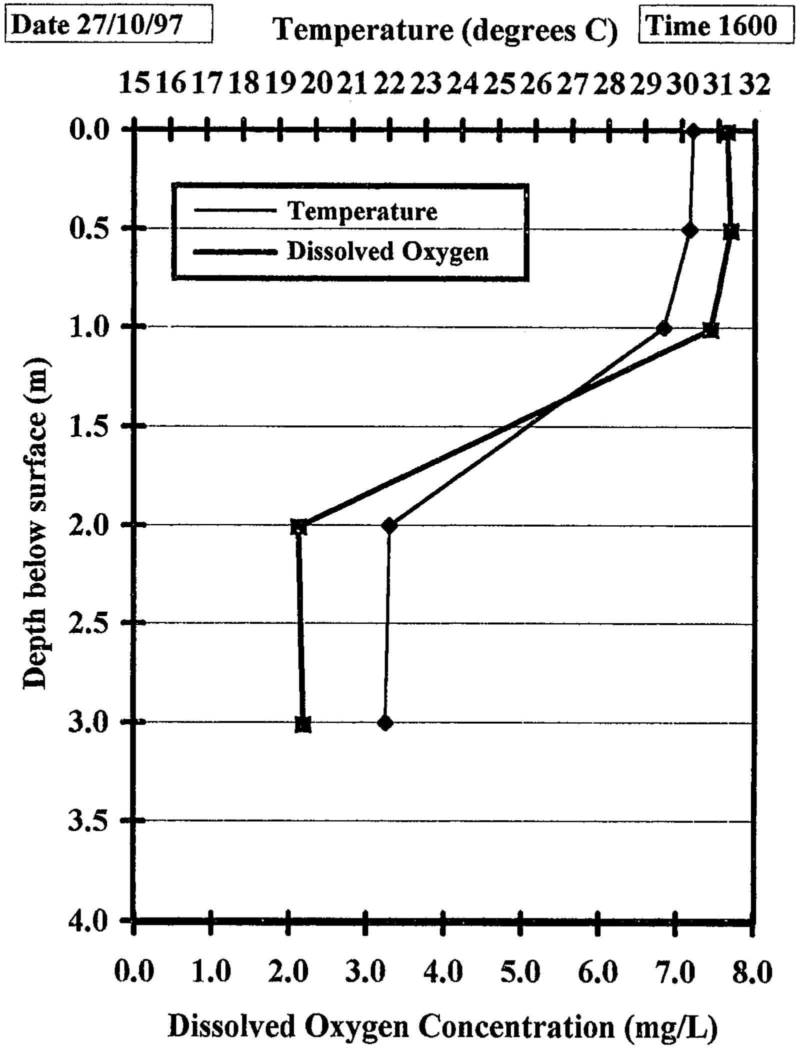




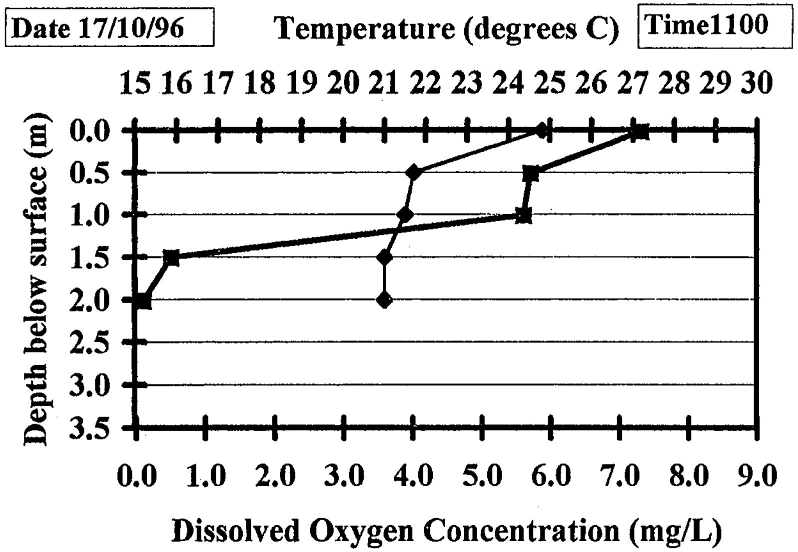
Temperature
Dissolved Oxygen

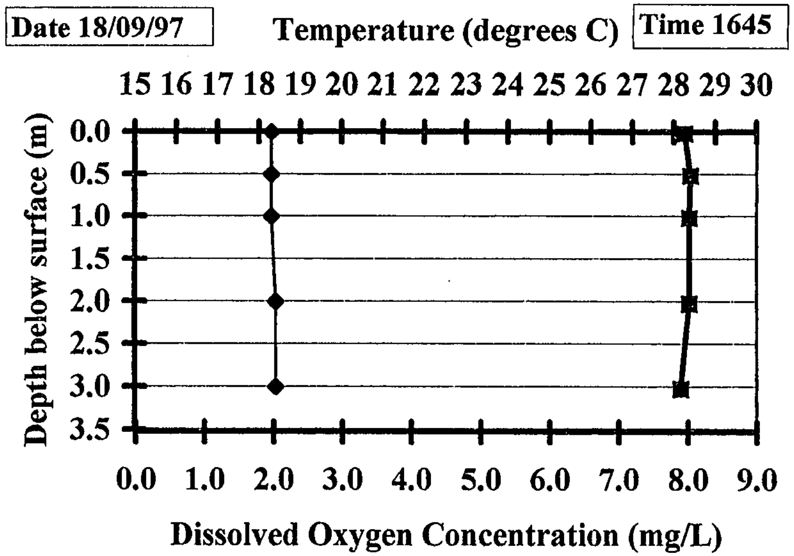


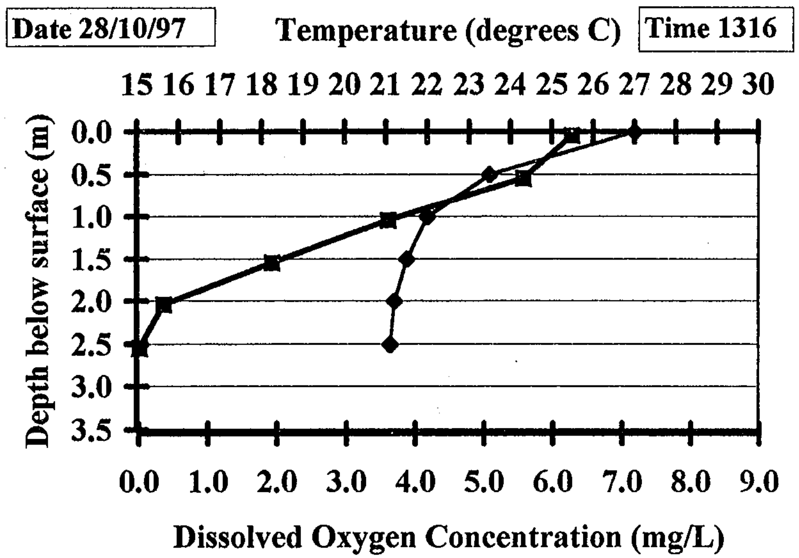
Date 17/09/97
Temperature (degrees C)
Time 1700
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Depth below surface (m)
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0
Dissolved Oxygen Concentration (mg/L)

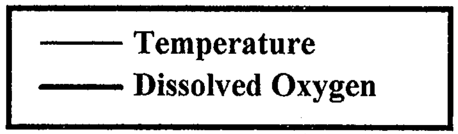


Date 27/10/97
Temperature (degrees C)
Time 1600
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
Temperature
Dissolved Oxygen
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Depth below surface (m)
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0
Dissolved Oxygen Concentration (mg/L)

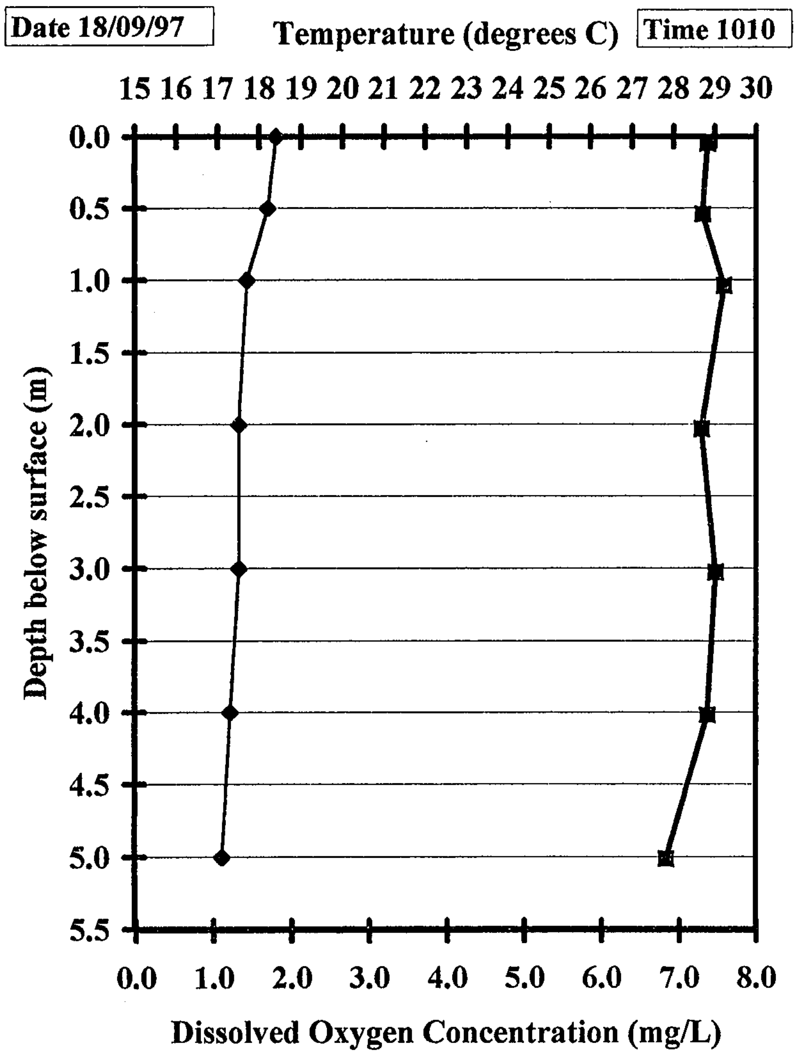


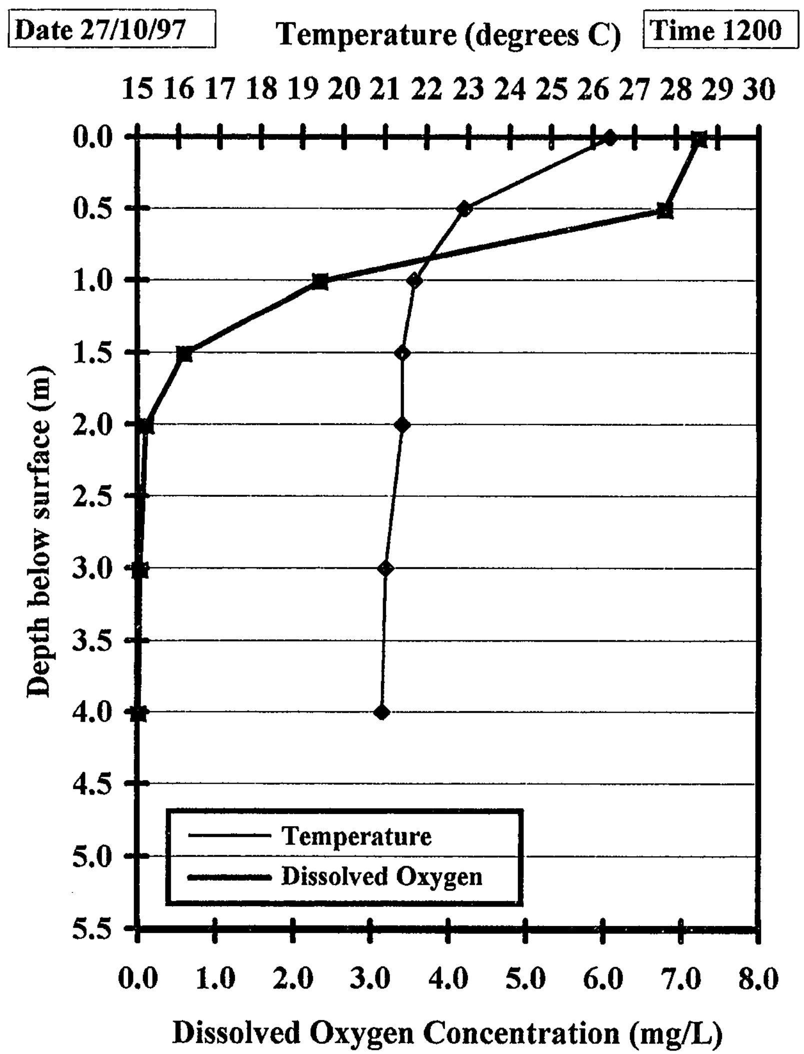


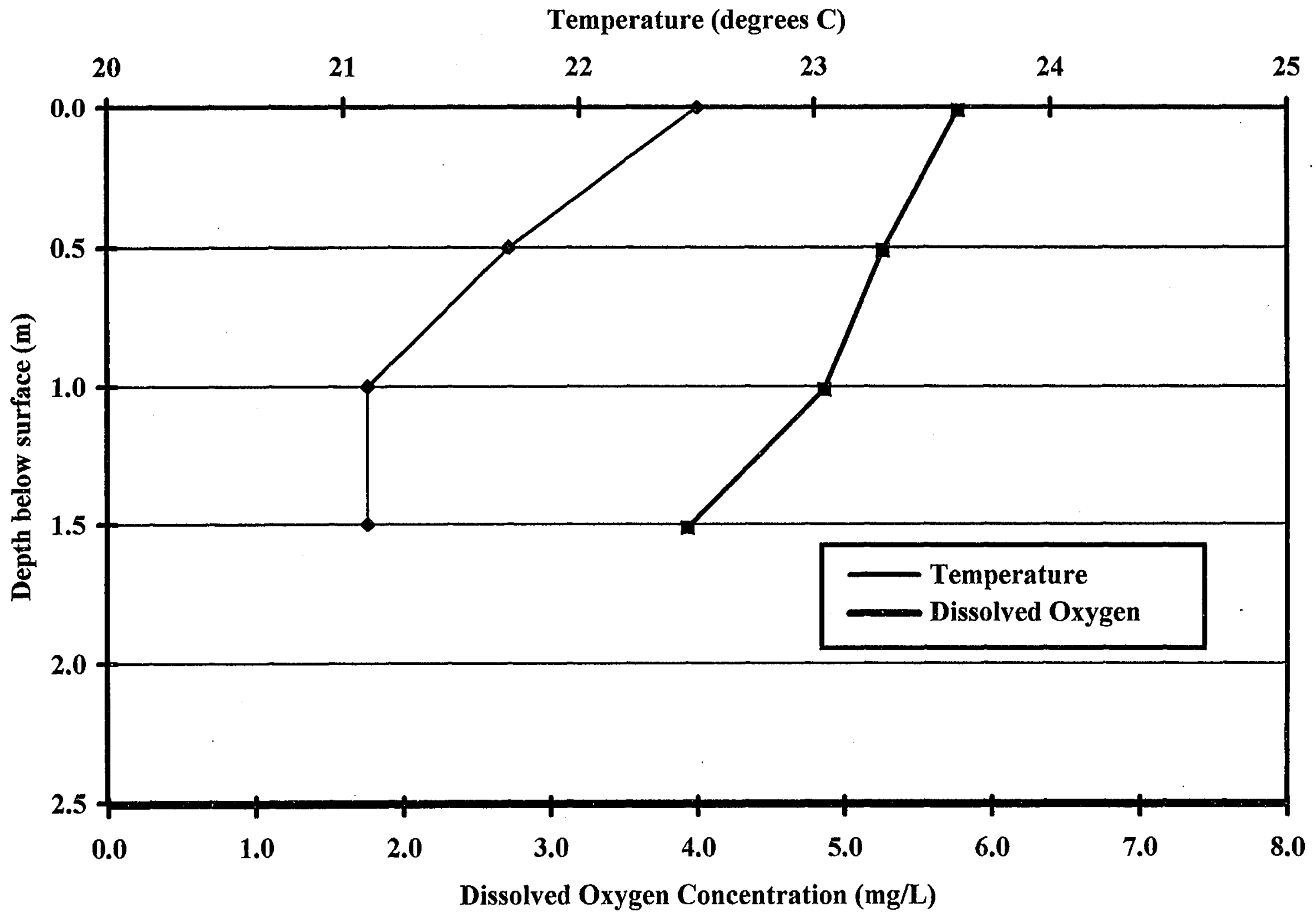




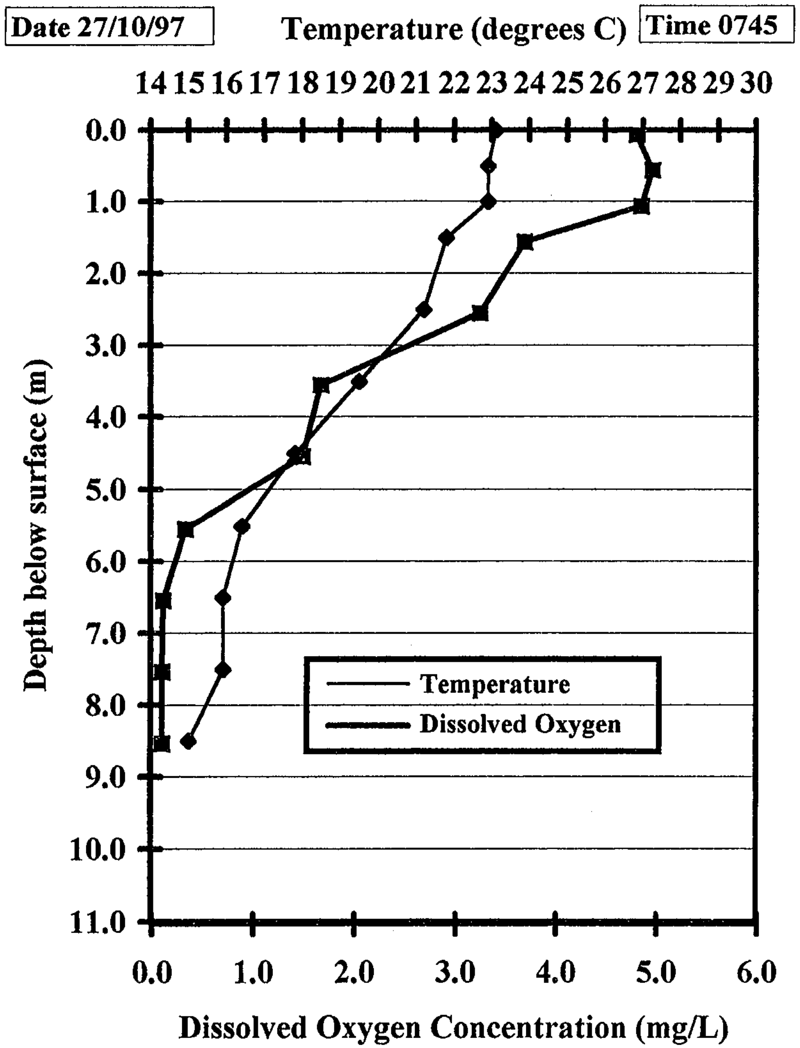
Site Number 921 -5km upstream Oxtrack Creek junction

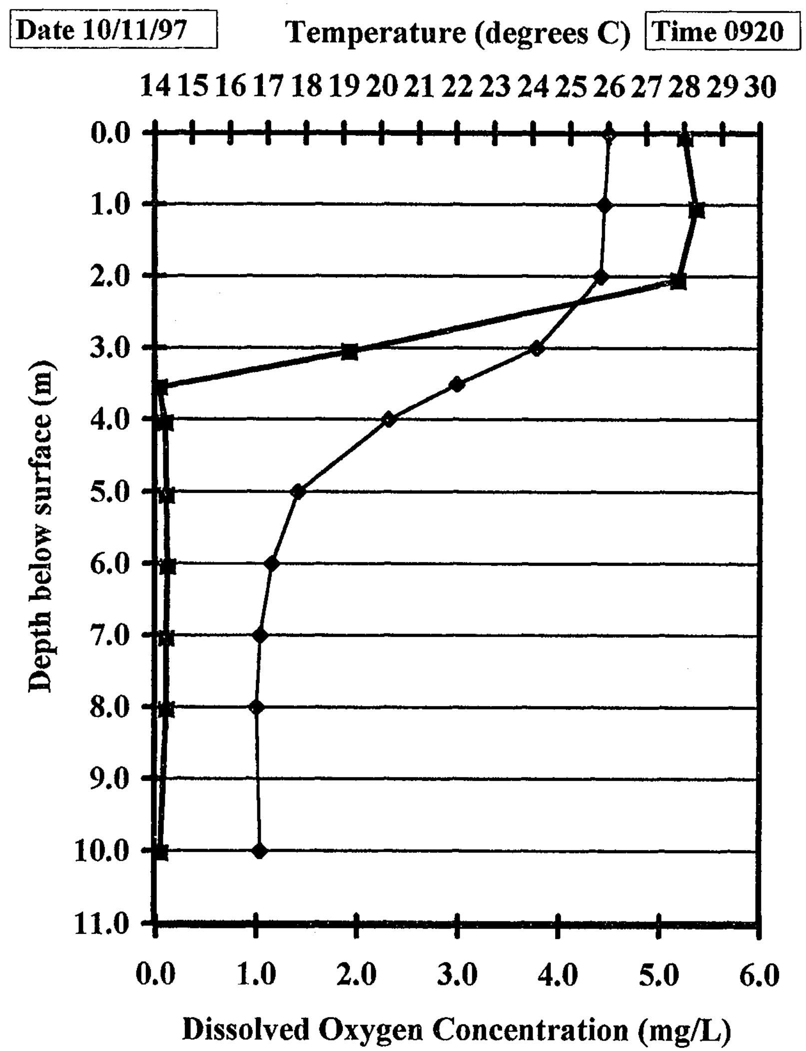

Date 18/09/97
Temperature (degrees C)
Time 1010
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Depth below surface (m)
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0
Dissolved Oxygen Concentration (mg/L)

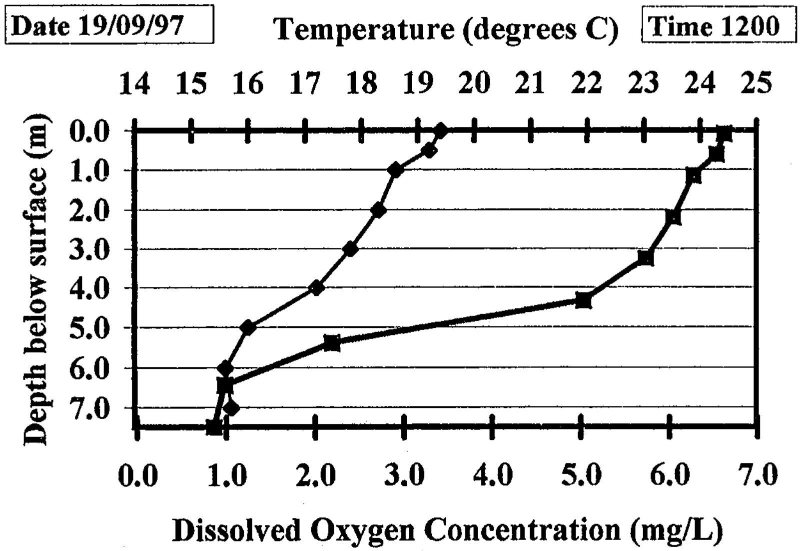

Date 27/10/97
Temperature (degrees C)
Time 1200
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Depth below surface (m)
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5
Temperature
Dissolved Oxygen
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0
Dissolved Oxygen Concentration (mg/L)

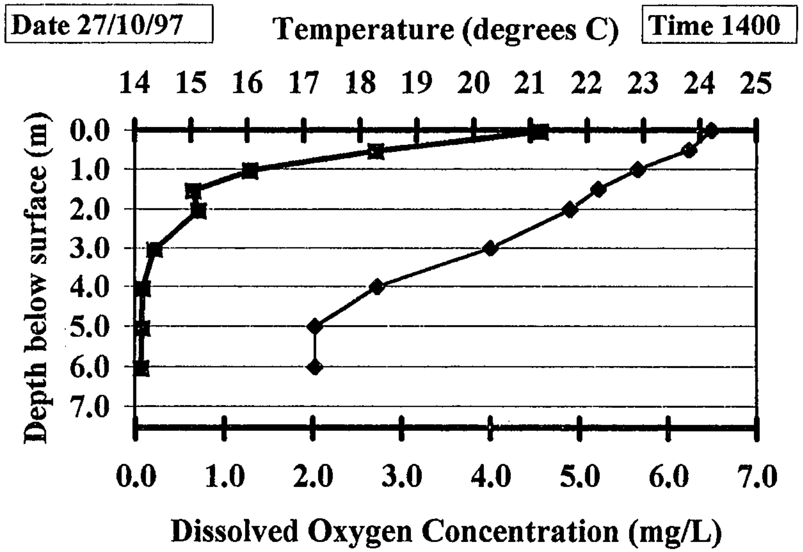


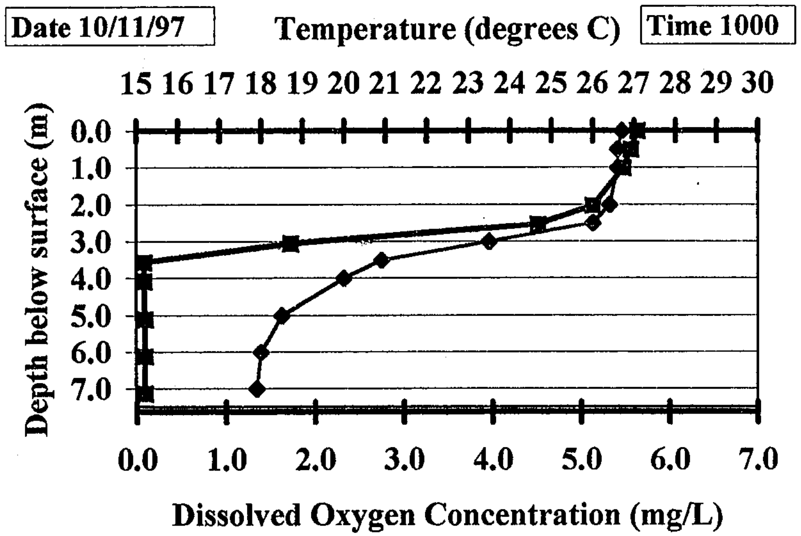
Site Number 246 -riffle area 1 km downstream Boam Creek junction

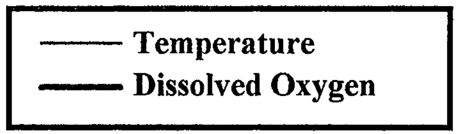

Date 27/10/97
Temperature (degrees C)
Time 0745
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Depth below surface (m)
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0
Temperature
Dissolved Oxygen
0.0 1.0 2.0 3.0 4.0 5.0 6.0
Dissolved Oxygen Concentration (mg/L)


Date 10/11/97
Temperature (degrees C)
Time 0920
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Depth below surface (m)
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0
0.0 1.0 2.0 3.0 4.0 5.0 6.0
Dissolved Oxygen Concentration (mg/L)

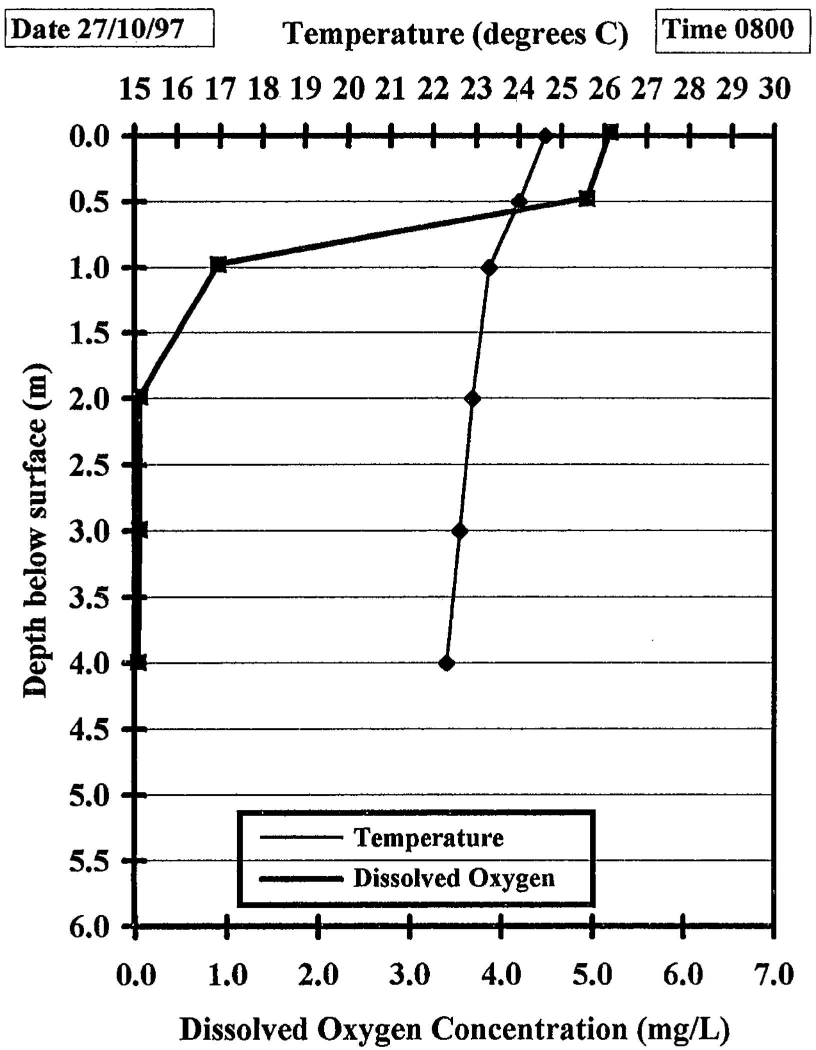


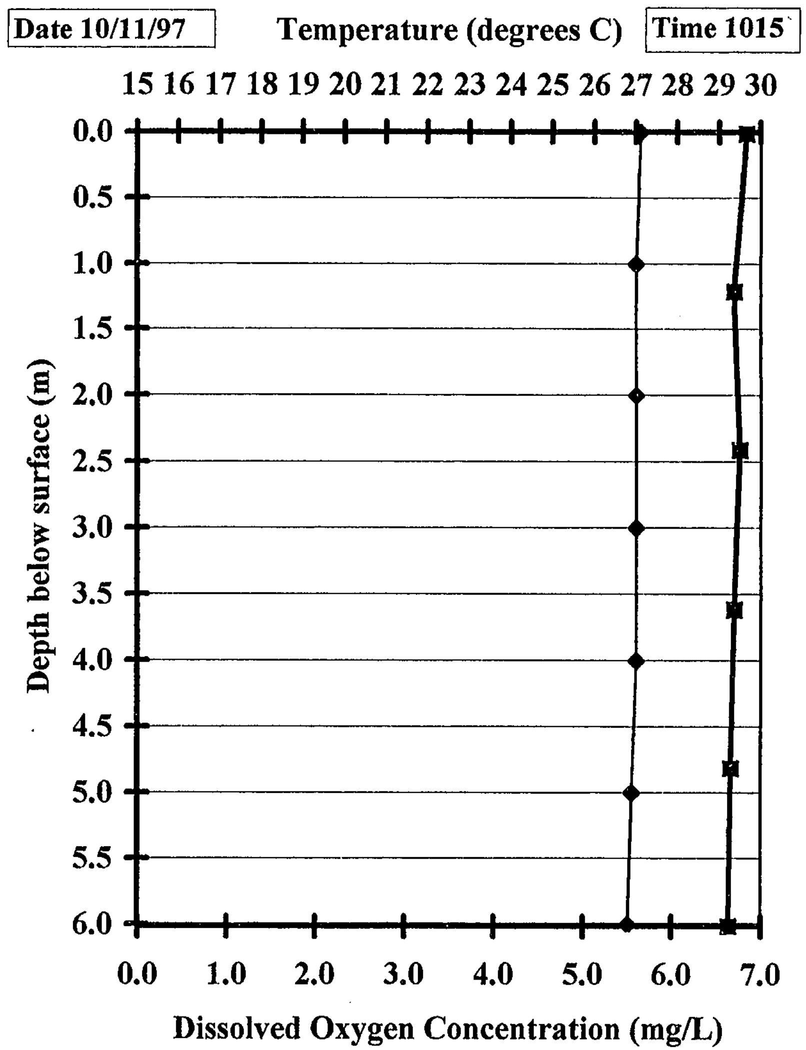






Site Number 243 -Theodore Weir Pool - just upstream of weir


Date 27/10/97
Temperature (degrees C)
Time 0800
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Depth below surface (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
Temperature
Dissolved Oxygen
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0
Dissolved Oxygen Concentration (mg/L)


Date 10/11/97
Temperature (degrees C)
Time 1015
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Depth below surface (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0
Dissolved Oxygen Concentration (mg/L)