AN INITIAL ENVIRONMENTAL ASSESSMENT OF WATER INFRASTRUCTURE OPTIONS IN THE BURDEKIN CATCHMENT

FINAL REPORT

To

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EXECUTIVE SUMMARY

A 1998 Scoping Study of Water Infrastructure Options in the Burdekin River Catchment assessed numerous potential dam development sites. Eight of these were identified as worthy of further consideration. These eight sites have now been further assessed to identify the major environmental impacts that may result if they proceed to construction and to provide a discriminatory basis for deciding which options should proceed to the next level of investigation. Each of the eight sites is scored against 10 criteria adopted by the northern region of the Department of Natural Resources – Regional Infrastructure Development, for use in a multiple objective decision support system (MODSS). The MODSS scores will be ratified by a Technical Advisory Panel convened as part of the Burdekin Catchment Study.

Of the eight sites, four are in the upper Burdekin, one is raising the wall of the existing Burdekin Falls Dam, one is on the Belyando River at Mt. Douglas and two are on the Broken River. Several different size dams were evaluated at most sites, bringing the total to 20 options from 8 sites. For the Mt. Douglas options, the impoundment area includes a significant proportion of land containing regional ecosystems of high conservation value, including some that are considered to be ‘endangered’. In addition, one of the properties to be inundated (Nairana) has recently been purchased by the EPA for a national park. Although several other significant environmental issues have been identified for this site, it is largely because of the inundation of the Nairana property and ‘endangered’ regional ecosystems, that this is not considered a suitable dam site.

Any of the larger dams in the upper Burdekin would, in conjunction with the Burdekin Falls Dam, trap a considerable proportion of the freshwater flows from the catchment. This will impact on coastal fishery production, estuarine productivity and sediment transport to downstream environments. For any dam in the upper Burdekin, it is possible that their capture of turbid wet season flows and subsequent release for irrigation throughout the year, will reduce the water clarity over the length of the river below the dam location (even as far as the Burdekin Falls Dam). This being the case, there are few options for mitgating or managing the impacts, other than smaller impoundments should be less likely to develop such problems, due to reduced trapping of turbid wet season waters. There is little data to test this assertion at this stage, and the turbidity response of the upper Burdekin River to rain events is variable depending on the intensity and shape of the hydrograph. Given the significance of potential impacts resulting from substantially lowered water clarity over several hundred kilometres of river length, a reliable prediction of the clarity and limnological performance of any dam in the upper Burdekin is crucial. Based on the value of the habitats within the impoundment areas, either the Mt. Fullstop or Hells Gates options would be preferable to the Greenvale or Mt. Foxton options. However, based largely on the idea that reduced water clarity and the effects of altered flow regimes will be less of an issue for the Greenvale impoundment, this option has rated highest among the upper Burdekin options. If the concerns over water clarity have been overrated, or misapplied, then the Greenvale options would be much less favourable.

Within the Broken River system, the Mt. Sugarloaf option would appear to be preferable to the Urannah option. The former would spill more often, yet has only a slightly less yield. Habitat values are high within both impoundments, though Urannah has a higher proportion of high value vegetation, including rainforest elements in common with the adjacent Eungella National Park. Due to their position well upstream in the catchment, it is expected that both options will have clear water. The existing Eungella Dam on the Broken River upstream of Urannah has suffered from blue-green algal outbreaks in recent years. Anecdotal reports suggest that these

are related to the clear water, impoundment stratification and low levels of water inflow. This argument further favours the Mt. Sugarloaf option which has a stronger and more persistent baseflow than the Urannah option. The larger Urannah option would take many years to fill compared to the Mt. Sugarloaf option, which should fill in 1-2 years. Due to their proximity (only 30km apart), and the current paucity of environmental data for both sites, they could be further investigated together.

The feasibility of a 130km irrigation channel (Elliot Main Channel) to supply coastal irrigation blocks between Home Hill and Bowen has recently been investigated. The dam options considered in the Belyando-Suttor or Bowen/Broken catchments are unable to supply water for this proposal in addition to needs (mainly irrigation) within their own catchment. The Burdekin Falls Dam and upper Burdekin options (except maybe Greenvale) will have enough excess water to supply such a scheme. For the upper Burdekin options, this will mean that water could effectively be transported over several hundred kilometres of river length before reaching its destination. The effect of flow regulation on riverine ecology is a relatively recent area of study. However, studies in the upper Burdekin have found that the flow pattern has a major determining effect on the structure of fish communities. A range of other significant instream impacts are also likely. Coastal development such as aquaculture and the Elliot Main Channel, should be supplied from the Burdekin Falls Dam.

The raising of the existing Burdekin Falls Dam would inundate much of the length of the lower Suttor River almost to Mt. Douglas. Thus it will also impact on a significant amount of land containing regional ecosystems of high conservation value, although it should not impinge upon the Nairana property. Many of the impacts of dam construction (eg, altered flow regime) have already occurred with the existing dam, though most of these will be exacerbated by its increased size. However, the effect of a significant raising of this dam, on freshwater delivery for estuarine/coastal fisheries and flood flows and sediment delivery to sensitive and internationally important coastal environments, would be seriously questioned, especially if another dam was also built elsewhere in the catchment. Smaller options than those presented for evaluation (eg, only a 2m wall raising) should be considered. Alternatively, the use of water conservation measures among the existing water users (irrigation, urban and industrial) may well supply the identified future water demand without the need for enlargement of this dam. The feasibility of this concept is a very high priority for further investigation.

As the various options under consideration occur in sub-catchments with very different conditions and environmental issues, comparing options across sub-catchments is fraught with difficulty. A combination of Urannah stage 1, the smallest Hells Gates option and even a small raising of the existing Burdekin Falls Dam, would extract more than 30% of the median annual streamflow of the entire catchment, and inundate or regulate more than 20% of the total river length within the catchment. Such a scenario runs a high risk of significant habitat degradation and disruption of ecological processes. The Burdekin Falls Dam option and all of the upper Burdekin options are far in excess of the currently identified future water demand. Inclusion of smaller options at these locations is necessary to evaluate a wider range of possible development scenarios. In addition, the Urannah options are very large relative to the amount of streamflow received at that location, and smaller options should be considered for the Broken River as well.

There are several lines of further investigation required that are highly relevant to all impoundments, regardless of their location. Specific consideration and study of these topics prior to a formal impact assessment process is essential to support ecological sustainability of water infrastructure development in the Burdekin catchment. These issues can be grouped under the following broad headings:

1) Predictive limnology of the impoundments. The clarity and quality of water in the impoundment will have an over-riding effect on impacts to the ecology of downstream riverine environments. The importance of this has already been shown by the almost permanently turbid nature of the existing Burdekin Falls Dam. For the Broken River options, limnological investigations would assist in predicting the likelihood of blue-green algae outbreaks.

2) The effects of altered flow regimes on aquatic and riparian biota and habitats. This has been studied for fish in the upper Burdekin and demonstrates the dominant influence that flow pattern has on fish community composition. As the other sub-catchments have distinctly different flow patterns, the results are not applicable there, though the importance of the issue and the study methods required to predict impacts of altered flow are applicable.

3) Effects on coastal environments and processes. This is particularly related to sediment transport and reductions of flood flows to the habitats and geomorphological features of the Burdekin delta, coastline and Cape Bowling Green sand spit, which are of immense environmental importance, yet are especially vulnerable to altered flood flows and sediment transport.

4) Size, location and crop configuration of the irrigation areas served from each dam. Impacts from irrigation areas are significant components of water infrastructure development. This applies to the land cleared for irrigation development, and impacts from the irrigation area sensitive downstream environments as far away as the Great Barrier Reef Marine Park. The nutrient and suspended sediment retentive capacity of impoundments downstream of irrigation areas is also relevant to coastal and offshore reef environments.

1.0 INTRODUCTION

The Australian Centre for Tropical Freshwater Research (ACTFR) has been commissioned by the Department of Natural Resources (DNR) Regional Infrastructure Development Program, North Region, to provide an environmental evaluation of prospective dam sites located within the Burdekin Catchment. This report is a scoping study that utilises existing data to determine the significant environmental issues for each development option and evaluate their potential impacts. Quantification of the extent of each potential impact will be required for those options that progress to more advanced stages of development. A scoping study of dam options for the Burdekin Catchment was undertaken in 1998 (DNR 1998) with input into environmental issues supplied by ACTFR (Burrows *et al.* 1998). This was a desktop study which considered ~50 water infrastructure development options with a view to reducing that number of options. From that study, eight dam sites remained in consideration. The original environmental scoping study considered a large number of options, with the extent of the evaluation being relatively limited (eg, no fieldwork). This was suitable for the purpose of identifying possible environmental issues and reducing the number of options to the current eight. It was however, insufficient for further discrimination between the remaining sites, and because of the limited depth of evaluation, it was considered that more detailed assessment was required. In addition, much additional vegetation mapping has occurred since 1998, particularly in relation to regional ecosystems. These options are evaluated in this report, through stakeholder consultation, consideration and review by a Technical Advisory Panel and analysis through a Multiple Objective Decision Support System (MODSS).

2.0 THE BURDEKIN CATCHMENT

The Burdekin catchment can be broken into four major sub-catchments – the upper Burdekin, the lower Burdekin, the Belyando-Suttor and the Bowen-Broken. Each is very different and in many respects, behave as distinctly different catchments. Behaviour of the lower Burdekin sub-catchment also varies, depending on which sub-catchment is contributing the majority of flow.

2.1 Variability of Water Flows in the Burdekin Catchment

Due to its large size and different sub-catchments emanating from different regions, there are several different flow regimes present within the Burdekin basin. Thus, there will be different levels of impact on environmental flows and downstream impacts for each dam depending on its location. For instance, Pusey and Arthington (1996) examined data from Burdekin river-gauging stations collected from 1970 to 1989 and found that the tributaries of the upper Burdekin did not flow for 20-25% of the time, the main channels of the Burdekin and Bowen River for <5% of the time and the Clarke, Cape, Belyando and Suttor Rivers did not flow 42% of the time. Volume of flow is also biased with 60% of the Burdekins' average annual discharge being derived from only 12% of its catchment area – this being the eastern highlands from Douglas Creek south to Fanning River (Ceplacha and Kaminskas 1972, Pusey and Arthington 1996). The lowest contribution is from the southern and western tributaries such as the Cape, Belyando and Suttor Rivers and also the north-western tributaries such as Gray Creek. Less variable flows occur in the creeks of basaltic areas such as Wyandotte Creek and Fletcher Creek, both of which receive more constant flows from groundwater springs.

Although there is a strong seasonality in the Burdekin catchment due the dominance of summer rainfall, flow is often related more to individual events rather than the seasons themselves. Thus high flow periods, and the length of prolonged dry periods, are very unpredictable. This is because of the high probability of failed wet seasons not resulting in significant discharge events while the episodic large flood events, which can occur anytime from November to May but do not last for a long time, dominate overall discharge and have a significant influence on longer-term averages. The influence of such episodic, but short-lived phenomena serve to mask seasonality of flows. The tributaries of the east coast drainages (Douglas Creek south to Fanning River) tend to be more seasonal due to more reliable wet season rainfalls in their catchments, whereas rivers more prone to event-driven processes include the Belyando/Suttor catchment and some tributaries of the Bowen River (Pusey and Arthington 1996). Greater flexibility will be required in the provision of environmental flows for these rivers.

2.2 Environmental Assessment of the Existing Burdekin Falls Dam

Since its completion in 1987, the Burdekin Falls Dam has overflowed every year except for 1993 (Griffiths and Faithful 1996). The dam probably reduces the natural flow to the sea by 10% on average, although, reflecting catchment conditions, this is variable. During January-February 1991, the dam overflowed its storage capacity by a factor of 15 yet from March 1992 – March 1994, no overflow occurred (Griffiths and Faithful 1996).

There are no environmental flow releases from the existing dam and there has been no assessment of its impact on downstream environments or on coastal environments and processes. These are significant issues with far-reaching environmental, economic and social implications that will need to be more thoroughly assessed before any further water storage development proceeds. One obvious impact of the existing dam is that the water in the Burdekin River below the dam is now permanently turbid. Previously, the river used to be turbid during and after high flow events but ran clear during the lengthy periods of lower flow. The Burdekin Falls Dam traps water from the Belyando-Suttor sub-catchment, the Cape/Campaspe sub-catchment and the upper Burdekin sub-catchment. Due to the presence of extensive areas of very fine clay soils and probably contributions from extensive land clearing, the Belyando-Suttor is very turbid. Large amounts of fine clay soils also come from other catchments during storm events. When flows from the Belyando-Suttor sub-catchment, and elevated flows from the other sub-catchments, are trapped by the dam, the sediment they contain remains in suspension due to the combination of their low sinking rate and the turbulence (wind) within the shallow dam. Water is released from the dam daily (or almost so), thus ensuring that the downstream river is permanently turbid. The dam has partially cleared for only brief periods on one or two occasion since its construction. The size of the dam allows it to trap a larger proportion of the turbid wet season flows, thus remaining turbid. A smaller dam may have had a greater water clarity potential.

As the water from the dam and river is moved to extensive irrigation land across the Burdekin floodplain, it is then released as run-off into numerous distributory channels and smaller coastal catchments and wetlands. Thus, most of the smaller creeks and numerous wetlands of the coastal floodplain are now also turbid as a result of receiving turbid water from the irrigation area. The impacts of this significant environmental change on the lower Burdekin River and the receiving wetlands and distributory streams, has not been studied, though this, and the assessment of the potential for restoration of ecosystem functioning are warranted. Due to the fundamental change in the functional ecology from clear water to turbid water (eg, limited plant and algal growth and altered food chain linkages) the impact is likely to have been severe and widespread.

The possibility of persistent turbidity appears not to have been considered during final assessment of the dam. In fact the Burdekin Project Assessment Committee, in their Summary report (1978) stated (p. 27-28) that "..there would be no adverse effect of the scheme on the environment" and that "Water quality in the Burdekin River would be largely unaffected by the proposed works with a possible advantage of a less turbid flow in the lower Burdekin River."

The limnological performance of any dam is a dominant influence on downstream environments and the ecology of the impoundment itself. It is thus of critical importance that the limnology and its effects be predicted as part of an informed evaluation of environmental effects. Fortunately, some studies (eg, Griffiths and Faithful 1996) on the limnology of the existing Burdekin Falls Dam provide some insight into possible limnological behaviour of new dams. Apart from wind-generated turbulence keeping fine sediment particles suspended, other factors also contribute. In the main section of the dam, differences in water density due to the temperature differential, provide enough stability for inflowing river water to remain above the colder, but more dense, lower water layers, even if the incoming water has a higher suspended sediment load (Griffiths and Faithful 1996). This keeps the sediment suspended rather than allowing it to sink to the bottom. During periods of no river flow, the turbidity of the water column becomes more evenly distributed.

The behaviour of suspended sediment loads are also influenced by the soil type of the catchment from which they emanate. Fleming and Loofs (1991) reported that floodwaters from the Belyando-Suttor catchment are rich in fine dispersed clay particles. Faithful (ACTFR, unpub. data) has recorded that flows from the upper Burdekin are on average, coarser, and the reservoir water has a higher clarity within a few months of flow from the upper Burdekin ceasing, compared to when significant flows have been received from the Beylando-Suttor. Although the sediment is not as fine as from the Suttor River, due to greater water volume, the upper Burdekin contributes a greater total suspended sediment load to the dam (Faithful and Griffiths in press). For both rivers, the suspended sediment load is dominated by clay and silt fractions and these remain is suspension within the reservoir. During the period of their study, Faithful and Griffiths (in press) found the incoming water from both rivers actually occupied a mid-water column position within the dam and mixing with the lower layer was minimal, even during a strong flow event. For both rivers more than 50% of the Total Nitrogen and nearly all of the Total Phosphorus were transported in particulate form (Faithful and Griffiths, in press). Nitrogen concentrations were twice as high for inflowing Suttor River water than for Burdekin water though phosphorus concentrations were similar. However, due to the much greater sediment load from the Burdekin, it contributes a greater nutrient load. The light limitation caused by the high turbidity limits algal production and hence the removal of dissolved nutrients from the water column. Although algal production is low, the organic content of the suspended particulate matter supports a rich microbial flora, and presumably, a heterotrophic food chain.

Due to the considerable effects of increased levels and lengthening periods of turbidity on instream ecological processes, and the transmission of this problem to downstream environments, impoundment limnology and the potential for turbidity-related impacts are essential parameters for assessing the overall environmental impacts of each dam option. The MODSS scores strongly reflect assumptions about this topic and in the case of the four upper Burdekin options, this has become an issue of considerable importance. There is no information available on sediment run-off volumes and sediment size fractions for the impoundment catchment areas. Thus, assessment of potential turbidity impacts has been based on the amount of erosion present within the catchment area of each impoundment. This assessment has been made on the basis of the knowledge of the catchment possessed by the authors, their immediate colleagues, and members of the Technical Advisory Panel.

3.0 ASSESSMENT METHODOLOGY

The environmental issues associated with each potential dam site was investigated by means of a desktop study and brief site visit to each impoundment area. The sites to be evaluated, and the various size options at each site, were provided by DNR – Regional Infrastructure Development, North Region. The amount of field time spent at each potential dam site was one day. The exception was Mt. Douglas, where 6 days field effort was spent. The results of flora, fauna and water quality survey from this option have been presented in a separate report (Burrows *et al.* 1999) but are summarised in this report for completeness, and for comparative purposes. Hydrology data for the sub-catchment, hydrological performances of each dam option (eg, storage, yield, crop area served and spill frequency) and the size of the impoundment area were taken from the summary table presented in the Burdekin Catchment Scoping Study (DNR 1998) as was much other data for each option. A modified version of this table is presented in Table 1. Further hydrology and water quality data were taken from selected gauging station records. The extent of each impoundment area was taken from the supplied FSL's and traced onto topographic maps prior to the field visits.

Other habitat and environmental assessments are the result of the authors' professional experience within the catchment and in water infrastructure related issues, and from consultation with colleagues and members of the Technical Advisory Panel. Published data sources are quoted were they have been used. Other significant information sources include the published and unpublished data of Dr. Brad Pusey on freshwater fishes of the upper Burdekin and their dependence on the prevailing flow regime, of John Faithful (ACTFR) on the limnology of the Burdekin Falls Dam and Alex Kutt (ACTFR) on terrestrial fauna.

The flora and fauna of conservation value known from, or potentially occurring in, each impoundment area was assessed by searches of herbarium and museum databases, published and unpublished data. For flora, species of conservation significance were those listed on the Queensland Nature Conservation Regulation. In addition, mapping of vegetation communities was undertaken according to the regional ecosystems concept. This system has been adopted by the Environmental Protection Agency (EPA) in Queensland as a means of evaluating, mapping and conserving vegetation communities, rather than just individual species. Regional ecosystem mapping by the EPA at a scale of 1:100,000 is in progress across Queensland with draft maps available for the Mt. Douglas area, most of the Burdekin Falls Dam impoundment area and underway for the Bowen/Broken area. Regional ecosystem maps for the upper Burdekin area are not available but mapping of vegetation communities in that sub-catchment was undertaken in conjunction with the EPA staff responsible for mapping the area. Confirmation of regional ecosystems was undertaken during the brief field visits where possible, as was compilation of other flora records. The availability of access tracks to the impoundments was limiting at some sites, particularly the Broken River sites.

Due to the brief nature of the field visit, observed fauna records are predominantly confined to birds, as these are most readily observed. There was insufficient time to undertake trapping and extensive field searches, or to quantify faunal abundances. The fauna of the Burdekin catchment is reasonably well known, although new discoveries are still being made and the distribution of many rare species is uncertain. Faunal data is more comprehensive in the upper Burdekin and the Desert Uplands area (includes the Mt. Douglas area) than the Bowen/Broken system. Fauna of conservation significance are evaluated from those listed on the Queensland Nature Conservation Regulation and those listed in the various action plans for Australian fauna.

The northern region of DNR-Regional Infrastructure Development, are utilising 10 criteria with regard to environmental assessment of potential dam developments. All of the dam options have been scored against each of the 10 criteria in this report. Scores are allocated from 0-10 on the basis of 10 = least impact and 0 = greatest impact. Section 7 of this report presents a descriptive summary of the environmental factors included under each criterion and how they have been judged. The actual scores given by the author are presented in Table 8. Although based on the best scientific understanding that we currently posses, the allocation of score remains highly subjective. The scores will be ratified by the Technical Advisory Panel prior to their acceptance for analysis in a Multiple Objective Decision Support System (MODSS). It must be remembered that the scores are meant to provide a discriminatory function between options, and are thus relative to other options. They do not represent absolute levels of impact. For example, a score of 10 does not necessarily mean the impact will be minor, only that it is less impactful than the other options considered. With the inclusion of new options, or the deletion of poorly scoring options, the scores should be re-evaluated before the MODSS simulations are re-run.

The 10 criteria for MODSS evaluation, as defined in the Scope of Works, are:

1) Net Biodiversity Change (impacts on diversity of species or other taxa, genetic composition, habitats, communities and ecosystems, connectivity, conservation status)
2) Rare and Threatened Ecosystems, Habitats and Taxa of High Conservation Value (including potential impact of the irrigation area)
3) Resilience of Impacted Ecosystem
4) Ecological Processes (loss of habitat quantity and quality, water quality impacts, nutrient and energy transfers)
5) Fluvial Dynamics, Riverine and Coastal (sediment transport, ability to pass flows, flow pattern)
6) Uniqueness of Impacted Area (representativeness, wilderness value, impact on existing values, recreation etc.)
7) Capacity to Manage Construction Impacts (possible contamination, existing uses)
8) Downstream Impacts (water quality, flow pattern, coast and estuaries, land and water use)
9) Aesthetics (naturalness, visual effects, health)
10) On-Farm Effects (land and water degradation, waterlogging, salinisation, nutrients)

The certainty of the evaluation for each criterion varies. The greatest amount of data, and therefore the highest level of certainty, is for the first two criteria. Even here, site-specific field data is limited, but there is sufficient knowledge for high confidence in the general findings. The most subjective criterion is impacts on aesthetic values. There are limited specific data available on the impacts on resilience, ecological processes, fluvial dynamics and downstream impacts. However, the potential impacts on these criteria are known from other catchments elsewhere and can be assessed by reference to the extent of hydrological abstraction using the data supplied in DNR (1998). Thus the nature of the impacts can be determined, though the extent of the impacts requires further studies.

TABLE 1. Summary of Hydrological Data for Each Dam Option in the Burdekin River Catchment (Modified From DNR 1998)

Development Option		Hydrologic / Water Management													Technical /Engineering / Economic			
		Catchment Area km2	Length of River Regulated[2]	Proportion of River Regulated	Storage Level RL	Storage Level Height	Submerged Area	Mean Annua Flow	Capacity	Development Yield ML/a			Proportion of 85% yield over Stored Volume	Potential Crop Area Served	Development Cost	Development Cost $/ML Yield		Provisional NPV
		AMTD (km)			m	m	ha	ML	ML	85% α	Environ β	Farm χ		(ha)	$M	At Dam δ	At Farm ε	$M φ
UPPER BURDEKIN																		
	335m	20,500			335	35	15,200		600,000	912,000	668,000	359,640	1.52	16,500 (16,800)	143.5	157	399	579.6
Mt Foxton	345m	437.9km	240km	45% (of 515km	345	45	22,900	~>2,100,000	1,250,000	1,258,000	967,300	480,860	1.01	16,500 (28,020)	170.2	135	354	804.8
	364m				364	64	29,300		5,000,000	1,875,000	1,555,000	718,880	0.38	16,500 (50,060)	247.2	132	344	1,213.1
	365m				365	40	10,500		970,000	1,006,000	771,000	401,360	1.04	16,500 (20,660)	115.7	115	288	707.9
Hells Gate	375m	17,750 466.7km	270km	52% (of 515km	375	50	22,500	~1,750,000[1]	2,580,000	1,378,500	1,116,230	541,170	0.53	16,500 (33,610)	124.6	90	230	997.8
	385m				385	60	40,500		5,720,000	1,551,500	1,294,000	613,170	0.27	16,500 (40,280)	133.0	86	217	1,141.8
	365m	17,500			365	30	10,050		550,000	774,200	592,000	328,860	1.41	16,500 (13,950)	106.1	137	323	564.6
Mt Fullstop	375m	483.0km	285km	55% (of 515km	375	40	16,200	1,736,000	1,650,000	1,200,000	980,000	486,000	0.73	16,500 (28,500)	126.8	106	261	875.6
	389m				389	54	24,400		5,000,000	1,505,000	1,264,000	601,020	0.30	16,500 (39,150)	179.7	119	299	1,050.3
	430m	8,070			430	32	8,800		460,000	388,000	280,500	202,700	0.84	16,500 (2,270)	57.1	147	282	359.9
Greenvale	439m	552.8km	355km	70% (of 515km	439	41	17,325	~<800,000[1]	1,380,000	489,200	374,000	240,490	0.35	16,500 (5,810)	61.7	126	257	435.6
	445m				445	47	27,100		2,430,000	528,000	407,800	254,260	0.22	16,500 (7,040)	88.8	168	349	427.2
BELYANDO-SUTTOR																		
Mt Douglas	182m	35,590	60km		182	10.2	60,000	~750,000[1]	400,000	155,000	150,000	125,000	0.39	14,470	139.6	901	1,117	-24.7
	192.5m	9.7km		10% (of several hundred km's)	192.5	20.7	70,000		5,000,000	173,600	168,000	140,000	0.03	16,200	194.4	1,120	1,389	-80.0
BOWEN/BROKEN																		
Mt. Sugarloaf	210m	2,280 7.7km	120km	60% (of 200km	210.0	57.0	5,200	~>420,000[1]	428,000	229,000	165,000	137,500	0.54	15,030	184.3 †	805	1,340	-11.5
Urannah Stage I	278m	1,100	150km	75% (of 200km)	278.0	59.5	3,600	340,000	863,000	186,250	146,000	121,670	0.22	13,300	113.1	607	930	58.5
Stage II	292m	36km			292.0	73.9	5,600		1,500,000	216,170	176,900	147,420	0.14	16,110	149.3	691	1,013	54.0
LOWER BURDEKIN																		
Burdekin Falls Dam	160m	114,220			160.0	38.0	40,000		3,570,000	3,315,000	2,700,000	705,600 φ	0.93	88,200 [33,200]	83.2 †	25	118	2,239.8
Burdekin Falls Dam	164m	159.3km	0km[3]	160km already regulated	164.0	42.0	55,000	~>7,000,000	5,280,000	3,820,000	3,147,000	902,730 φ	0.72	112,840 [33,200]	146.7 †	38	163	2,810.4
Burdekin Falls Dam Stage II	168.6m				168.6	46.6	75,000		8,700,000	4,440,000	3,745,000	1,166,450 φ	0.51	145,810 [33,200]	194.4	44	167	3,624.6

α Denotes yield with 85% monthly reliability
β Denotes yield with 20th percentile environmental flow at 85% monthly reli
χ Development yields at farm are based on b yield less attributed transmiss
δ Development $/ML use 85% monthly reliability yields
ε Development $/ML use c farm yields
φ BFD farm yields based on β yields, less present irrigation demand of 1,1

λ Development $/ML yield represent only transmission and distribution costs associated with the EMC scheme and not storage infrastructure.
( ) Bracketed figures indicate additional area served in the Lower Burdekin and Coastal Plains sub-catchment.
[ ] Bracketed figures indicate actual identified area within Lower Burdekin and Coastal Plains sub-catchment.
† Denotes low reliability of storage option costs.
1 Approximations made from nearest available gauging stations
2 Estimated length of unregulated river which would become regulated
3 River below dam is already regulated

4.0 THE REMAINING DAM OPTIONS

4.1 Upper Burdekin Sub-Catchment

This sub-catchment was defined for the scoping study (DNR 1998) as being upstream of Sellheim (at AMTD 300km) and occupies 28% of the total Burdekin catchment. The mean annual discharge of the Burdekin River at Sellheim is 4,067,000ML, which represents 54% of the total discharge at the mouth of the Burdekin (DNR 1998). Apart from the main Burdekin channel, most of this comes from rivers (Running, Star, Keelbottom and Fanning) emanating from the coastal ranges, but also from the large Clarke River sub-catchment.

Within the upper Burdekin, there are existing water storages on a small rainforest tributary at Paluma (11,800ML capacity) and a weir on the Burdekin River at Charters Towers (upgraded to 5,227ML capacity in 1996). There is also an off-stream storage of 3,300ML at Gap Creek, adjacent to the Charters Towers weir, which supplies water to Mt. Leyshon gold mine. Groundwater yield in the upper Burdekin is estimated at 80,000ML/year with 85% of this coming from basalt aquifers of the western ranges (DNR 1998). However, this water often has a high sodium content which limits its use for irrigation (DNR 1998).

In the 1998 scoping study, 13 potential water storage sites were investigated for the sub-catchment, including 8 on the Burdekin River, 2 on the Star River and one each on Running River, Keelbottom Creek and Fanning River. All of the options on tributary streams were rejected on the grounds of insufficient yield, lack of suitable irrigable soils in close proximity, or poor economic returns. Currently, four options remain in this sub-catchment – Mt. Foxton at AMTD 437.9km (above the Star River junction but below the Running River junction with the Burdekin), Hells Gates at AMTD 466.7km (several km above the Douglas Creek junction with the Burdekin), Mt. Fullstop at AMTD 483km and Greenvale at AMTD 552.8km. The Hells Gates and Mt. Fullstop options have similar inundation areas and capacities, and are located only 16km apart. The Mt. Foxton option is the only one that will capture Running River and the Greenvale option is the only one that will not capture the extensive Clarke River sub-catchment.

The upper Burdekin catchment has large areas of undulating hills, especially on the eastern side, which rises in the rainforest-covered coastal ranges. The western side of the catchment is also bounded by undulating hills of the Great Dividing Range. Such topography constrains irrigation development potential. Existing irrigation is limited to 2,564ha, utilising 20,400ML of water (DNR 1998). It is anticipated that due to pumping costs, only land within 60m vertical lift from the river bed will be economically suitable for irrigation. DNR (1998) found there to be nearly 40,000ha of suitable alluvial and basalt soils within the upper Burdekin catchment within this 60m lift. However, due to proximity to identified storages, stoniness of basalt soils and flood-prone nature of many alluvial soils, DNR (1998) reduced their estimate of the extent of suitable soils to ~12,000ha. These are located on alluvial soils within 1-2km of the Burdekin River, in a reach 30km upstream and downstream of the Burdekin/Star River junction. In addition, ~3,000ha of suitable basalt soils have been identified as commandable (<60m above the river level) in the Hillgrove/Fletcherview area. The predominance of alluvial soils linearly aligned with a major river channel is not a favourable configuration for protection of riverine environments from irrigation developments.

Soil erosion is an increasing problem in the upper Burdekin, including along the banks of the Burdekin River itself. Erosion of the Burdekin riverbank is particularly severe within the impoundment of the Mt. Foxton option. Other areas where erosion is of major concern (as observed by the author) include the Granite Creek area (Mt. Foxton impoundment) and Redbank and Camel Creeks (captured by all options except Greenvale). Undulating topography, erodible soils, episodic high rainfall and overgrazing may all have contributed to this problem. It is not known how much soil is being lost from each area and what is the relative contribution of soil from eroding riverbanks compared to other sources. Such information is critical to prioritising restoration and erosion repair works within the catchment.

4.2 Belyando-Suttor Sub-Catchment

In addition to the Belyando and Suttor Rivers, this sub-catchment also includes the Sellheim River and the Cape-Campaspe River system, and occupies 56% of the total Burdekin catchment. This sub-catchment is very dry and despite its size, only contributes approximately 2,300,000ML/yr to the Burdekin River, which is ~30% of the mean annual flow of the Burdekin River (DNR 1998). The high proportion of ancient, weathered fine soils, combined with high rates of land clearing, results in high turbidity and suspended solids in the waterways year round. In the scoping study (DNR 1998), 10 water infrastructure development options were considered in this catchment, including 4 water harvesting schemes. The only remaining dam option is at Mt. Douglas on the Belyando River, just 10km upstream of its confluence with the Suttor River.

Apart from western parts of the sub-catchment which can access artesian groundwater, there is limited scope for groundwater use in this sub-catchment. There are no existing water storages, though off-stream storages total 64,000ML and pump capacity is 63,000ML (DNR 1998). Almost 10,000ha of land are licensed for irrigation in the sub-catchment with over half being for cotton (DNR 1998). The Belyando-Suttor has the lowest topography of any of the major sub-catchments. Using criteria of 60m uplift from the riverbed, and no more than 30km from the distribution point, the scoping study estimated that 36,000ha of potentially suitable irrigation land was within 30km of Mt. Douglas and another 27,000ha adjacent to the river. Well over 100,00ha of potentially suitable land is to be found in other parts of the catchment but not within practical distances of any suitable impoundment.

For the 1998 scoping study, 26 regional ecosystems were recognised as potentially occurring within the vicinity of the impoundment areas, including 8 listed as ‘of concern’ and 9 listed as ‘endangered’. Land clearing has been extensive within this sub-catchment, thus greatly elevating the conservation status of the remaining habitats. Significant remnant stands of these habitats, especially brigalow habitats, within any impoundment area, is likely to be a strong factor in restricting impoundment construction.

4.3 Bowen/Broken Sub-Catchment

The Bowen/Broken Rivers rise in high rainfall mountainous hills of the Clarke Range near Eungella, behind Mackay. This sub-catchment occupies only 7% of the total Burdekin catchment but contributes about 14% of the total catchment streamflow (DNR 1998).

Eungella Dam (storage capacity of 131,000ML) on the Broken River (AMTD 71.8km) was constructed in 1969 and largely supplies mining operations to the west. The Collinsville Weir (storage capacity of 2,360ML) on the Bowen River (AMTD 94.4km) was constructed in 1983 to supply water to Collinsville and surrounding towns. Releases from Eungella Dam contribute to the yield from the Collinsville Weir. Twelve potential sites were investigated in the scoping study, including raising the wall of the existing Eungella Dam. Based on technical, cost and future expansion opportunity, only two options were considered worthy of further investigation. These are both on the Broken River high up in the catchment – Mt. Sugarloaf at AMTD 7.7km and Urannah at AMTD 36km.

In the scoping study, it was noted that the topography surrounding Mt. Sugarloaf was probably favourable to a larger option than what was considered. An impoundment here would also capture waters from the high run-off Emu Creek and Grant Creek, which enter the Broken River below the Urannah dam site. Urannah has previously been investigated for a dam site on several occasions and more information is available for this site compared to Mt. Sugarloaf.

A large area (~41,000ha) of potentially suitable irrigation soils occur in this sub-catchment. Most of these are located from the Bowen/Broken confluence down to near the Bowen/Burdekin confluence with the largest blocks near Havilah Station and adjacent to the Collinsville Weir (DNR 1998). The Bowen and Broken catchments have a very limited potential for groundwater irrigation (DNR 1998).

4.4 Lower Burdekin

This sub-catchment occupies about 8% of the total catchment area. It is dominated by the Burdekin River, but also includes several other major waterways such as the Bogie River, Millaroo Creek and Expedition Pass Creek. It also includes a myriad of highly significant environmental features on the coastal plain associated with the delta and floodplain of the Burdekin River. The mean annual flow of the Burdekin River at Clare was 10,895,585ML from 1950-1976 and 7,225,248ML from 1974-1998 (DNR 1998). This result indicates long-term differences in water availability and suggests that even 30-year time-frames are insufficient for projecting natural water availability. Only a very small proportion of this derives from the local sub-catchment, with most coming from areas a considerable distance upstream.

Agricultural development in this sub-catchment is extensive and dominated by groundwater irrigation on the Burdekin delta and surface irrigation on the Burdekin-Haughton floodplain supplied from the existing Burdekin Falls Dam. There are also irrigated lands along the Burdekin River at Dalbeg, Millaroo and Clare. Around 90,000ha of sugar cane and 3,000ha of horticulture are now supplied (DNR 1998).

Current water demand in the lower Burdekin and coastal plains is 956,500ML/yr (DNR 1998) with increases expected for urban (including the pipeline to Townsville), irrigation and aquaculture uses. The largest area of remaining suitable irrigation soil (totalling 24,610ha) occurs along the coastal strip from Home Hill south to Bowen. DNR-RID is investigating supplying this area with water from the Burdekin River via the Elliot Main Channel. This channel is currently 12.7km long but its proposed extension would take it an additional 122km at a total cost of $178M. In contrast to other sub-catchments, because this development is at the downstream end of the system, water to supply this development could be sourced from any of the dams in the other sub-catchments. Other areas within this sub-catchment identified as having soils suitable for irrigation include the right bank of the Burdekin River at Strathalbyn (3,100 ha), near Majors Creek, a tributary of the Haughton River (3,400-8,700ha) and the Haughton relift (3,700ha).

The four existing storages within this sub-catchment are the Burdekin Falls Dam (159.3km AMTD - 154m FSL) constructed in 1987 with a storage capacity of 1,860,000ML and three weirs (Gorge, Blue Valley and Clare) below the dam with a total storage capacity of nearly 29,000ML. The scoping study examined 11 options in the lower Burdekin/coastal plains area, although only three were actually within the Burdekin catchment. The others were in the Don River catchment near Bowen or the Haughton River catchment near Giru.

5.0 VEGETATION AND TERRESTRIAL FAUNA ASSESSMENT

5.1 Vegetation Assessment

Vegetation associations for this report have been described on the basis of regional ecosystems, where these have been mapped. Regional ecosystems have become the standard units for vegetation mapping and conservation planning in Queensland adopted by the Environmental Protection Authority (Sattler and Williams 1999). The concept of regional ecosystems involves a hierarchical classification incorporating biogeographical regions and provinces at the first level, land zones (geology, soils and landforms) at the second level and the vegetation community at the third level. Mapping of regional ecosystems throughout the state is currently being undertaken at 1:100,000 scale or greater. Thus, field work is required to identify smaller units of vegetation communities in any study area. Within the Burdekin catchment, mapping is available at 1:100,000 scale for the impoundment areas of the Burdekin Falls Dam and Mt. Douglas options. For the Bowen/Broken system, the mapping is currently at 1:250,000 scale but work is continuing. For the upper Burdekin, no mapping is yet available but it is in progress. Where available, the draft maps were examined and from these, sites to be prioritised during the brief field visits were determined. This enabled some ground-truthing to take place within high priority locations. For the upper Burdekin, vegetation communities for this study were mapped by the EPA officer responsible for producing the regional ecosystem maps for the area, using vegetation units which have been related to known regional ecosystems where appropriate.

During the brief field survey, all vegetation communities encountered were recorded, including over-storey, mid-storey and ground stratum floristic information, and notes on existing disturbance, condition and weeds. In addition to the field survey, existing flora information for the area was reviewed. A search of the Queensland Herbarium database was made to determine the locality of any individual plant species of recognised conservation significance.

Vegetation community significance is assessed by assigning the described vegetation community association to a corresponding regional ecosystem for the bioregion. Regional ecosystems are recognised by federal and state governments through the Natural Heritage Trust Partnership agreement, which commits to prohibiting clearing of 'endangered' regional ecosystems on crown and leasehold lands, and prevention of any regional ecosystem moving to a more threatened status. Regional ecosystems are also used by the state and federal governments in selecting reserves that are representative of each bioregion in Queensland.

Conservation status for each regional ecosystem is assigned as one of three categories (Sattler and Williams, 1999.):

- **endangered:** <10% of the pre-European extent remains in an intact condition across the bioregion, or the ecosystem is naturally rare and subject to a threatening process, or the ecosystem is naturally restricted and has been reduced to between 10 and 30% of its natural distribution;

- **of concern:** 10-30% of the pre-European extent remains in an intact condition in the bioregion, or the ecosystem is naturally restricted and is subject to a threatening process; and

- **no concern at present:** >30% of the pre-European extent remains in an intact condition.

5.2 Plant Species of Conservation Significance

A search of the Queensland Herbarium HERBRECS database was undertaken for the Burdekin catchment. From this, records that are within or near potential impoundment areas were extracted and are presented in Table 2. Due to the generalised or poor locality information supplied with some of the records, especially the older records, some records may be erroneous or geographically misplaced. All of the listed species could be considered likely to be effected by proposed inundation levels. Without targeted and intensive survey, the extent of these species distribution within the potential impoundment areas cannot be accurately determined. It is anticipated that the species listed below represent a relatively small fraction of significant plant species that would be found by a more detailed survey.

Table 2. Records of plant species of high conservation status from the Queensland Herbarium HERBRECS database.

FAMILY	SPECIES	STATUS	LOCATION
Greenvale			
Aponogetonaceae	*Aponogeton queenslandicus*	Rare	Reedy Brook Station
Asteraceae	*Peripleura scabra*	Rare	Valley of Lagoons
Mimosaceae	*Acacia crombiei*	Vulnerable	Wyandotte Station
Mimosaceae	*Acacia jackesiana*	Rare	Greenvale Nickel Mine
Myrtaceae	*Eucalyptus howittiana*	Rare	Valley of Lagoons
Myrtaceae	*Eucalyptus howittiana*	Rare	Christmas Creek nr. Greenvale
Myrtaceae	*Eucalyptus howittiana*	Rare	Greenvale Station
Myrtaceae	*Leptospermum pallidum*	Rare	Burdekin River nr. Lake Lucy
Myrtaceae	*Leptospermum pallidum*	Rare	near Greenvale
Myrtaceae	*Leptospermum pallidum*	Rare	Marble Creek, SE of Greenvale
Poaceae	*Paspalidium udum*	Vulnerable	Saltern Lgn, Valley of Lagoons
Proteaceae	*Grevillea glossadenia*	Vulnerable	Reedy Brook Station
Sterculiaceae	*Brachychiton albidus*	Rare	Pandanus Ck, 50km SW of Greenvale
Mt. Foxton			
Sapindaceae	*Alectryon tropicus*	Rare	Burdekin River, Ewan-Mt.Fox Rd
BFD			
Apocynaceae	*Cerbera dumicola*	Rare	Barrabas Scrub nr. Ravenswood
Apocynaceae	*Wrightia versicolor*	Rare	Barrabas Scrub nr. Ravenswood
Apocynaceae	*Wrightia versicolor*	Rare	Rochford Scrub nr. Ravenswood
Apocynaceae	*Wrightia versicolor*	Rare	Mt Hope Station
Arecaceae	*Livistona lanuginosa*	Vulnerable	Glenroy Creek nr. Burdekin Dam
Arecaceae	*Livistona lanuginosa*	Vulnerable	Harvest Home Station
Asclepiadaceae	*Tylophora williamsii*	Vulnerable	Rishton Scrub, Cameron Downs
Asteraceae	*Peripleura scabra*	Rare	17km S Belyando Crossing
Chenopodiaceae	*Sclerolaena everistiana*	Rare	Taemas Station
Chenopodiaceae	*Sclerolaena everistiana*	Rare	Mt. McConnell Station
Fabaceae	*Leptosema sp. (Burra Range)*	Rare	Mt Douglas Station
Goodenaceae	*Goodenia viridula*	Rare	St Anns Station
Goodenaceae	*Goodenia viridula*	Rare	10km S Cape River Crossing
Mimosaceae	*Acacia jackesiana*	Rare	Burdekin Gorge nr. Falls

FAMILY	**SPECIES**	**STATUS**	**LOCATION**
Myrtaceae	*Callistemon chisholmii*	Rare	Mt Hope Station
Myrtaceae	*Eucalyptus howittiana*	Rare	Harvest Home Station
Myrtaceae	*Eucalyptus howittiana*	Rare	Scartwater Station
Myrtaceae	*Eucalyptus howittiana*	Rare	Lornesleigh Station
Myrtaceae	*Eucalyptus howittiana*	Rare	East of Mt. Cooper
Myrtaceae	*Eucalyptus raveretiana*	Vulnerable	Burdekin River at Broughton
Myrtaceae	*Eucalyptus raveretiana*	Vulnerable	Pandanus Ck SW of Silver Valley
Poaceae	*Dicanthium setosum*	Rare	12km N of Burdekin Falls
Poaceae	*Dicanthium setosum*	Rare	Burdekin Falls-Mingela Rd
Sapindaceae	*Alectryon tropicus*	Rare	Kirk Range, nr. Ravenswood
Sapindaceae	*Alectryon tropicus*	Rare	Mt. Cooper Station
Mt. Douglas			
Apocynaceae	*Wrightia versicolor*	Rare	Mt Hope Station
Asteraceae	*Peripleura scabra*	Rare	17km S Belyando Crossing
Fabaceae	*Leptosema sp. (Burra Range)*	Rare	Mt Douglas Station
Goodenaceae	*Goodenia viridula*	Rare	Mt Bingeringo
Goodenaceae	*Goodenia viridula*	Rare	St Anns Station
Mimosaceae	*Acacia jackesiana*	Rare	Burdekin Gorge
Myrtaceae	*Callistemon chisholmii*	Rare	Mt Hope Station
Myrtaceae	*Eucalyptus howittiana*	Rare	Scartwater Station
Bowen/Broken			
Apocynaceae	*Wrightia versicolor*	Rare	Havilah Station
Boraginaceae	*Ehretia grahamii*	Rare	Exmoor Station
Boraginaceae	*Ehretia grahamii*	Rare	Mt. Blackjack, Weetalaba Station
Euphorbiaceae	*Croton magneticus*	Vulnerable	Havilah Station
Euphorbiaceae	*Croton magneticus*	Vulnerable	Mt. Blackjack, Weetalaba Station
Myrtaceae	*Eucalyptus raveretiana*	Vulnerable	Blenheim Creek
Myrtaceae	*Eucalyptus raveretiana*	Vulnerable	Turrawalla Homestead
Myrtaceae	*Eucalyptus raveretiana*	Vulnerable	Hazelwood Ck nr. Eungella Dam
Sapindaceae	*Atalaya calcicola*	Rare	Exmoor Station
Sapindaceae	*Atalaya calcicola*	Rare	Havilah Station
Sapindaceae	*Atalaya calcicola*	Rare	Mt. Blackjack, Weetalaba Station
Sapindaceae	*Atalaya calcicola*	Rare	Redcliffe Tableland

5.3 Terrestrial Fauna Assessment

Detailed fauna surveys were not possible during the brief field visits. Incidental records were made of fauna observed. These are presented in the Appendices, though they are mostly limited to birds. A list of fauna species of conservation significance that can reasonably be expected to occur within the vicinity of each impoundment was compiled from known existing data and our own extensive unpublished records for the Burdekin catchment. These are listed with their conservation significance in Table 3, and the likelihood of their occurrence in each impoundment area in Table 4. The actual occurrence of these faunal species will need to be determined during any future environmental impacts assessments.

In addition to fauna species, the significance of habitats for fauna can be evaluated by the following criteria:

- the level of human, mechanical or other disturbance (eg: altered fire regimes, weed invasion)
- the dominance of weed species in the vegetation community
- whether it constitutes a wildlife corridor
- whether it represents a remnant community
- whether it acts a refuge;
- and whether it contains an unusual or important community structure.

Such considerations were taken into account when evaluating the faunal values of each potential impoundment area.

The conservation significance of individual faunal species was identified from National and State ratings found in published lists recognised by the scientific community and government bodies. For national significance, Schedule 2 of the (Commonwealth) Endangered Species Act 1992 and the Australian Nature Conservation Agency Action Plans for vertebrate fauna are used. Currently seven terrestrial vertebrate fauna Action Plans are published: marsupials and monotremes; reptiles; shorebirds; birds; rodents; frogs; and bats. For state significance, conservation status levels and species listed in the Queensland Nature Conservation (Wildlife) Regulation was used. Regional significance is assessed by reference to previously published surveys and assessments of the study area.

Sources for conservation significance listings in Table 3 include: Commonwealth Endangered Species Protection Act 1992 (ESA); Queensland Nature Conservation Act (wildlife) Regulations 1994 (QNCA) and Action Plans for Australian fauna (AP). Definitions for conservation status listed for each species are: lower risk, near threatened (LRnt); rare (R); vulnerable (V); endangered (E); and insufficiently known (K).

In addition to the conservation status, the general habitat preference for each species is identified in Table 3. This information was obtained from the authors' own experience and standard reference texts for terrestrial vertebrates. Codes for habitat types are as follows: eucalypt woodland (EW); acacia woodland (AW); melaleuca woodland (MW); grevillea woodland (GW); mixed woodland (Mix); all woodland types (W); vine-thicket (V); rainforest/closed forest (CF); wetlands and swamps (SW); rocky outcrops (O); riparian forest (R); grasslands (G); karst and caves (K); marine and coastal habitats (M).

Table 3. Conservation significance and status of species known or potentially occurring in the Burdekin catchment.

Common Name	Species	ESA	QNCA	AP	Habitat
MAMMALS					
Northern Quoll	*Dasyurus hallucatus*			LR(nt)	W, R, O, K
Brush-tailed Phascogale	*Phascogale tapoatafa*			LR(nt)	EW
Rufous Bettong	*Aepyprymnus rufescens*			LR(nt)	G,W
Spectacled Hare-Wallaby	*Lagorchestes conspicillatus*			LR(nt)	W, G
Bare-backed Sheathtail-bat	*Saccolaimus saccolaimus*		R		EW
Semon's Horseshoe Bat	*Hipposideros semoni*		V	V	EW, V
Ghost Bat	*Macroderma gigas*		R	V	V, O, K
Pebble-mound Mouse	*Pseudomys patrius*				EW, O
Squirrel Glider	*Petaurus norfolcensis*			LR(nt)	W
Koala	*Phascolarctos cinereus*			LR(nt)	W
Little Pied Bat	*Chalinolobus picatus*		R		W, R
Greater Long-eared Bat	*Nyctophilus timorensis*			V	W
Greater Broad-nosed Bat	*Scoteanax rueppellii*			V	W, R
Coastal Sheath-tail Bat	*Taphozous australis*		V	V	EW, M
BIRDS					
Grey Goshawk	*Accipiter novaehollandiae*		R		W
Red Goshawk	*Erythrotriorchis radiatus*	V	E	V	R, EW
Square-tailed Kite	*Lophoinctinia isura*		R	R	R, EW
Grey Falcon	*Falco hypoleucos*		V		W
Cotton Pygmy-Goose	*Nettapus coromandelianus*		R	R	SW
Burdekin Duck	*Tadorna radjah*		R		SW
White-rumped Swiftlet	*Aerodramus spodiopygia*		R		V, K, EW
Ground Cuckoo-Shrike	*Coracina maxima*		R		W, G
Black-necked Stork	*Ephippiorhynchus asiaticus*		R		SW
Buff-breasted Button Quail	*Tunix olivei*		V		W
Squatter Pigeon	*Geophaps scripta*	V	V	V	W
Black-chinned Honeyeater	*Melithreptus gularis*		R		W, R
Crimson Finch	*Neochmia phaeton*		V		SW, R
Star Finch	*Neochmia ruficauda*	E	E	E(Cr)	SW, R
Black-throated Finch	*Poephila cincta cincta*		V	V	SW, R, W
Great Crested Grebe	*Podiceps cristatus*		R		SW
Masked Owl	*Tyto novaehollandiae*			R	W
REPTILES					
Estuarine Crocodile	*Crocodylus porosus*		V		SW, R
Southern Death Adder	*Acanthophis anarcticus*		R	K	W, V, O, R, K
Yellow-naped Snake	*Furina barnardi*		R	K	W
Blind snake	*Ramphotyphlops broomi*		R	K	W
Snake	*Simoselaps warro*		R	K	W, R
Common Bandy Bandy	*Vermicella annulata*			V	W
Collared Delma	*Delma torquata*	V	V	V	W, V
Striped-tailed Delma	*Delma labialis*		V	K	W, O
Skink	*Anomolopus gowi*			K	W, V
Skink	*Ctenotus eutenius*				W, O, V
Yakka skink	*Egernia rugosa*		V	K	W
Skink	*Lerista cinerea*			V	W, V
Skink	*Lerista karlscmidti*		R		V, W, O

Table 4. Predicted and known significant species occurrence in each of the five Burdekin sub-catchments under consideration.

1= recorded from impoundment area
2 = good chance of being found in impoundment area
3= possibly within impoundment area

Species	Species	GVL	FULL	HG	FOX	BFD	DOUG	SUG	URNH
Northern Quoll	*Dasyurus hallucatus*	2	2	2	2	2	2	2	2
Brush-tailed Phascogale	*Phascogale tapoatafa*	2	2	2	2	2			
Rufous Bettong	*Aepyprymnus rufescens*				2				
Spectacled Hare-Wallaby	*Lagorchestes conspicillatus*	2	2	2	2	2	2	2	
Pebble-mound Mouse	*Pseudomys patrius*	3	3	3	2	2	3	2	3
Squirrel Glider	*Petaurus norfolcensis*	2	2	2	2	3	3	2	2
Koala	*Phascolarctos cinereus*	3	3	3	3	3	3	3	3
Coastal Sheath-tailed Bat	*Taphozus australis*								
Bare-backed Sheathtail Bat	*Saccolaimus saccolaimus*				3				
Semon's Horseshoe Bat	*Hipposideros semoni*				3				
Little Pied Bat	*Chalinolobus picatus*	1	2	2	2	1	2	2	2
Greater Long-eared Bat	*Nyctophilus timorensis*						2		
Greater Broad-nosed Bat	*Scoteanax rueppellii*	2	2	2	1			2	2
Greater Large-eared Horseshoe Bat	*Rhinolophus phillipensis*				1				
Ghost Bat	*Macroderma gigas*	2	2	2	2				
Grey Goshawk	*Accipiter novaehollandiae*	3	3	3	3	3	3	3	3
Red Goshawk	*Erythrotriorchis radiatus*	3	3	3	3	3	3	3	3
Square-tailed Kite	*Lophoinctinia isura*	1	1	1	1	2	2	3	3
Grey Falcon	*Falco hypoleucos*					3	3		
Cotton Pygmy-Goose	*Nettapus coromandelianus*	1	1	1	1				
Burdekin Duck	*Tadorna radjah*	1	1	1	1				
White-rumped Swiftlet	*Aerodramus spodiopygia*	3	3	3	2			3	3
Ground Cuckoo-Shrike	*Coracina maxima*	1	1	1	1	2	2	3	3
Black-necked Stork	*Ephippiorhynchus asiaticus*	1	1	1	1	2	2	3	3
Buff-Breasted Button Quail	*Tunix olivei*								
Squatter Pigeon	*Geophaps scripta scripta*							3	
Black-chinned Honeyeater	*Melithreptus gularis*	2	2	2	2	2	2	3	3
Crimson Finch	*Neochmia phaeton*	1	3	3	3	2	2	3	3
Star Finch	*Neochmia ruficauda*	3	3	3	3	2	1		
Black-throated Finch	*Poephila cincta cincta*					2	3		
Great Crested Grebe	*Podiceps cristatus*	1	2	2	2				
Masked Owl	*Tyto novaehollandiae*	3	3	3	3	3	3	3	3
Estuarine Crocodile	*Crocodylus porosus*					1	1		
Southern Death Adder	*Acanthophis anarcticus*	2	2	2	2	2	2	2	2
Yellow-naped Snake	*Furina barnardi*	2	2	2	2	2			
Blind snake	*Ramphotyphlops broomi*	2	2	2	2	2	2	2	2
Snake	*Simoselaps warro*	2	2	2	2	2	2	2	2
Common Bandy Bandy	*Vermicella annulata*	2	2	2	2	2	2	2	
Striped-tailed Delma	*Delma labialis*	2	2	2	2	2			
Skink	*Anomolopus gowi*	2	2	2	2	2			
Skink	*Ctenotus eutenius*	2	2	2	2	1	2		
Yakka skink	*Egernia rugosa*	2	2	2	2	1	2	2	2
Mt. Cooper Striped Lerista	*Lerista vittata*					1			
Skink	*Lerista cinerea*					1			
Skink	*Lerista karlscmidti*	2	2	2	2	2			

6.0 AQUATIC FAUNA AND ECOSYSTEMS
(by Dr. Brad Pusey – River Research Pty. Ltd.)

Information concerning the fish fauna of the Burdekin river and its tributaries is drawn from data collected by quantitative sampling of fish assemblages over the period of 1989-1992. Data were collected by electrofishing, seine netting and gill netting. Each of 12 sites was visited twice a year (a wet and a dry season sample). The location of these sites and details of the results are given in Pusey *et al.* (1998). In addition, 5 of the 12 sites were further sampled by electrofishing over the period 1993-1997. Quantitative information concerning reproductive biology and feeding ecology were also made during the first period (1989-1992).

6.1 Background Information on the Ecology of Fishes in the Burdekin River

6.1.1 Species Complement and Distribution

Several studies have examined the distribution of fishes in the Burdekin basin and Table 5 is compiled from these various sources. It should be noted that several translocations of fishes have been made by government agencies and private individuals. Not all have been successful, nor is the degree to which other species have been inadvertently translocated known.

A total of 37 fish species have been recorded from freshwaters of the Burdekin River basin. Of this total, 7 have been translocated either deliberately or inadvertently into the basin. Not all of these translocations have been successful, for example Silver Perch and Murray Cod are no longer present. The original introductions of Yellowbelly into Valley of Lagoons were largely unsuccessful but the more recent introductions into Lake Dalrymple (Burdekin Falls Dam) have proved successful and this species has been recorded as far upstream as Charters Towers (Pusey unpublished data) and in the Belyando River (Burrows *et al.* 1999). *Gambusia holbrooki* is the only exotic species thus far recorded from the Burdekin River and it appears limited to the downstream reaches. Two of the species listed in Table 5 as occurring in the Burdekin River (*Hypseleotris galii* and *Craterocephalus marjoriae*) may have been so because of misidentification. Both species are limited to rivers south of the Burdekin River and are sometimes easily confused with congenerics.

Most of the fish species present are not of great conservation significance, being listed as 'Non-threatened'. Two species, *Neosilurus mollespiculum* and *Scortum parviceps*, are listed as 'Restricted'. Both species are endemic to the Burdekin River. *Scortum parviceps* is largely restricted to that section of the river upstream of the Burdekin Falls whereas *N. mollespiculum* occurs at low abundance in the Bowen River also. The Burdekin Falls has had an overriding influence on the distribution of the fishes within the drainage (Pusey *et al*. 1998*).* Species with a marine component to their life history have been effectively excluded from the upstream reaches due to the insurmountable barrier posed by the falls. The only species apparently capable of traversing the falls regularly was the long-finned eel, *Anguilla reinhardtii.* However it appears that this species is no longer able to access the upper reaches since the construction of the Burdekin Falls Dam, and currently, the only specimens found in the upper reaches are large individuals which presumably colonised the upper reaches prior to the dam's construction.

Pusey *et al.* (1998) suggested that in addition to the Burdekin Falls function as a downstream landscape filter, the other important determinant of the distribution of fishes in the Burdekin River was the capture by deflection, of the upper reaches of the Gilbert River (and some of its fauna) about 6 million years ago. Recent genetic research on sooty grunter (*Hephaestus fuliginosus*) has corroborated this proposed landscape evolution event. Populations of sooty grunter in the Burdekin River and the Gilbert River are over 6% genetically divergent (Pusey and Bermingham unpublished data). Divergence of this extent is usually associated with interspecific comparisons (if not inter generic) suggesting that the two populations are sufficiently different to be considered different species. This landscape event is probably responsible for the allopatric speciation of the two endemic species present in the river although further work is needed to confirm this.

Although landscape scale features are the most important factors influencing the distribution of fishes within the river, the composition and abundance of fishes at the local scale is determined by the characteristics of the habitat at that scale (Pusey *et al.* 1998). Significant habitat parameters include water velocity, depth and the abundance of in-stream cover, especially macrophytes. Macrophytes are not an abundant feature of the aquatic habitats of the Burdekin River (Pearson 1991, Pusey *et al.* 1998) yet they are important in determining the abundance of a number of species.

6.1.2 Flow Related Changes to Fish Populations

Temporal variation in habitat structure and fish assemblage structure associated with changes in discharge have been studied (Pusey *et al.* in prep.). Flooding was shown to drastically change the distribution and abundance of important habitat elements such as leaf litter and macrophytes, and consequently cause changes in the abundance of species associated with these habitats. Flooding *per se*, even a 1 in 20 yr event (early 1991), caused little change in the abundance of other species not associated with macrophytes, with the exception of bony bream, *Nematolosa erebi* . This species was drastically reduced in abundance but recovered to pre-flood levels within six months. No other species suffered a major reduction in abundance associated with this event. In contrast, many species showed increases in abundance following flooding. This was because of greater recruitment associated with the provision of increased and enhanced habitat from elevated flows.

The study of Pusey *et al.* (1998) coincided with entry into a period of prolonged drought (late 1991 - 1995). The reduction of flows and habitat, and the absence of wet season flushes had a greater impact on fish assemblage structure and abundance than did the 1 in 20 year flood occurring in early 1991. These changes were associated with failed recruitment and increased intensity of competition and predation (Pusey *et al.* in prep).

6.1.3 Reproductive Styles and Spawning Phenology

The fishes of the Burdekin River exhibit a variety of reproductive strategies (Table 6). The majority of species are oviparous and show minimal parental care. Of the 27 species listed in Table 6, 55.5% spawn predominantly in the wet season and 29.6% spawn during the dry season. The remainder either spawn year round or their phenology is unknown. For many of the wet season spawners, reproduction was not necessarily cued by flooding, but the increase in available habitat following flooding certainly enhanced recruitment, giving an apparent relationship between flooding and spawning (Pusey *et al*. in prep.). Other species such as the *Neosilurus* catfishes appear to require elevated flows to stimulate them to migrate upstream into tributaries to spawn (Orr and Milward 1984). Many of the species which spawn during the dry season appear to be taking advantage of the low flow conditions which provide suitable habitat for larvae and juveniles. Changes in flow regime which reduce the frequency, extent and duration of flooding are likely to impact severely on such species.

Other species, such as the barred grunter, *Amniataba percoides*, may time their reproduction to avoid competition between their progeny and the progeny of other similar species, such as spangled perch, sooty grunter and catfishes. Competition for food resources is intense within the community of juvenile fishes as they, being gape limited by virtue of their small size, consume a very similar array of prey (mainly chironomid larvae and trichopteran nymphs) (Pusey *et al.* in prep.).

6.1.4 Spawning Requirements

At least seven of the species listed in Table 6 require macrophytes and bank associated structures such as root masses, as a spawning substrate. Consequently, changes in flow regime which impact on the abundance of macrophytes (ie. prolonged elevation), or isolate banks and root masses, are likely to impact on population levels in the short term and species persistence in the long term.

Seven of the species listed in Table 6 spawn over coarse substrates in areas adjacent to flowing water. Changes in flow that reduce the availability of such areas or their extent are likely to impact on these species. Sooty grunter, for example, spawn in low flow habitats (usually marginal) adjacent to riffles and in so doing are susceptible to the stranding of their eggs if water levels fluctuate markedly. Bony bream (*Nematolosa erebi*) are the most dominant species by biomass in the Burdekin River, and this species spawns over fine gravel beds during the wet season. Changes in flow regime which expose such beds before metamorphosis is complete, will impact severely on this species. In addition, elevated flows which cause bed instability and mobilisation of gravel beds are also likely to impact on bony bream populations. Bony bream is a detritivore and consequently occupies a very basal level in the aquatic food web. Moreover, they are an important forage species for higher level predatory fishes. Changes in the population size of this species are likely to have major secondary impacts on a variety of other species and ecological processes.

6.1.5 Movement

Fish communities in tropical Australian rivers are characterised by a variety of movement patterns associated with reproduction, colonisation and acquisition of food (Bishop *et al.* 1995, Pusey *et al.* in prep). Fifteen of the species occurring in the Burdekin River are known elsewhere to make substantial movement (Table 6). Often these movements are associated with reproduction, and consequently, any developments that interfere with the ability of these species to access the spawning habitats in which juveniles develop, or make return migrations as adults or juveniles, will have long-term consequences for these species. Importantly, migrations are made at different times of year and under different flow conditions, and are made by different life-history stages. Therefore, remedial measures such as the incorporation of fish passage devices into dam infrastructure, must be capable of allowing fish passage under a variety of flow conditions and must be designed in order to allow passage by a variety of species and life-history stages with a variety of swimming abilities.

Some species may not make substantial movements but none-the-less, connectivity is important for the maintenance of gene flow between sub-populations, and to allow the recolonisation of areas denuded by natural phenomena, such as drought.

6.1.6 Larval Habitat

Fish larvae are generally delicate and of poor swimming ability. Moreover, fish larvae form an important component of the diet of many species. Consequently, zero flow environments and abundant cover provided by macrophytes and rootmasses are critical requirements. For many of the small bodied species present, changes in flow regime which impact on these critical habitat types will be deleterious to long-term species persistence. As mentioned above, species such as sooty grunter deposit their eggs in low flow habitats adjacent to high flow habitats, and the developing larvae remain in the natal habitat until their swimming ability is sufficient to allow them to move and forage in the high flow, more productive habitats. During this period they are highly susceptible to stranding by lowered water levels or physical removal by elevated flows. Moreover, as mentioned above, the juveniles of many species present in the Burdekin River consume an almost identical array of prey. Changes in flow regime which alter the availability of their food base (either reductions in flow which simply desiccate preciously inundated areas or elevated flows which cause bed instability and decreased suitability as habitat for invertebrates) will impact on adult populations in the long term.

6.1.7 Flow Dependency

Table 6 lists the extent to which the individual species present in the Burdekin River are dependent on the flow regime. The Burdekin River is an ancient river and the fauna present are likely to have been present and adapting to the flow regime for many millions of years. Therefore it is not surprising that most of the species listed in Table 6 exhibit some level of dependency on the flow regime. It is virtually inconceivable that any alteration to the flow regime will not impact on the resident fish fauna. Importantly, Table 6 lists only the relationships between flow and reproduction. Many other areas of daily life are likely to be linked to the flow regime (ie. food acquisition, prey availability, predation pressure, disease transmission, physicochemical tolerances *etc*.).

6.2 Assessment of the Impacts Associated With the Various Options

6.2.1 Greenvale

The proposed Greenvale development is the most upstream option under consideration in the upper Burdekin sub-catchment. It will effectively isolate the Valley of Lagoons region from the remainder of the upper Burdekin River. Under no circumstance should the integrity of the wetlands systems of the Valley of Lagoons be compromised by flooding given their value as bird habitat and recognition as important wetlands in the Directory of Important Wetlands (Burrows *et al.* 1998).

Hogan and Vallance (1998) raised two important issues concerning the aquatic habitats of the Valley of Lagoons region. First, it may serve as an important refuge from drought for the fishes of the river. Whilst it is not proposed that fishes retreat to this region during drought, the permanent wetlands may serve as a source from which colonists may disperse to repopulate impacted downstream reaches. It is important to note that the Valley of Lagoons region contains a very high diversity of fishes at the local scale, relative to areas downstream (Pusey *et al.* 1998); a situation in contrast to that occurring in most rivers where diversity tends to increase downstream. Thus, if the Valley of Lagoons were to act as a drought refuge and a source of downstream colonists, then it contains a very large proportion of the species present in the entire upper Burdekin. Any development which reduces the extent to which this may occur has the potential to impact on fish populations downstream.

Second, Hogan and Vallance (1998) identify the riffle and rapid sections of this area as important spawning habitat for sooty grunter. Sooty grunter may make extensive movements associated with spawning although the extent of downstream reaches which contain individuals that utilise the spawning habitat present here is unknown. However, any development which prevents fish passage in both an upstream or downstream direction has the potential to impact upon downstream populations. This argument also applies to the three neosilurid species which also migrate upstream to spawn during high flows and may also apply to the endemic theraptonid grunter, *S. parviceps*.

The impoundment of this section of the river may provide habitat for the many bird species that use the Valley of Lagoons region, and for the fishes that occur naturally in the Valley of Lagoons region, given that they are already adapted to the lentic environment provided by the many lagoons. Translocation or stocking of sport species should not be allowed to take place. A repeat of the disastrous situation concerning the stocking and subsequent spread of sleepy cod (*Oxyeleotris lineolatus*) must not be allowed to occur. This applies particularly to the stocking of any reservoir located in the upper Burdekin with barramundi or sooty grunter. The fish communities of the upper Burdekin River have evolved in the absence of barramundi, a large predator, for at least 10 million years (Pusey *et al.* 1998). In the case of sooty grunter, the research of Pusey and Bermingham (unpublished) indicates that the natural stocks present in the Burdekin River have evolved in isolation from other populations for at least 6 million years and therefore represent a highly distinct genotype and should be regarded as an Evolutionary Significant Unit. The case where easterly flowing rivers have been “polluted” with genetic stocks of sooty grunter from westerly flowing streams must be avoided.

Although the Greenvale development may provide lentic aquatic habitat, this must be balanced against the loss of flooded lotic habitat and the effect on downstream reaches of the river. The data presented in Table 1 suggest that the 439m and 445m options for this development would capture most of the large events and greatly decrease the frequency of downstream flooding. This would impact on the nature and extent of downstream habitat as well as reducing the opportunities of flood spawning fishes to reproduce.

Although it commands the least amount of catchment area, this option has the potential to effect a very large length of river (over 100km to the confluence with the Running River). Moreover, the flow regime of the length of river downstream of the Valley of Lagoons is more predictable and less prone to periods of no flow than reaches downstream of say Running River (Pusey and Arthington 1996). The fauna of this reach is likely adapted to the more constant flow and least likely to accommodate a substantial reduction in flow.

6.2.2 Mt Fullstop and Hells Gates

These proposed developments are sufficiently close to one another, and of similar size, to be treated together. The arguments raised above and applied to the Greenvale proposal, also apply to these developments. Both dams will effectively isolate the upper reaches of the Burdekin River and unless remedial measures are incorporated into their design will severely restrict the movement of fishes.

Both proposals are for very large dams which would capture discharge originating from upstream catchments, and severely reduce the extent and frequency of downstream flooding. Even the smallest of the proposals for each site would effect even flows approximating the 1 in 1 year flood. It is expected that major channel alteration would occur downstream as a result of this.

6.2.3 Mt Foxton

This option would capture a great proportion of the flow of the upper Burdekin. The loss of flooding would seriously impact on a large number of species over a very great length of the river. It is expected that this would result in substantial changes to channel morphology downstream and hence alteration of habitat structure and availability to fishes. Changes in habitat structure may be difficult to predict. For example, both the Star River and Keelbottom Creek discharge into the main stem of the Burdekin River below the dam. If flood intensity is decreased in the main stem but not in these tributaries then it is likely that deposition of carried sediment will occur at the point where the floodwaters of these tributaries enter the main channel. This may cause impoundment of waters upstream of these depositional zones and cause difficulties for migratory fishes in accessing the upper reaches for spawning.

The Mt Foxton option will cause impoundment of the lower reaches of Running River. This river is of high conservation significance, being an important spawning area for several species such as sooty grunter and catfishes, as well as habitat for a distinctive phenotype of the common rainbowfish. A reduction in the genetic diversity of fishes in the upper Burdekin is to be avoided.

6.2.4 Mt Douglas

The larger of the two options planned for this site (192.5m) represents a very large harvest of the flow in the Belyando River. Flows in this section of the catchment are highly variable, and a great proportion of the discharge is restricted to a few large events (Pusey and Arthington 1996). Such a large dam would in most likelihood, capture most of the flow originating from a large event and certainly capture all of the flow from lesser floods. This would have severe downstream ecological and geomorphological consequences. The smaller development option (182m) would capture less of the large flood events but still seriously influence the passage of smaller events.

Low or zero flows are common in rivers of the south-west of the Burdekin catchment (mean proportion of days less than 0.125 ML discharge = 42% (Pusey and Arthington 1996)). If captured flows are used to augment downstream storages, then this would change the pronounced ephemeral nature of the river to one of greater constancy. Many of the issues raised above for the upper Burdekin concerning changes to seasonal patterns of flow apply equally, if not more so, to this proposal.

Given the highly episodic nature of the flow in the Belyando River, it is probable that fish movements assume greater importance in the maintenance of fish abundance and diversity, than they do in the upper Burdekin. If so, any development will pose problems for fish passage unless remedial structures are put in place. Given the low yield to stored volume ratio of the larger option, it would be highly unlikely that any fishway could be designed so as to be effective.

6.2.5 Mt Sugarloaf and Urannah

Both of these options are located downstream of the current Eungella Dam which has not spilled for several years. When this is considered with the low yield to storage volume ratios (particularly of the Urannah option), it is very likely that most, if not all floods, both large and small, will be captured. The loss of flood and flush flows from this sub-catchment is of great importance to the maintenance of habitat structure in the Bowen River and for ecological function in the lower Burdekin River. Fish habitats in the Bowen River are distinctive because of the higher gradient (relative to the upper Burdekin River) and as a consequence, riffle and rapid habitats are more common (Pusey *et al.* 1998). The loss of high flows will likely result in gradual loss of these habitats and increased deposition of fine sediments.

Currently, the Bowen River is the major, largely unregulated, tributary of the lower Burdekin River and consequently is high quality fish habitat. In addition, the flow regime present in the

Bowen is distinctive compared to other rivers and tributaries in the basin (Pusey and Arthington 1996). It contains many fish species not recorded from elsewhere (Pusey *et al* 1998) in the catchment, and changes to flow regime type and to habitat structure may result in a loss of fish diversity. In addition, a reduction in discharge in the Bowen River will impact on flows in the lower Burdekin River which are already impacted by the Burdekin Falls Dam (see below).

6.2.6 Raising the Burdekin Falls Dam (BFD)

The three storage heights being considered for this option (see Table 1) all have relatively high yield to storage ratios, and although they would impact on the passage of floodflows, this effect would be less than many of the other development options for which these ratios are much lower. The effects of the loss of floodflows are much the same as those detailed above for the other proposals, but to some degree these effects would be mitigated if the Bowen River and other downstream tributaries remain largely unregulated.

The impact of raising the Burdekin Falls Dam on fish passage is not an issue, unlike in other proposed developments, given that the Falls have historically been a barrier to fish movement (Pusey *et al*. 1998). The only species likely to be impacted would be the long-finned eel, which is largely already extinct in the upper Burdekin River because of the construction of the existing dam. Care would be needed to ensure that fish movements from the lower reaches to the confluence of the Bowen River are maintained.

The construction phase of impoundments has a number of impact issues unrelated to changes in flow regime (Marchant 1989). The Burdekin Falls Dam options would avoid many of the impacts associated with construction that would occur with the other options.

6.3 Other Aquatic Issues Associated With Dam Construction on the Burdekin River

6.3.1 General Issues

Whether the upper Burdekin options provide water for irrigation developments in the immediate vicinity, or is used to augment the supply from the Burdekin Falls Dam, it is almost certain that dry season flows will be increased. A change in the natural wet/dry cycle of stream flow is to be avoided for several reasons. First, as detailed above, a substantial proportion of the fish species found in the upper Burdekin River are dry season spawners. Such a phenology allows larvae to develop in a fairly benign flow environment. Elevated baseflows will effectively decrease the recruitment success of such species, and imperil local abundance and persistence.

Alteration of the normal regimes of temporal changes in water quality associated with release of water from impoundments may impact on the resident fish populations. Seasonal variation in water temperature, for example, is substantial in the Burdekin River (Pusey *et al*. 1998). Data in Table 6 suggests that many of the summer spawning species do not rely on flooding to cue spawning, but rather reproduction is stimulated by elevated water temperatures. Releases from impoundments have the potential to depress summer water temperatures and interfere with spawning.

Elevated baseflows may encourage the spread and proliferation of exotic weeds, especially ponded pasture species such as paragrass (*Urochloa mutica*) and hymenachne (*Hymenachne amplexicaulis)*. Ordinarily the seasonal changes in hydrologic regime, particularly annual drying, prevent these weed species from establishing dense stands. These plants choke channels and deny fishes access to important feeding areas, and to bank associated structures necessary for spawning. They influence water passage, concentrating flow into a restricted area, thus reducing flow diversity and consequently habitat diversity and suitability. Aquatic grasses contribute very little to aquatic food webs (Bunn *et al.* 1997) and the senescence of their leaves often leads to smothering and deoxygenation of the streambed (Bunn *et al.* 1998).

Changes in flow regime which encourage prolific invasive weed growth of pasture grasses, and either decreases overall water velocity or increases the proportional amount of low flow habitats, will increase the suitability of stream reaches for exotic species such as *Gambusia*. This is of particular concern in the lower reaches of the Burdekin River.

The trophic ecology of the fishes of the Burdekin River is tightly governed by the flow regime. The absence of flooding, and the increase in baseflows that might occur if the channel is used as a conduit for downstream distribution, will increase the intensity of predation and competition for food resources. Pusey *et al.* (in prep) noted that predation and competition increased in intensity during a prolonged period of stable flows. Disturbance is probably necessary to maintain the diversity of fishes in this system.

Benthic algal mats (desmids and diatoms) may be an extremely important link in the food webs of the river. In a variety of subtropical Australian systems, these flora have been shown to drive much of the aquatic food web (S.E. Bunn, pers. comm.). Changes in flow regime which interfere with primary productivity are likely to have severe secondary impacts throughout the riverine ecosystem. Such changes could arise from a number of causes. First, if the proposed developments increase turbidity in the river for prolonged periods, then primary productivity will diminish. Although the Burdekin River is a naturally turbid system during the wet season, high water clarity is re-established by the early winter. Dam development, deteriorating land condition and increased agricultural development in the upper reaches of the catchment will result in greater input of fine sediment and hence increased and prolonged turbidity. Of equal importance is the relationship between discharge and bed stability. Sand and fine gravel are the dominant substrate in the Burdekin River and are thus unstable substrates for the attachment of periphyton. Elevated baseflows are likely to disrupt the establishment of stable mats and may disrupt the aquatic food web. If the entire length of the upper Burdekin is used to transport water down to Burdekin Falls Dam, disruption of the food web base may be substantial.

Aquatic vascular macrophytes and charaphytes are not only important habitat elements for aquatic fishes of the Burdekin River (Table 6), but form an important component of the diet of many species, particularly during the dry season. For example, macrophytes and algae contribute up to 65% of the dry season diet of adult rainbowfish, about 35% of the diet of sooty grunter and 80% of the diet of the endemic grunter *S. parviceps* (Pusey *et al.* in prep.). Given the unstable nature of the sandy substrate that dominates in the upper Burdekin, the extent and abundance of macrophytes and algae are sensitive to elevated baseflows. Under such conditions, the expected outcome would be reduced abundance of aquatic plants and a reduced diversity of food resources for the resident fishes. Aquatic plants may form the most abundant areas of stable attachment for periphyton and filter feeding invertebrates. In the absence of flooding (which annually strips such plants from the channel). It is reasonable to expect that macrophytes and algae may proliferate and reduce the diversity of habitats available, and reduce the diversity of fishes at the local scale, and lead to more pronounced and potentially deleterious diel changes in oxygen concentrations.

Freshwater turtles are an important component of the fauna of the upper Burdekin River and the fauna is comparatively rich (5 spp.) and distinctive (Cann 1998). The lower Burdekin contains a rare turtle, *Elseya irwini* Cann, which appears to be restricted to the lower reaches and tributary streams such as the Bowen River (Cann 1998). In other northern Australian river systems the emergence of vulnerable hatchlings is timed to coincide with benign flow conditions (Cann

1998). Elevated baseflows may be detrimental to the survival of this life history stage. Turtles nest in sand and gravel beds adjacent to the main river. If water levels fluctuate greatly during the development period and inundate such nests then the eggs cease to develop. The extent to which any of the proposed options permanently inundates nesting habitat is unknown but it is likely to be substantial given the size of the proposed dams. Most turtles have a diet dominated by plant matter and changes in flow regime which impact on aquatic macrophytes or fruiting riparian trees many impact on turtle populations.

The upstream reaches of the Running River (and probably other riparian areas) are used as daytime roosts for vast numbers of fruit bats (*Pteropus* spp.). *Melaleuca* blossoms constitute the major food sources for fruit bats during the warmer months (Pusey pers. obs.). Changes in flow regime which impact on riparian trees such as paperbarks or impoundment which floods large distances of riverbank and associated riparian vegetation are likely to impact on these species. The loss of riparian litter from the lotic environment may impact on invertebrates which use them directly as food, on fish species which use terrestrial insects emanating from the riparian zone and indirectly on fishes which feed on aquatic invertebrates.

6.3.2 Fish Stocking

(by B. Pusey and D. Burrows)

Proposals to stock sportfish species are almost universal with recent dam developments. These are often listed as environmental benefits resulting from the development. However, fish stocking, as it is currently practiced, usually has negative environmental impacts. This is particularly so where the stocked species is translocated to an area outside of its range.

A highly relevant example in the Burdekin catchment is that of sleepy cod, *Oxyeleotris lineolatus.* This species was introduced into the Valley of Lagoons in the mid-1970's and has resulted in a massive assault on the native fishes of this system. Over the period 1989-1992, abundance levels of this species were relatively stable and the site of introduction remained the area of greatest abundance (Pusey *et al.* 1998, unpublished data). However, annual sampling thereafter has revealed rapid increases in abundance occurring progressively down the river length with time, suggesting a colonising front. Sleepy cod have now also invaded almost the entire length of Star and Fanning Rivers and Keelbottom Creek (Burrows and Tait unpublished data) and undoubtedly other major tributaries. Progressive declines in the abundance of several species, notably the purple spotted gudgeon, *Mogurnda adspersa*, were correlated with the increase in sleepy cod numbers (Pusey unpub. data). Adults of the former species consume an almost identical array of prey as juvenile sleepy cod, and adult sleepy cod prey upon all age classes of *M. adspersa* (Pusey *et al.* in prep.). The causes of the range expansion and increased population sizes are unknown, but were correlated with a prolonged period of low flows. In addition to the direct impacts of sleepy cod on other fishes via predation and competition, high incidence of infection with epizootic ulcerative syndrome ("red spot disease") have been noted (up to 50% infection rates). Transmission of this disease to other fish species may have been facilitated by the spread of sleepy cod, leading to other indirect effects on fish populations not directly impacted by competition and predation.

Importantly, sleepy cod numbers have remained relatively stable in the Bowen River. It is unknown whether the populations occurring below the dam are the result of the upstream translocations or are a natural component of the fauna. Their presence in the Bowen River is significant because the habitats are generally characterised by higher water velocities. Under these conditions sleepy cod tended to be more restricted in the choice of microhabitats, none-the-less, they are still abundant. Similarly, in the upper Burdekin abundant sleepy cod are also found in the relatively uncommon higher flow habitats. Thus, any suggestions that sleepy cod numbers could be controlled by increasing flows down the main channel of the upper Burdekin (a scenario that would occur if any of the upper Burdekin development options are used to deliver water downstream to the Burdekin Falls Dam) are totally unfounded. The translocation of yellow-belly (*Macquaria ambigua*) into the upper Burdekin and Belyando-Suttor may also be having a similar effect. They have dominated the catch in some samples recently collected from the lower Belyando River where prey species were in low numbers (Burrows *et al.* 1999). Barramundi (*Lates calcarifer*) have also been stocked into the upper Burdekin, where they do not occur naturally.

Even where locally-native fish species are used, stocking densities are not based on environmentally sustainable criteria. Fish stocking needs to take into account predatory and competitive effects not only on existing fish populations, but also other aquatic fauna such as invertebrates, frogs and piscivorous birds. Where stocked fish species move from the impoundment into upstream riverine environments, this may lead to a significant increase in predation pressure and resource competition. For example, riverine environments upstream of the Broken River options contain frog species of high conservation significance. Like most frog species, they are intolerant of even low levels of fish predation. The Valley of Lagoons area is significant for its waterbirds, many of which feed upon aquatic invertebrates and small fish. Increases in populations of large predatory fish which utilise the same food resources, may impact upon the bird populations.

Where fish passage has been restricted by a dam wall, stocking will only supplement this impact if the stocking program is designed to maintain the aquatic populations in balance. All options for reinstating fish passage should be thoroughly investigated in the first instance. Any purported benefits of fish stocking for dam developments should be considered as social/recreational benefits, not environmental benefits.

Table 5. Fish species present in the Burdekin River basin, conservation status (based on Wager and Jackson 1993) and distribution. Based on data derived from Midgley (1977), Williams *et al.* (1993), NSR (1998), Pusey *et al.* (1998), Pusey unpublished data, Hogan *et al.* (1997), Hogan and Vallance (1998).

Species	Common name	CS[1]	S[2]	Distribution				Comments
				U B[3]	U T[4]	B R[5]	L B[6]	
Melanotaeniidae								
Melanotaenia splendida splendida (Peters)	Eastern Rainbowfish	NT	N	X	X	X	X	common throughout, numerically abundant, distinctive penotypes present in upper reaches and tributaries
Pseudomugilidae								
Pseudomugil signifer Kner	Pacific blue eye	NT	N			X	X	Present but not abundant
Atherinidae								
Craterocephalus stercusmuscarum stercusmuscarum (Gunther)	Fly-specked hardyhead	NT	N	X	X	X	X	locally abundant but patchily distributed
Craterocephalus marjoriae Whitley	Marjorie's Hardyhead	NT	D	X				probable misidentification, unlikely to be present
Anguillidae								
Anguilla reinhardtii Steindachner	Long-finned Eel	NT	N	X	X	X	X	marine spawner, previously widespread, presently very low abundances upstream of BFD[7]
Anguilla obscura Gunther	South Pacific Eel	NT	N				X	marine spawner, prefers wetlands and swamps, uncommon
Therapontidae								
Hephaestus fuliginosus (Macleay)	Sooty Grunter	NT	N	X	X	X	X	large predator, recreationally important,
Leiopotherapon unicolor (Gunther)	Spangled Perch	NT	N	X	X	x	X	predator, numerically abundant
Amniataba percoides Gunther	Barred Grunter	NT	N	X	X	X	X	abundant
Scortum parviceps (Macleay)	Small-headed Grunter	R	N	X	X	?	?	endemic, important herbivore
Bidyanus bidyanus (Mitchell)	Silver Perch	PT	T	?				translocated into Valley of Lagoons, unknown if still present
Plotosidae								
Neosilurus ater (Perugia)	Black catfish	NT	N	X	X	X	X	common throughout
Neosiluris hyrtlii Steindachner	Hyrtl's Tandan	NT	N	X	X	X	X	common but predominantly in upper reaches
N. mollespiculum Allen and Feinberg	Soft-spined catfish	R	N	X	X	X	?	endemic
Porochilus rendahli (Whitley)	Rendahl's Tandan	NT	N	X	X			patchily distributed and uncommon
Tandanus tandanus Mitchell	Freshwater catfish	NT	T	X				translocated into Valley of Lagoons
Gobiidae								
Mogurnda adspersa (Castelnau)	Purple-spotted Gudgeon	E	N	X	X	X	?	Murray-Darling stocks endangered, currently in decline in Burdekin due to translocated Sleepy Cod
Hypseleotris compressa (Krefft)	Empire Gudgeon	NT	N	X	X		?	usually restricted to coastal reaches, may represent evolutionary significant unit (ie. restricted genetic stock)
Hypseleotris sp. A	Midgley's Gudgeon	NT	N	?	X			
Hypseleotris galii (Ogilby)	Fire-tailed Gudgeon	NT	D	?	?	?	?	listed in NSR (1998) but probable misidentification
Phylipnodon grandiceps (Krefft)	Flathead Gudgeon	NT	T	X				probable inadvertent translocation, restricted to Valley of Lagoons

Oxyeleotris lineolatus (Steindachner)	Sleepy Cod	NT	T	X	X	X	X	Translocated into Valley of Lagoons in 1976, now widespread, unkown whether downstream populations natural
Glossogobius giurus (Hamilton)	Flateheaded Goby	NT	N				X	Marine spawner
Glossogobius sp	Goby						X	Marine spawner
Ariidae								
Arius graeffei Kner & Steindachner	Lesser Salmon Catfish	NT	N			x	X	
Clupeidae								
Nematolosa erebi (Gunther)	Bony bream	NT	N	X	X	X	X	Widespread detritivore, dominates biomass
Chandidae								
Ambassis agassizi Steindachner	Glass perchlet	NT	N	X	X	X	?	widespread but not abundant, dependent on aquatic macrophytes
Toxotidae								
Toxotes chatareus (Hamilton)	Archer Fish	NT	N	X	X	X	X	reliant on riparian vegetation, juveniles common in tributaries
Hemiramphidae								
Arramphus sclerolepis (Gunther)	Snub-nosed Gar	NT	N			X	X	estuarine spawner?
Belonidae								
Strongylura kreffti Gunther	Long Tom	NT	N			X	X	estuarine spawner
Scorpaenidae								
Notesthes robusta (Gunther)	Bullrout	NT	N			X	X	estuarine spawner
Megalopidae								
Megalops cyprinoides (Broussonet)	Tarpon	NT	N			X	X	estuarine spawner
Centropomidae								
Lates calcarifer (Bloch)	Barramundi	NT	N			X	X	estuarine spawner
Percichthyidae								
Macquaria ambigua (Richardson)	Yellowbelly	NT	T	X	X			common in BFD and colonising upstream
Maccullochella peeli (Mitchell)	Murray Cod	NT	T	?				translocated into Valley of Lagoons, unlikely to be still present
Apogonidae								
Glossamia aprion (Richardson)	Mouth Almighty	NT	N			X	X	reliant on woody debris and macrophytes for cover
Poeciliidae								
Gambusia holbrooki (Baird and Girard)	Gambusia		E				X	problematic pest species favoured by low flow, weed invasion and provision of marginal habitat

1. CS = conservation status: NT = non threatened; PT = potentially threatened; R = restricted; E = endangered
2. S = distribution status: N = native; T = translocated; E = exotic, D = doubtful (probable misidentification).
3. UB = Burdekin drainage above Burdekin Falls
4. UT = tributary streams of upper Burdekin River
5. BR = Bowen River.
6. LB = Burdekin River below confluence with Bowen River
7. BFD = Burdekin Falls Dam

? = unknown if present but potentially so.

Table 6. Characteristics of the reproductive biology of the major fish species in the Burdekin River and their relationship to the flow regime. Information sourced from Merrick and Schmida (1984), Stuart (1997), Pusey *et al.* (in prep.), Pusey unpublished data.

Species	Reproductive style	Phenology	Habitat requirements	Movement	Larval habitat	Flow dependency	Comments
Melanotaeniidae							
Melanotaenia splendida splendida (Peters)	Oviparous, batch spawner	year round with greatest effort during wet season	requires macrophytes and bank associated structures for oviposition	unknown but some populations known to be phenotypically distinct, inferring little gene flow whilst lowland populations probably use floodplains	requires very low flow environments during development prior to metamorphosis	lowland populations probably dependent on flooding	prolonged high flows likely to be detrimental in upstream reaches, isolation of banks by low flows likely to be detrimental, loss of macrophytes due to high flows also likely to be detrimental
Pseudomugilidae							
Pseudomugil signifer Kner	Oviparous	unkown phenology in Burdekin system, elsewhere spawning associated with stable low flows	requires macrophytes and small woody debris for oviposition	probably limited, implications for recolonisation of impacted reaches	requires low flow environments during development	unknown in the Burdekin but unlikely to be favoured by changes in flow	prolonged high flows likely to be detrimental if occurring during major spawning period, isolation of banks by low flows likely to be detrimental, loss of macrophytes due to high flows also likely to be detrimental
Atherinidae							
Craterocephalus stercusmuscarum stercusmuscarum (Gunther)	Oviparous	unkown phenology in Burdekin system, elsewhere spawning associated with stable low flows	requires macrophytes and small woody debris for oviposition	Probably limited, implications for recolonisation of impacted reaches	requires low flow environments during development	unknown in the Burdekin but unlikely to be favoured by changes in flow	prolonged high flows likely to be detrimental if occurring during major spawning period, isolation of banks by low flows likely to be detrimental, loss of macrophytes due to high flows also likely to be detrimental
Anguillidae							
Anguilla reinhardtii Steindachner	Oviparous	migrate seaward during high flow events	spawns at sea, recently metamorphosed larvae migrate upstream	Both adult and juveniles make extensive movements	unkown, juveniles require coarse substrate high flow habitats	high flows required for downstream passage of adults, juveniles probably require high outflows in order to orient to rivers	high flows likely to be critical at several life history stages.
Therapontidae							
Hephaestus fuliginosus (Macleay)	Oviparous, limnophilic	wet season	require flowing water and gravel/cobble substrates, observations from elsewhere suggest that spawning occurs in low flow habitats adjacent to high flow habitats	upstream and downstream migrations to areas of suitable habitat, including tributaries	larvae remain in natal habitat, juveniles utilise moderate flows	will spawn during summer in the absence of floods, flooding not essential for stimulation of spawning	although capable of spawning in low flow periods low survival of larvae results, survivorship and recruitment much higher during floods. Highly susceptible to recruitment failure if water levels fluctuate greatly during spawning period

Leiopotherapon unicolor (Gunther)	Oviparous, limnophilic broadcast spawners	wet season	will spawn over sand and fine gravel	upstream migrations made by juveniles and subadults	as above	as above	as above
Amniataba percoides Gunther	as above	dry season	as above	as above	as above	spawning asyncronous wiith that of other therapontids, possiblye to avoid competition between larvae.	elevated flows during dry season lokely to be detrimental to recruitment
Scortum parviceps (Macleay)	Oviparous, broadcast spawner	wet season	proably similar to therapontid species above	Unkown	Unknown	Unkown	Unknown
Plotosidae							
Neosilurus ater (Perugia)	Oviparous, broadcast spawner	wet season	tributaries and high flow environments	makes mass upstream movements during high flow events	larvae and juveniles closely associated with instream cover	apparently requires flooding to stimulate movement and spawning	appears highly dependent on access to tributaries and flooding
Neosilurus hyrtlii Steindachner	as above	as above	as above	as above	as above	as above	as above
Nelsilurus mollespiculum Allen and Feinberg	as above	detalis probably very similar to other *Neosilurus* spp.					
Porochilus rendahli (Whitley)	as above	details unknown but probably similar to *Neosilurus* spp.					
Gobiidae							
Mogurnda adspersa (Castelnau)	Oviparous batch spawner, some parental care	dry season	requires bank associated structures for nesting	little movement recorded	low flow environments with abundant cover	elsewhere larval mortality correlated with high flows	Changes in flow which isolate banks or cause prolonged flow elevation likely to impact on recruitemnt and long-term survival
Hypseleotris compressa (Krefft)	Oviparous batch spawners, limited parental care	warmer months	requires bank associated structures for nesting	larvae are negatively geotactic shortly after hatching and are passively transported downstream to low flow or estuarine environments, upstream movement by vast numbers often observed	low flow habitats for upstream populations, estuarine habitats for lowland populations	unknown but spawning more likely to be stimulated by rising water temperatures than flooding	upstream movements likely to be comprised by unseasonal high flows
Hypseleotris sp. A	Oviparous	unkown but likely to be similar to other species in this genus within spawning phenology varying from region to region	as above	Unknown in Burdekin, spring movements upstream observed in Fitzroy River	Unkown	unknown but likely similar to above	

Oxyeleotris lineolatus (Steindachner)	Oviparous, nester, limited parental care, highly fecund	warmer months, prolonged	woody debris and bank associated structures	juveniles disperse from the natal habitat. Upstream movements by adults during warmer months observed in the Fitzroy River	as for spawning habitat, but very closely associated with cover	reproduction not flow dependent but cued by rising water temperatures	apparently favoured by low flows but often recorded from high flow environments containing cover. Although generally sluggish, capable of rapid swimming.
Glossogobius giurus (Hamilton)	Details unknown	breeding associated with warmer months and increased dlows	probably breeds in freshwater but larval development probably occurs at sea	likley that larvae require passive dispersal to estuarine or marine environments and juveniles make return upstream migration	Unknown	reproduction poorly documented but elsewhere breeding is known to be protracted and limited to the monoonal season	high flows probably required for dispersal of larvae and low flows required for return migration
Ariidae							
Arius graeffei Kner & Steindachner	Oviparous, mouth brooder	summer	breeds in freshwater	migrates upstream to spawn, other movements unrelated to reproduction also occur	Unknown	spawning not associated with flooding *per se* but elevated temperatures	
Clupeidae							
Nematolosa erebi (Gunther)	Oviparous broadcast spawner, protracted spawning period	throughout the warmer months but predominantly in wet season	breeds in freshwater over sand gravel beds	unkown but may make substantial movements. Upstream movement through fishway recorded throughout the year in the Fitzroy River	larvae probably pelagic and vulnerable to high flows, Juveniles occur in riffles and runs	Reproduction not directly related to flooding although recruitment enhanced following flooding, adult mortality high during large floods	changes in flow which interfere with detrital deposition and benthic algal growth likely to impact on adult populations. Juveniles are carnivorous and loss of high flows likely to reduce secondary production and impact on recruitment
Chandidae							
Ambassis agassizi Steindachner	Oviparous batch spawners	spring	highly dependent on aquatic macrophytes	limited although observed to recolonise newly inundated reaches	restricted to low flow environments in vicinity of natal habitat	spawning restricted to low flow periods	artificial elevation of flows during dry season likely to impact on recruitment as is changes in flow regime which deleteriously impact on macrophytes
Toxotidae							
Toxotes chatareus (Hamilton)	Oviparous	late dry early wet season	unknown	unknown	unknown	reproduction apparently timed to take advantage of expanded habitat during wet season	
Hemiramphidae							
Arramphus sclerolepis (Gunther)	Oviparous	late dry season	apparently capable of reproducing in freshwater	unkown	Unknown	reproduction cued by temperature not changes in flow	reported to be herbivorous and changes in flow regime which impact on macrophytes likely to secondarily impact on this species

Belonidae							
Strongylura kreffti Gunther	Oviparous	unknown	may spawn in freshwater but more likely to occur in estuarine areas	unknown but likely to involve downstream movements by adults for spawning, upstream movements during January recorded in the Fitzroy	unknown	Unknown	barriers to movement likely to impact on populations
Scorpaenidae							
Notesthes robusta (Gunther)	Probably oviparous but other scorpaenids ovoviviparous	winter	seasonally migrate to estuarine eras to breed	downstream movements in winter, upstream movements recorded from july to November in the Fitzroy River	unknown but juveniles prefer riffles and runs with a coarse substrate	movement made under a variety of flow conditions	barriers to movement likley to impact on this species
Megalopidae							
Megalops cyprinoides (Broussonet)	Oviparous broadcast spawner	wet season	seasonal migrates to estuarine and marine areas to breed	thought to be catadromous with adults and juvenile making upstream movements during autumn	unknown	larvae poor swimmers	barriers to movement are likely to seriously impact on thi s species
Centropomidae							
Lates calcarifer (Bloch)	Protrandrous hermaphrodite, oviparous	prolonged spawning season over the wet season	estuarine areas needed for spawning	catadromous, seasonally migrates to estuarine and near shore areas to spawn	juveniles migrate to floodplain habitats and upstream to mature	need high flows to link adult and juvenile habitat and flooding of off channel habitats	barriers to movement will impact on barramundi population as will reduced frequency, duration and magnitude of flooding and changes in flow which impact on estuarine productivity
Apogonidae							
Glossamia aprion (Richardson)	Oviparous mouth brooder	prolonged	abundant macrophytes	unknown	abundant cover	unknown	
Poeciliidae							
Gambusia holbrooki (Baird and Girard)	Viviparous	continuous	low flow habitats, adjacent marginal habitat		low flow habitats		fluctuating water levels which create isolated marginal habitats favour this species, changes in flow which encourage invasive pasture grasses also favour this species

7.0 ASSESSMENT OF ENVIRONMENTAL ISSUES

7.1 Upper Burdekin Sub-Catchment

The four options under consideration in this sub-catchment all have relatively large inundation areas and similar vegetation and habitat composition, being dominated by eucalypt woodlands on river levees and terraces, or on small hills. Along the main river and creek channels, the riparian melaleuca communities and woodlands on alluvial soils dominate. Most of these riverine/alluvial-associated communities are considered to be regional ecosystems ‘of concern’. In the surrounding hills, there may be limited occurrences of other regional ecosystems listed as being ‘of concern’. These include vine thickets and stony hill habitats. Such habitats are of conservation significance for vegetation and fauna. The brief field visit was not able to provide a map of the distribution and occurrence of these smaller features.

For each of the four sites, three different storage levels were evaluated. The maximum storage volume of the Greenvale option is less than half that of the maximum storage available at the other three sites. The large options at Mt. Fullstop, Hells Gates and Mt. Foxton may take several years to fill, even longer under low rainfall conditions and, in conjunction with the Burdekin Falls Dam, may impact on flood flows and sediment transport processes to the coastal areas. Suitable sites for irrigation are limited by the undulating topography of the area except in close proximity to the Burdekin River channel. Suitable alluvial soils have been located along the Burdekin River channel downstream of the Star River junction and suitable basalt soils have been found in the Hillgrove/Fletcherview area north of the basalt wall. A considerable proportion of the alluvial soils are flood prone and much of the basalt soils are either more than 60m above the river level or very stony, making them a poor economical option. Though a significant amount of economically viable suitable soil remains, the amount of available water greatly exceeds the amount required for irrigation, or other potential developments currently identified for this sub-catchment.

A large storage in this sub-catchment may be used to supply water for future irrigation development on the coastal plains (ie, Elliot Main Channel), coastal aquaculture and urban/industrial development in Townsville. This will have a greater environmental impact on instream processes than accessing this water from the Burdekin Falls Dam, even if that storage needs enlarging. Firstly, the development of a larger upstream storage to accommodate the extra water required would have a greater impact on flooding frequency in the upper catchment than a similar-sized impoundment further downstream would on the river below it. Releasing the water downstream to the Burdekin Falls Dam would utilise the Burdekin River as an irrigation channel for delivery of water and thus alter the flow regimes present over a great length of currently unregulated river. An upstream storage that only supplies water to irrigation development within its sub-catchment will have a lesser impact on flow regimes downstream of that irrigation area. In this case, the distance between the potential upper Burdekin irrigation area and the Burdekin Falls Dam is over 200km. Water for use on the coastal plains should be sourced from the Burdekin Falls Dam, not an upper Burdekin storage.

Of prime importance for any dam site in the upper Burdekin, is the limnology of the impoundment, especially whether the water will remain turbid or whether it will clear to any great extent. It has already been discussed (section 2.2) how the construction of the existing Burdekin Falls Dam has persistently reduced the clarity of the lower Burdekin River. The upper Burdekin River usually runs clear shortly after the end of the wet season. Any impoundment that would trap the turbid wet season water and release it to downstream users throughout the dry season before it is able to settle within the impoundment, will greatly reduce the clarity of the upper Burdekin River. Water quality data associated with flow events from the DNR gauging station at Mt. Fullstop were examined during the preparation of this report. This confirms the relationship between flow and turbidity, however, due to the numerous gaps in the data, and the poor replication of sampling over the course of the hydrograph, more detailed interpretations cannot be made. The best available dataset is that of John Faithful (ACTFR) who studied the limnology of the Burdekin Falls Dam from 1988-1996. He found that during flood events, the upper Burdekin will supply large quantities of suspended sediment to the dam, including material of sufficient fineness to remain in suspension. In all the years since its construction in 1987, the dam has remained turbid throughout the year, except for 1991 where it briefly cleared during the dry season. This clearing was associated with two situations. The first was minimal inflow from the permanently turbid Belyando-Suttor sub-catchment and the second was an extended elevated inflow of the hydrograph tail from the upper Burdekin. This water had presumably come from sub-surface baseflows as it was clear and had higher conductivity, which promotes sediment flocculation. The conductivity of the Burdekin Falls Dam at this time was around 450us/cm. It is not expected that an upper Burdekin dam would become as turbid as the Burdekin Falls Dam, only that the existing water clarity may be reduced. The extent of the reduction would be variable between years and can only be predicted by specific studies into this issue. Reduced water clarity in the upper Burdekin would thus also further reduce the limited potential for the existing Burdekin Falls Dam to clear to any degree.

Any dam in the upper Burdekin is likely to be variable in its limnological performance depending on the weather and water delivery pattern. During storm events, flows with high suspended solids will always occur and the dam will be turbid. Factors such as the extent of ground cover at the time of the storm event, will affect sediment run-off. If, as normally occurs, significant sub-surface baseflows follow the flood, then the water should clear. This sub-surface water has a greater clarity and a higher conductivity, which promotes flocculation and improved clarity. Situations where baseflows are limited or where the suspended sediment is very fine and does not settle, will tend towards retention of turbid conditions. Deteriorating land condition of the upper Burdekin would promote increased loss of fine sediment, which will further increase the chances of more persistent turbidity conditions prevailing. In addition to these processes, wind is also a strong factor affecting turbidity. All of the dam options in the upper Burdekin also have relatively large surface areas and extensive shallow areas. Such conditions are also present in the existing Burdekin Falls Dam and allow fine suspended particles to remain in suspension as the windy conditions stir up the water and bottom sediment.

The current erosion state and potential of the upper Burdekin has not been mapped but would be useful in planning considerations such as for dam development. From aerial observations along the river channels and adjacent habitats, there appears to be extensive and severe erosion on the banks of the Burdekin River in the vicinity of Mt. Foxton and also in the tributary creeks of the Hells Gates and Mt. Fullstop sites. There are also badly eroding small tributaries that enter into the Greenvale option. Being the most downstream site, Mt. Foxton captures a greater area of eroding landscapes than the other sites. At the other end, the Greenvale site captures a significantly reduced area of eroding landscape, and has permanent groundwater inflow which should aid in improving clarity. A related issue worthy of consideration is the potential benefits of flooding an area of land that would otherwise contribute a significant sediment load to the Burdekin River. This question is probably of most relevance to the Mt. Foxton site where erosion of the massive Burdekin River banks and nearby tributaries is extensive and severe. If permanently flooded, this eroding land will not contribute further to instream sediment loads. Current CSIRO research projects are examining the sources and extent of sediment erosion in the upper Burdekin and should contribute to further evaluation of the complex but extremely important sediment/turbidity issues.

Essentially the limnological performance of any dam in the upper Burdekin is uncertain. There is however, a real risk that the clarity of the Burdekin River downstream of any of the dam sites will be reduced, and that the reduced clarity will be maintained for longer periods than at present. Due to a lack of suitable data, the likelihood and extent of this risk cannot be accurately evaluated. It would however, appear likely that a dam at the Greenvale site would have a lesser probability of turbidity issues being prevalent. This is due to the lesser area of eroding land that it captures, the higher proportion of groundwater inflow and the smaller storage compared to the volume of clear waters that emanate from tributaries downstream of this site. Smaller storages at the other sites would also have less chances with greater spill frequency should trap less of the turbid wet season flows and a greater proportion of the clearer baseflows. The conversion of an essentially clear water system to one of turbid conditions would have a very significant and far-reaching effect on the ecology of the riverine ecosystems and instream processes.

7.1.1 Greenvale

The Greenvale option at AMTD 552km is a long way up the river and would regulate the greatest length of river of any of the options being considered in this study (Table 1). At the highest storage level, this option would impinge on the lower edges of the Valley of Lagoons area and Reedy Brook Creek (Figure 1). The Valley of Lagoons area is significant for its permanent wetlands, cultural values and biological values. It is listed on the Register of the National Estate and included in the Directory of Important Wetlands in Australia (ANCA 1996). This region of the river also has the highest fish diversity and more significant habitat values than most other locations in the catchment. As discussed in section 6, the Valley of Lagoons area serves as a source of fish colonists for other reaches of the upper Burdekin after impacts such as drought, but a dam, especially with a low spill frequency, would limit this benefit. Baseflows in this section of the river are more stable and permanent than elsewhere and include significant flow from groundwater springs. The fauna assemblages there are adapted to a more stable river flow than other parts of the catchment and may be more affected by altered riverflow patterns. Although the vegetation communities of the Greenvale site are generally similar to the other upper Burdekin sites, the habitats at this site are in better condition (less weeds, erosion etc.) and are considered to have greater general values. The smallest option at this site inundates less area of land than any of other options in the upper Burdekin for the same storage capacity (Table 1). The larger options however, inundate similar land area for similar storage capacities, as the other upper Burdekin options.

Although having the smallest storage capacities of the upper Burdekin options, due to its upstream location, this site has the lowest ratio of yield over storage volume of the upper Burdekin options, and should spill less frequently. Despite this, its location high in the catchment means that lesser environmental flow releases should be required, as downstream tributaries will not be captured. It should also have less impact on downstream flood flows (eg, to coastal environments). Due to a much lower yield than the other options, this impoundment will be able to irrigate a considerably reduced area of land (from 22,790-30,510 ha cf. to 35,000 ha for the other upper Burdekin options), though this is still much more than the currently identified requirements. As discussed in the previous section, due to better land condition and persistent groundwater baseflows, and despite lesser spill frequency, it is postulated that the options at this site would have a greater chance of providing higher clarity water than the other upper Burdekin sites.

Access to the Greenvale site is relatively simple. The proposed dam wall is only ~4km by dirt track from Greenvale homestead, which is about 12km from the Gregory Developmental Road.

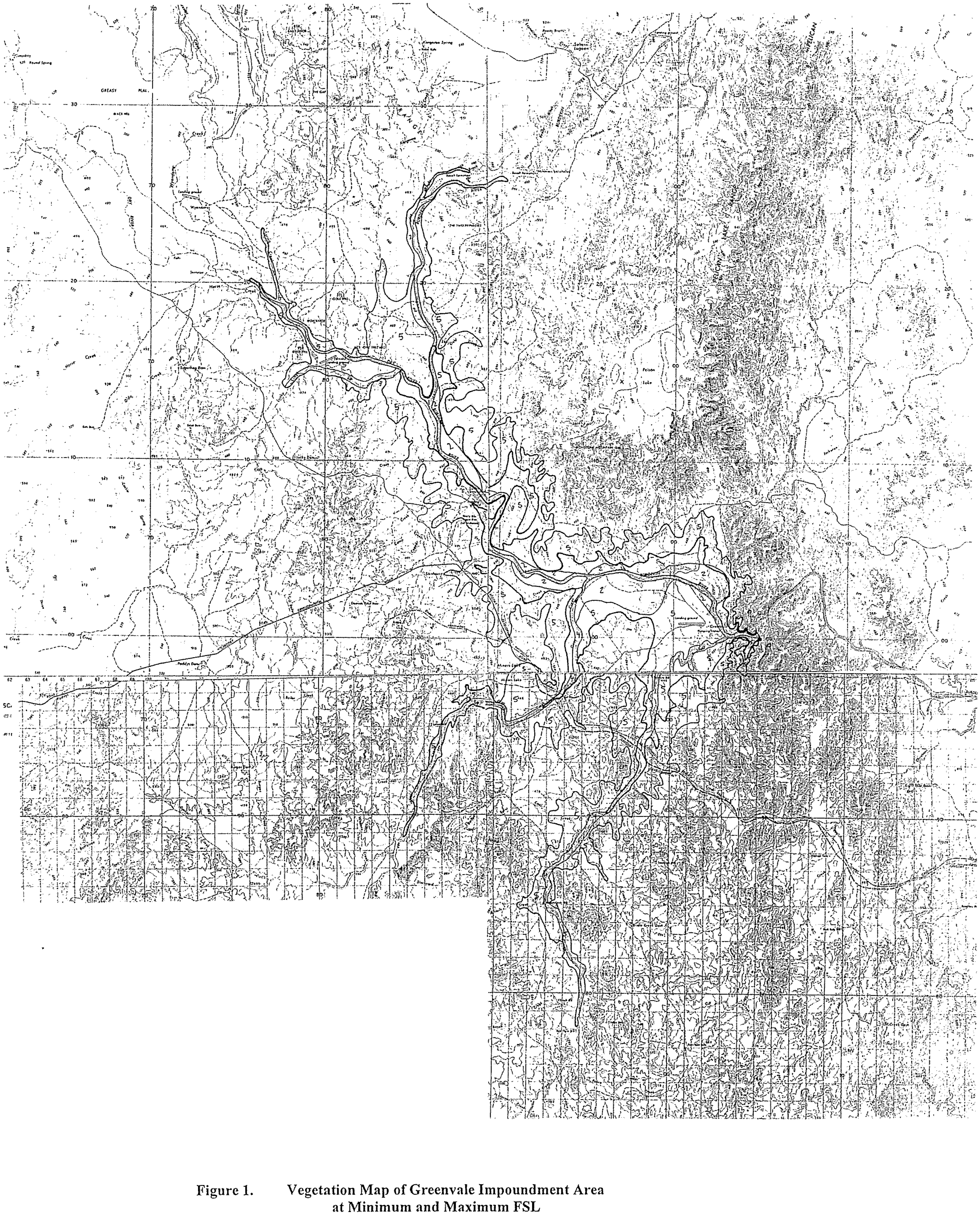


Figure 1. **Vegetation Map of Greenvale Impoundment Area at Minimum and Maximum FSL**
(refer to Appendix B for vegetation unit descriptions)

Photo 1 – Burdekin River (hidden by trees) at proposed Greenvale dam site

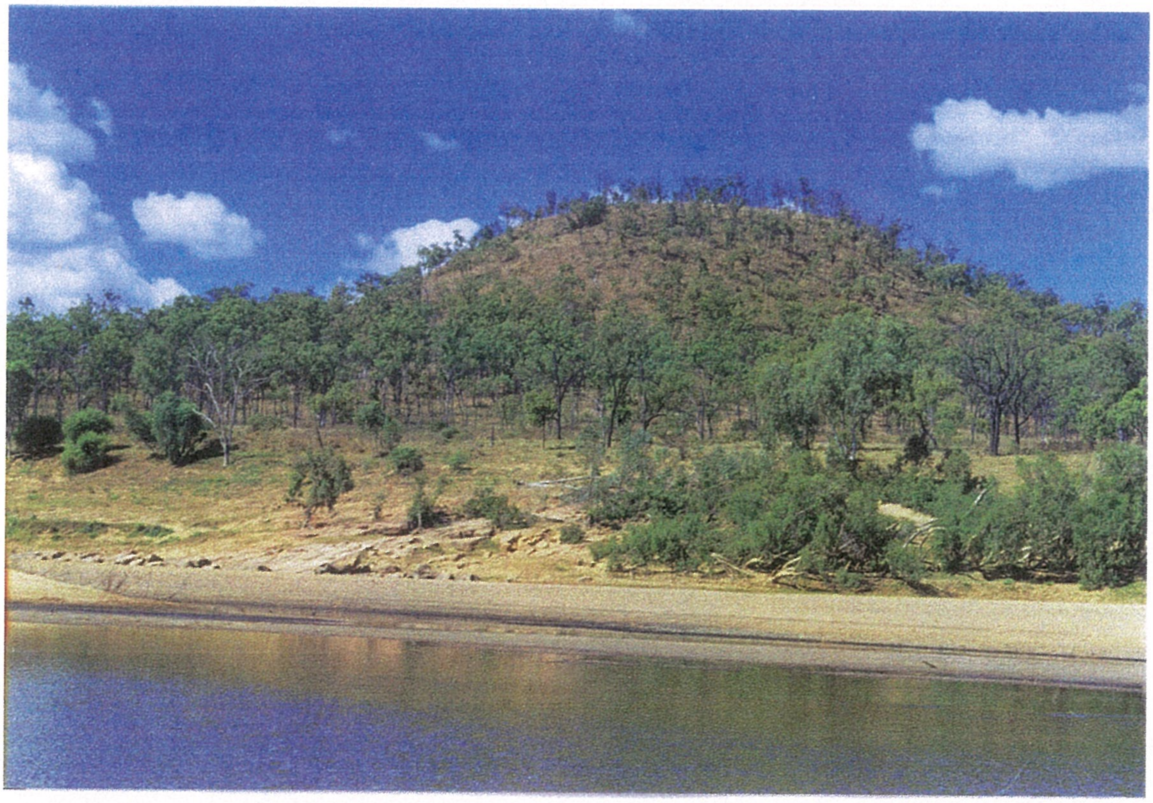


Photo 2 – Burdekin River at proposed Mt. Foxton dam site

7.1.2 Mt. Fullstop

This option (at AMTD 483km) is very similar to the nearby Hells Gates option. Both have similar capacities, similar effects on the length of river inundated and regulated, and both have similar vegetation communities and faunal habitats present. The Mt. Fullstop option will inundate a similar area of land (~10,00ha) to the Hells Gates option when both are considered at their lowest FSL's of 365m, but a much lesser area of land than the Hells Gates option when considered at the highest FSL's of 385/389m (24,400 cf. 40,500 ha) (Table 1 and Figure 2). Because of its similar location but smaller storage capacity compared to Hells Gates, this option will spill more frequently, although the differences are minor when both options are considered at maximum size. In conjunction with other dams in the catchment, the larger options at this site may have a measurable effect on flood flows and sediment transport to the coastal zone and estuarine habitats, and for coastal/marine fisheries which depend on downstream transport of nutrients.

Several of the tributaries captured by this site and Hells Gates (eg, Camel Creek and Redbank Creek) are badly eroded and may be major suppliers of sediment to the Burdekin River. This may promote turbid conditions within these impoundments and affect the clarity of water delivered downstream. As discussed throughout this report, this issue is of prime importance for the upper Burdekin sites.

There is currently no access to the impoundment wall at this site, though an existing dirt track does come close. The site is however, only 5-6km from the Gregory Developmental Road.

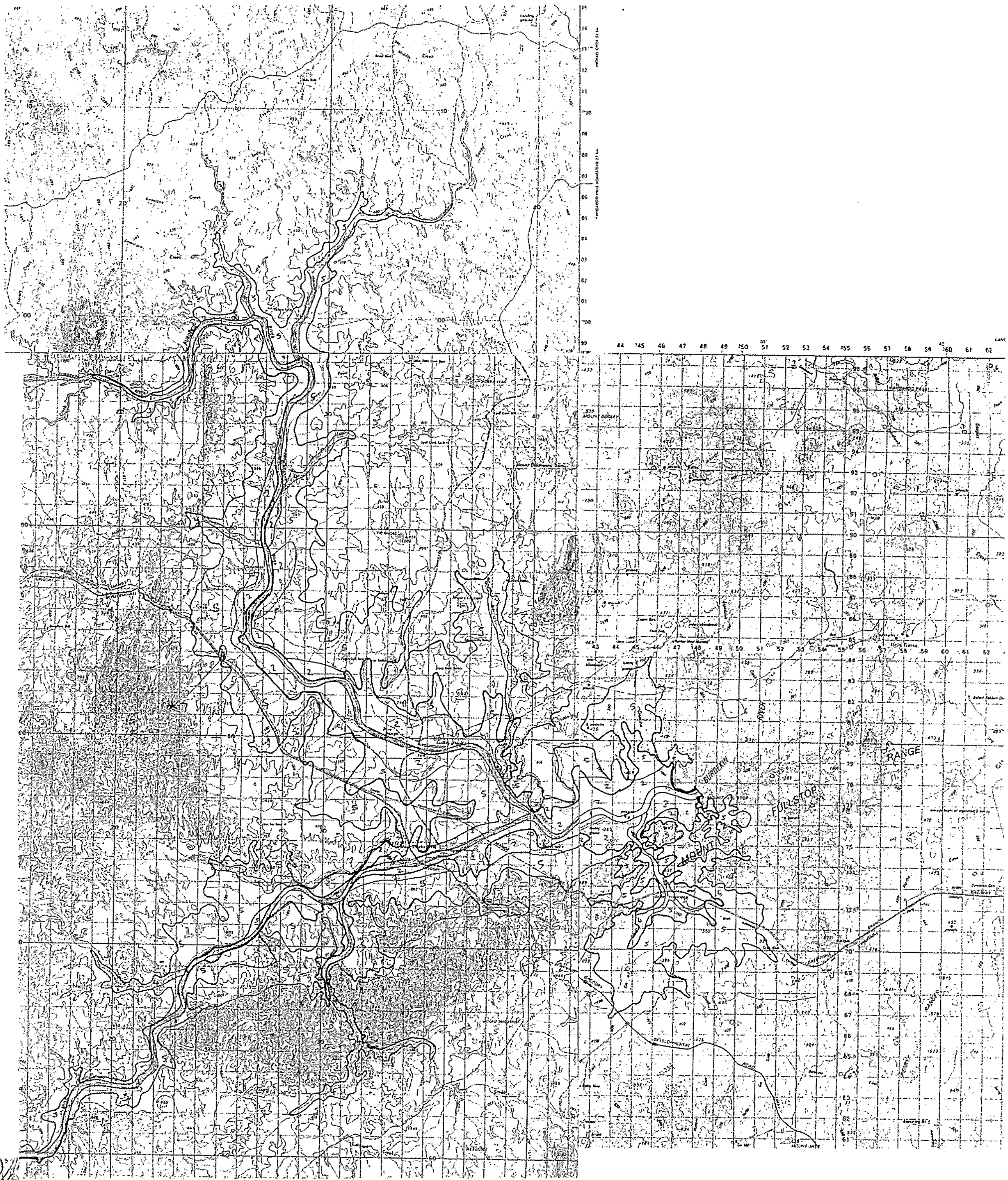
7.1.3 Hells Gates

At AMTD 466km, Hells Gates is only 17km downstream of Mt. Fullstop. It has a larger storage capacity and will spill less frequently than the Mt. Fullstop option, though this difference is not apparent at the maximum FSL. In conjunction with other dams in the catchment, the larger options at this site may have a measurable effect on flood flows and sediment transport to the coastal zone and estuarine habitats, and for coastal/marine fisheries. Apart from the lowest FSL of 365m, this option will inundate a greater area of land than the Mt. Fullstop option (Table 1 and Figure 3). The vegetation and faunal habitat values are similar for the two sites, as are the downstream impacts (the reduced spill frequency and greater capacity of this option not withstanding). At the lowest option, Hells Gates will have a greater yield, but at the highest FSL, the yield is almost the same (Table 1). There are no major creeks entering Hells Gates that do not enter Mt. Fullstop and the area is no more remote. There is currently no access to the proposed impoundment wall location, which is 20km in a direct line over the Fullstop Range from the Gregory Developmental Road.

Although the two sites are very similar, due to a smaller inundation area, reduced capacity (unless at maximum FSL), lower yield/greater spill frequency, and better access, on environmental grounds, the Mt. Fullstop site is preferred to the Hells Gates site at this level of investigation.

7.1.4 Mt. Foxton

At 437.9km AMTD, this option is 29km downstream of Hells Gates. However, over this distance, three major watercourses enter the Burdekin River that greatly increase the discharge at this point. These are Douglas Creek, Oaky Creek and Running River. Douglas Creek is a large ephemeral creek. No flow data are available for this creek, but its morphology (steep, high



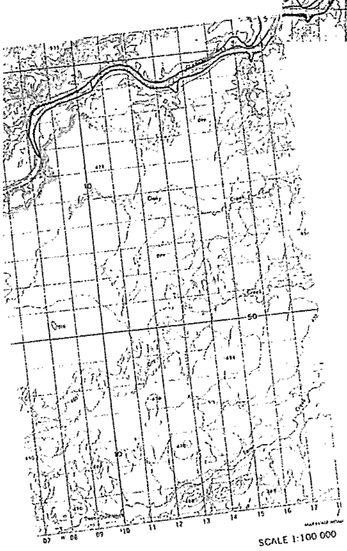


Figure 2. **Vegetation Map of Mt. Fullstop Impoundment Area at Minimum and Maximum FSL**
(refer to Appendix B for vegetation unit descriptions)

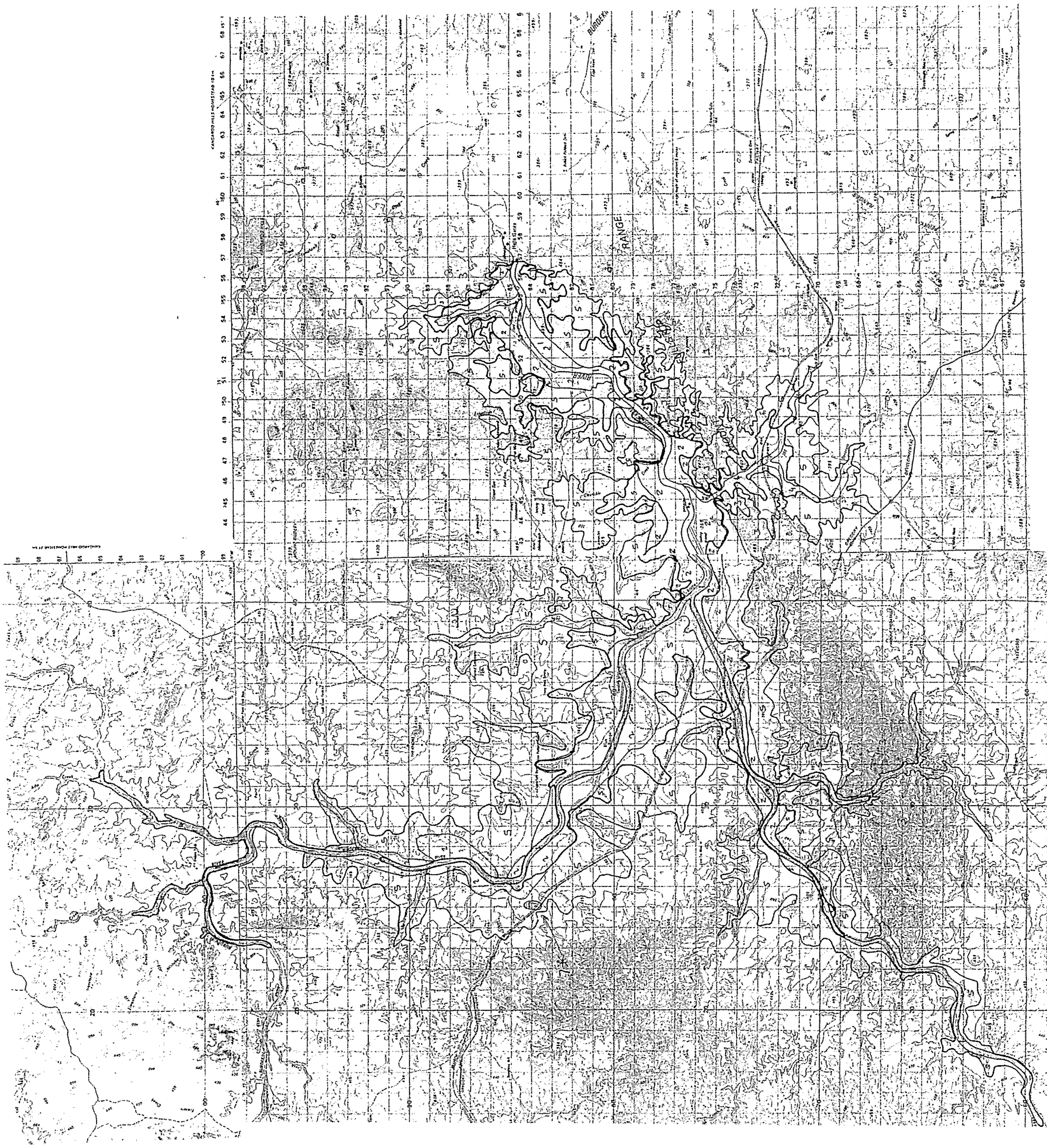


Figure 3. Vegetation Map of Hells Gates Impoundmenta Area at Minimum and Maximum FSL
(refer to Appendix B for vegetation unit descriptions)

Photo 3 – Typical river bank in the upper Burdekin. Note *Melaleuca fluviatilis* along the riverbank and eucalypt woodland on the outer terraces.

Photo 4 – Typical picture of the upper Burdekin River near Mt. Foxton

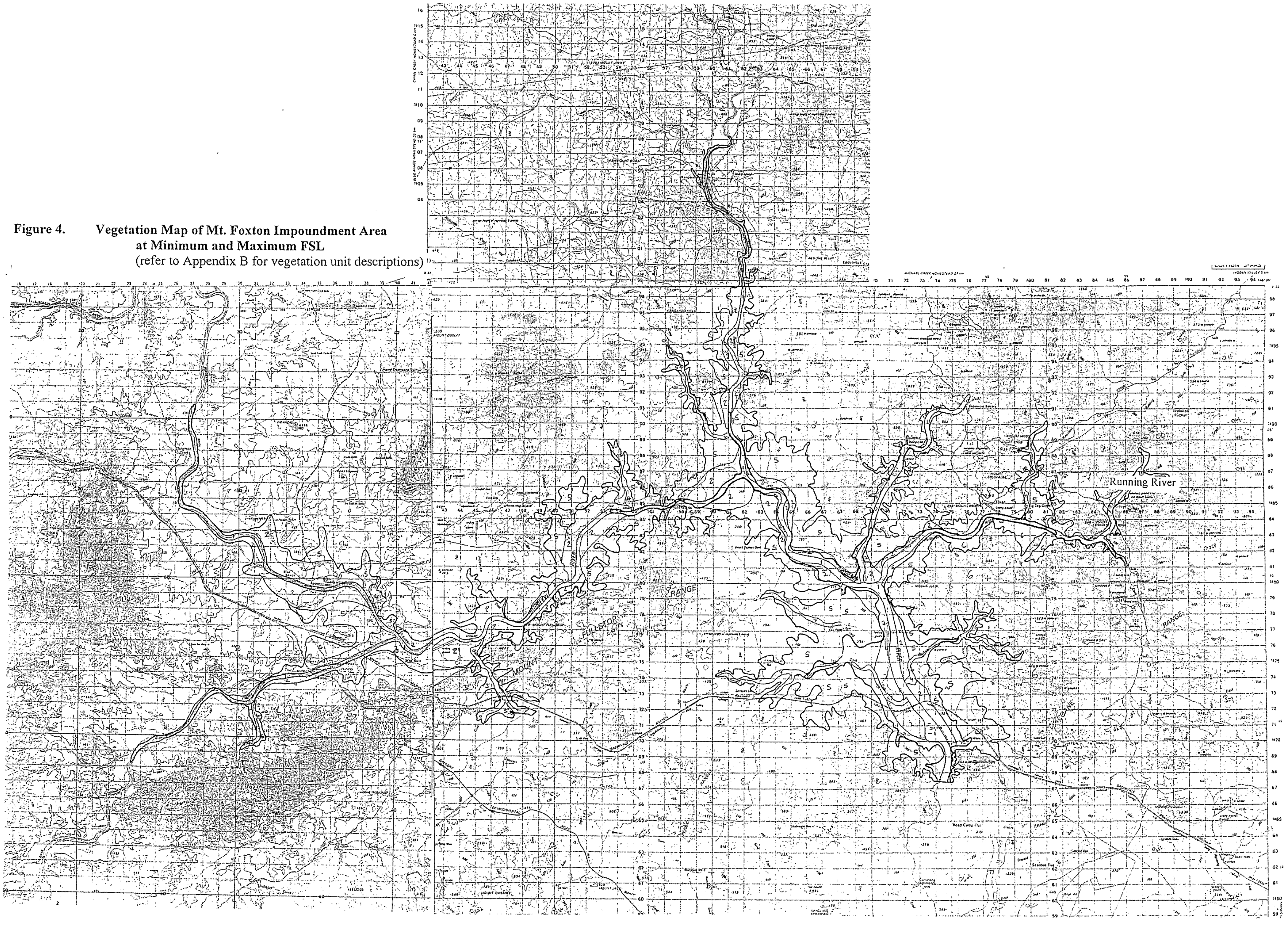


Figure 4. **Vegetation Map of Mt. Foxton Impoundment Area at Minimum and Maximum FSL**
(refer to Appendix B for vegetation unit descriptions)

banks) suggests that powerful wet season flushes do occur. Its catchment includes the high rainfall Mt. Fox area behind Ingham. Oaky Creek is also quite large but even more ephemeral than Douglas Creek. Running River drains the rainforest-covered Paluma Range and already supports the Paluma Dam (11,800 ML storage capacity) on one of its upstream tributaries. Running River does not flow all year in every year but is reasonably permanent and contains numerous waterholes and long stretches of permanent water. It thus has very high aquatic habitat values. At maximum FSL of 364m, it is estimated that this option would inundate Douglas Creek to upstream of the Kangaroo Hills homestead, Oaky Creek to Endeavour Battery and Running River to the base of the Running River Falls (Figure 4). Running River Falls is a major geological structure in the area that provides spectacular visual amenity and has high environmental values. The falls have acted as a natural fish passage barrier for millions of years, thus isolating the fish populations that are present above them. The race of eastern rainbowfish found above the falls have been recognised as being phenotypically distinct from specimens collected below the falls. Other distinct, isolated populations may also be found above the falls.

Due to its provision of permanent waterholes, Running River is a very valuable aquatic habitat in this reach of the Burdekin River. This option would reduce within basin movement of fish between Running River and other similar tributaries downstream, such as the Star River and Keelbottom Creek. The extent and significance of any within-basin fish movements is not known but may be significant for many fish species.

There is extensive and severe erosion in the section of the Burdekin River and its tributaries just upstream of Mt. Foxton. This area would be inundated by the impoundment which may reduce overall river erosion to some extent. The contribution of erosion from this area to river sediment loads, and therefore the extent of possible benefits of inundating this area are not known, but are worthwhile areas of research in relation to future water infrastructure development within the upper Burdekin. The possible benefits of flooding eroding land would have to be weighted against the fact that a more downstream storage such as Mt. Foxton would capture a greater sediment load from upstream eroding areas that are not inundated by the impoundment. The whole issue is extremely complex.

Due to the presence of several river arms, the Mt. Foxton option inundates a relatively large area at the lowest FSL (335m) compared to the other sites. However, at the highest FSL (364m), it inundates less area than the other sites, for the largest yield of any upper Burdekin site. This is due to its more downstream location and larger inflow from a greater number of tributary creeks. These same features ensure that a Mt. Foxton dam would have a greater spill frequency than the other upper Burdekin sites for any of the given yields in Table 1. In conjunction with other dams in the catchment, the larger options at this site may have a measurable effect on flood flows and sediment transport to the coastal zone and estuarine habitats, and for coastal/marine fisheries.

Mt. Foxton is readily reached, being approximately 15km by a good dirt road from Herveys Range Developmental Road. The site also has very good proximity to Townsville, being little more than 100km away.

7.1.5 Upper Burdekin Irrigation Area

The size of any potential irrigation area in the upper Burdekin is limited by the undulating topography and the uplift required from the river. There is thus an excess of harvestable water over the available irrigable land. Much of the irrigable land is in close proximity to the main Burdekin River channel with numerous potential contaminant entry points. This in itself poses considerable management problems in protecting the riverine environment from run-off, spray drift and other potentially deleterious effects. The presence of the Burdekin Falls Dam downstream may partially act as a retention basin for contaminants emanating from the irrigation area. The alluvial and basalt soils targeted for the irrigation area have not been surveyed but are likely to contain significant areas of regional ecosystems listed as 'of concern'.

7.2 Belyando-Suttor Sub-Catchment

7.2.1 Mt. Douglas

The proposed Mt Douglas dam site on the Belyando River has been investigated in a separate report (Burrows *et al.* 1999). It is located approximately 200 km south of Charters Towers and lies within the Northern Brigalow Belt bioregion in province 7, the Belyando Downs, an area of undulating lowlands and plateau remnants generally dominated by brigalow, *Acacia harpophylla* and gidgee, *Acacia cambagei* open forest (Sattler and Williams 1999).

The Northern Brigalow Belt is an extremely large and complex bioregion encompassing over 36 million hectares and lying within the 500-750 mm rainfall zone from Townsville to the NSW border (Sattler and Williams 1999). The most characteristic vegetation type within this area, and the nominate type for the bioregion, is the brigalow, *Acacia harpophylla* forests and woodlands which are estimated to have covered up to 6 million hectares prior to European settlement. However since extensive land clearing, especially from development schemes initiated in the 1960's, much of the low-lying vegetation on the fertile clay soil types, has been subjected to broad-scale clearing, and as a consequence, many of the remaining regional ecosystem remnants are of high conservation significance (Sattler and Williams 1999). In contrast, only 2.2% of this region is protected in conservation reserves (Sattler and Williams 1999).

At the scale of mapping and length of field visit undertaken for this study, it was not possible to determine the exact extent of 'endangered' vegetation communities within the impoundment area, although they are common. Along with the raising of the Burdekin Falls Dam, it is the only impoundment in which we were able to identify 'endangered' regional ecosystems as occurring. As their label suggests, 'endangered' regional ecosystems are not commonly found, and more detailed survey work is therefore required to locate them. Where they do occur, they are afforded a very high conservation status. In addition to the presence of 'endangered' brigalow communities within the impoundment area, there are extensive stands of coolabah (*Eucalyptus coolabah*) on alluvial soils. This is a regional ecosystem listed as being 'of concern'. It is common along the river channels within the impoundment area. Thus, although land clearing is common in this area, the remaining vegetation is of a high conservation value. At least 60% of the 182m option and at least 40% of the 192m option covers land that may contain regional ecosystems that are 'of concern' or 'endangered' (Figure 5, Appendix A).

In July 1999, the Environmental Protection Agency purchased the 19,800 ha Nairana property for a new National Park. This property lies partly within the proposed 192m and 182m inundation levels of the Mt. Douglas site. Nairana was purchased to protect Northern Brigalow Belt regional ecosystems. Nairana contains 10 regional ecosystems that are of conservation significance. At least 5-10% of the property would be inundated at even the low 182m FSL, and at least 30% at the higher 192m FSL (Figure 5). Approximately half of the annual clearing of native vegetation occurs within the Northern Brigalow Belt and only 2.2 % of this region is protected in conservation reserves. Almost all of the area of Nairana within both the 182m and the 192m inundation levels consists of regional ecosystems of conservation significance. The proposed Mt Douglas dam site will severely and irreversibly effect the significant values of this new National

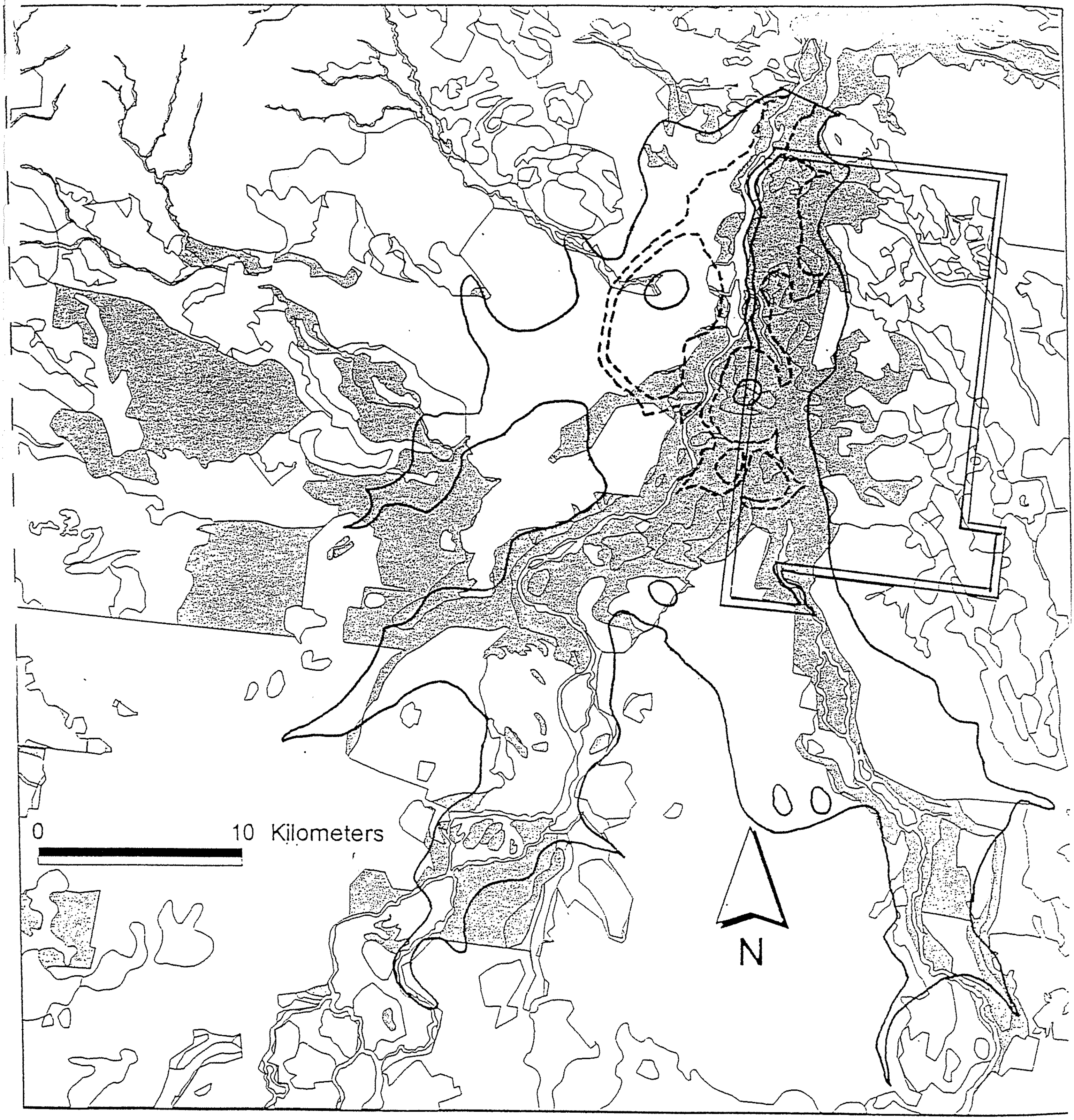


Figure 5. Vegetation Map of Mt. Douglas Impoundment Area at Minimum and Maximum FSL

Shaded areas contain vegetation communities of conservation concern (refer to Appendix B for vegetation unit descriptions)

Map derived from Thompson and Turpin (1999) Tambo, Buchanan, Jericho and Galilee 1:250,000 Map Sheets and Clarkson and Wilson (1999) Bowen 1:250,000 Map Sheet. Queensland Herbarium, Environment Protection Agency.

Park and impact on the level of regional ecosystems protected in reserves in the Northern Brigalow Belt.

Due to its low banks and wide flat floodplain, the Mt. Douglas site also contains numerous lagoons and off-river waterbodies. Although many are degraded, they still have significant environmental values. Several of these have recently been sampled for fish and water quality by ACTFR, and are reported in Burrows *et al.* (1999). The fish community structure was found to be substantially different to a previous brief survey in 1976, reflecting significant environmental changes since then. A dam at this site would have a very low spill frequency, so environmental releases would need to ensure that the significant off-river water bodies received enough water, and at appropriate times.

The Mt. Douglas site would create a very large and shallow impoundment, with a wide and greatly fluctuating shoreline. Such a shoreline would create management difficulties and promote weed infestations. For such a large inundation area (14,000-78,000 ha), the yield is comparatively low. Due to the dryness of the catchment, the dam will trap a significant proportion of the river flow for a relatively low return. At the highest FSL, the dam would very rarely spill naturally and would take many years to fill. The need for environmental releases would further strain the hydrological performance of a large dam at this site. The scoping study (DNR 1998) has already indicated that the capacity of the 192m FSL option is probably twice that which could be achieved in reality. The hydrological performance of the 182m option is also questioned in Burrows *et al.* (1999).

Currently, the Belyando-Suttor system provides much of the fine sediment that keeps the existing Burdekin Falls Dam turbid. Given the high trapping efficiency of any dam at Mt. Douglas, this may serve to significantly reduce flows of turbid water to the Burdekin Falls Dam, and improve its water clarity. This may also serve to increase water clarity in downstream receiving environments. The extent of this effect in uncertain, and may be masked to a considerable extent by supply from the Suttor River and the Cape River, which are not captured by the Mt. Douglas site. Although improved water clarity in the Burdekin Falls Dam for whatever reason would be a return to a more natural state, it has a high probability of leading to blue-green algal outbreaks. Small temporary outbreaks have already occurred when clarity improves (J. Faithful ACTFR pers. comm.).

Although nearly 200km from the nearest town, the dam site is easily accessed, being located beside the Gregory Developmental Road. There is insufficient yield from this dam to effectively supply any large irrigation development in the lower Burdekin. There is an abundance of suitable soils in the Belyando-Suttor catchment, however the catchment is quite dry, and suitable dam sites are lacking. Water harvesting at various points along the river is a more likely option. With 10,000ha of irrigated land already within the catchment, this sub-catchment has more existing irrigation than the Bowen/Broken and upper Burdekin combined.

One of the biggest environmental problems with irrigation developments is that of run-off and impacts on receiving environments. With lower run-off potential and the presence of the Burdekin Falls Dam (a major retention basin) below the Belyando-Suttor catchment, downstream impacts from irrigation in this sub-catchment should be less than for the irrigation areas proposed near Collinsville and along the Elliot Main Channel. The Elliot Main Channel is further compromised by its proximity to the very high value estuarine and nearshore communities, and the numerous small creeks that would drain the irrigated areas into the ocean. Any irrigation area above a large impoundment is likely to have less environmental impacts than an irrigation development downstream, due to the retention facility offered by the impoundment. The Mt. Douglas site offers such advantages. However, the impacts on significant vegetation communities, and other environmental, hydrological and economic constraints, make options at this site unlikely to eventuate.

7.3 Bowen/Broken Sub-Catchment

Both options being considered in this sub-catchment are in hilly country high up in the catchment on the Broken River. The impoundments are deep and have much smaller surface areas than the other sites in the Burdekin catchment. There is a large area of suitable irrigable soils beginning just downstream of the Broken/Bowen junction. Compared to other parts of the Burdekin catchment, the Bowen/Broken has been studied less and comparatively little is known about it. Just above the Bowen River/Pelican Creek junction on Myuna Station, there is a large permanent instream waterhole that is approximately 5km long and 300-400m wide. It contains relatively warm water and supports a permanent population of estuarine crocodiles among many other environmental values (J. Aldrick, EPA pers. comm.).

Due to the smaller yield of the two options being considered in this sub-catchment (compared to the options in the upper Burdekin or the option of raising the Burdekin Falls Dam) it is doubtful that storages here would provide water to developments along the Elliot Main Channel in addition to servicing an irrigation area in the Collinsville district. The mean annual flow from the entire catchment is approximately 900,000-1,000,00 ML (estimated from the nearest gauging station at Myuna, 46km upstream of the Bowen/Burdekin confluence). The mean annual flow at Urannah is 340,000ML (DNR 1998). The median annual flows in this sub-catchment equate to about 60% of the mean annual flows (DNR unpublished data).

7.3.1 Urannah

Urannah has long been a considered as a dam site, having been assessed in 1963, 1967, 1969, 1976/77 and 1978 (DNR 1998). It has the advantage of being a deep impoundment, which will reduce the amount of land inundated. Because of its topography, this site has a very large potential storage capacity relative to its inflow. Until 1998, Eungella Dam (118,000ML storage capacity), just 35km upstream, had not overflowed for 7-8 years (Eungella Dam Ranger pers. comm.). A dam at Urannah would have a lower spill frequency than the Mt. Sugarloaf option, and at maximum FSL, the lowest natural spill frequency of any dam still under consideration in the catchment (except Mt. Douglas). The larger of the two options at Urannah has a storage capacity that is 4-5 times greater than the mean annual flow at this site, and 7-8 times greater than the median annual flow there. This indicates that the dam would take up to 8 years to fill under average conditions and longer with below average rainfall. Given that the flow at Urannah comprises approximately 40% of the total flow for the entire Bowen sub-catchment, environmental flows will have to provided during this time, else this would be imposing a severe and prolonged drought on the riverine ecosystems when none is actually occurring. Allowing environmental flows would increase the time taken to fill the dam. Even the smaller 278m option (storage capacity is 4 times the median annual flow) could take many years to fill.

For the larger size impoundment, tracing the 292m FSL level onto topographic maps indicates that the inundated area of Urannah Creek comes to within 1-2km of the Eungella National Park, and that of Massey Creek, to within 3km of Eungella National Park (Figure 6). The elevational difference to the lowest part of Eungella National Park along Urannah Creek, as estimated from topographic maps, is about 20-25m for the 292m option and up to 40 m for the 278m option. The proximity to this national park provides strong indication, confirmed by the field visit, of the habitat values of the impoundment area, especially as the habitats between the two sites are in very good condition and the connectivity strong. In particular, movements of fish species in and

Figure 6. Map of Mt. Sugarloaf and Urannah Impoundment Areas at Maximum FSL. (Note that minimum FSL is little different)
(refer to Appendix B for vegetation unit descriptions)

Photo 5 – *Eucalyptus crebra* and *Corymbia erythrophloia* on colluvial slopes at Mt. Sugarloaf.

Photo 6 – Instream habitat of the Broken River at the Mt. Sugarloaf dam site.

Photo 7 – Vegetation and terrain of proposed Urannah impoundment (after recent fire)

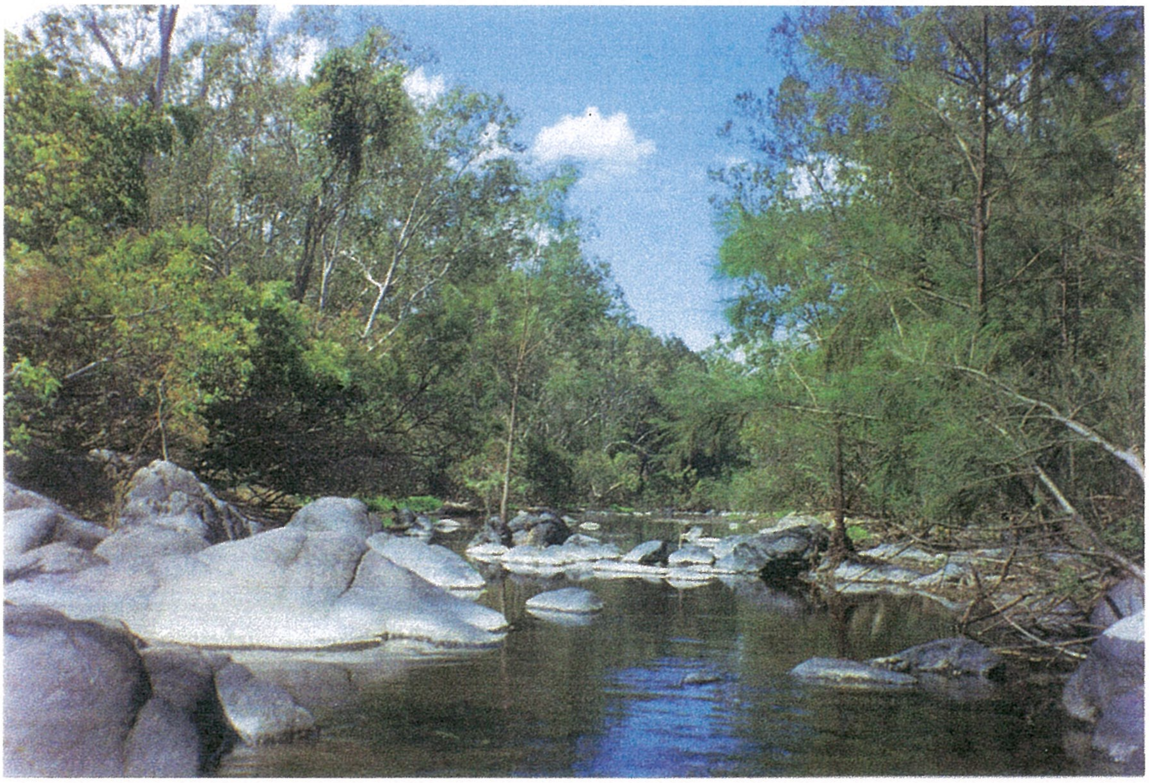


Photo 8 – Instream habitat within the proposed Urannah impoundment.

out of the National Park would be affected. Most species present in this section of the catchment would complete their entire life cycle in freshwaters, though within-river movements would still be affected. Species such as the long-finned eel, may be excluded from upstream habitats by the dam wall, as appears to have occurred for the Burdekin Falls Dam. Because of the direct connectivity with the National Park, sportfish stocking within this impoundment should not be permitted. Blue-green algae management issues would probably reduce the use of this reservoir for recreational pursuits such as fishing.

The hills within the Urannah impoundment consist of open woodland vegetation communities, whereas in the gorges along the river channels, broad-leaved rainforest species are common. These riparian habitats provide strong connectivity with habitat types upstream. The impoundment area contains significant populations of *Eucalyptus raveretiana,* which is listed as Rare on the Queensland Nature Conservation (Wildlife) Regulation. Within the impoundment, these trees are common, and many specimens are 35-40m tall. The gorge country which flows through this impoundment would also have high scenic values.

As this site is high in the Bowen/Broken catchment, and the surrounding lands are in good condition, erosion (at least of fine material) should not significantly impede water clarity. Thus the impoundment should remain clear and this will avoid the turbidity issues associated with the existing Burdekin Falls Dam and any future dams in the upper Burdekin catchment or at Mt. Douglas. However, clear waters are not without management problems of their own. The existing Eungella Dam has considerable management problems related to the occurrence of blue-green algal outbreaks. These appear to be more common during periods of low inflow to the dam (from the Broken River) and appear to disperse when inflow increases (Eungella Dam Ranger pers. comm.). The Urannah site is only 35km downstream from Eungella Dam and will be subjected to similar problems. Greater and more reliable inflow to the Urannah impoundment from Urannah Creek and Massey Creek as well as the Broken River, may reduce the frequency and severity of the problem. The Department of Natural Resources has been regularly monitoring blue-green algae levels at Eungella Dam, and other dams in the area, for several years. However, predicting the severity and frequency of outbreaks in proposed new storages is an issue not easily answered. Indications are however, that blue-green algal problems requiring regular routine monitoring, and leading to management action, are probable.

7.3.2 Mt. Sugarloaf

The Mt. Sugarloaf site is 28km downstream from the Urannah site. From topographic maps and the RL data in the scoping study (DNR 1998), the elevational drop is estimated to be 45-50 metres. Some of the significant vegetation and habitat features noted for the Urannah site, especially those related to the presence of rainforests elements along creek lines, will also be present here, although to a lesser extent. Like Urannah, this site has the advantage of having a relatively deep impoundment which will inundate a much smaller area than most other sites, although it inundates a larger area than the Urannah site (Figure 6).

Although the estimated storage of Mt. Sugarloaf is much smaller than Urannah, it has almost the same yield, and a more favourable yield to storage volume ratio. This is because the Mt. Sugarloaf site captures Grant Creek and Emu Creek, both of which receive reasonable flows, and which probably increase the streamflow by about a third, over that passing Urannah. This site should thus be more reliable. Due to its smaller storage, it will probably have a lesser effect on flushing (wet season) flows. However, because of the need to trap baseflows to provide the yield from a relatively small storage capacity, it may have a greater effect on dry season baseflows, unless these are provided for as environmental flows. The Mt. Sugarloaf site is closer to any potential downstream irrigation area, so there will be less water transmission costs and losses. In stark contrast to Urannah, the identified storage at Mt. Sugarloaf is only approximately equal to the mean annual flow at that point (or approximately 1.6 times greater than the median annual flow) and should fill much more rapidly.

As for Urannah, it is unlikely that this option would become turbid, but an impoundment at this site would also encounter blue-green algae problems. Due to a smaller storage capacity but greater water inflow from additional sources (Grant and Emu Creeks), the water in this dam would be replaced more often than for a dam at Urannah. This should reduce the frequency and severity of blue-green algae problems compared to the Urannah site, but they will remain a significant issue.

Compared to Urannah, this site has less scenic values (eg, reduced less gorge-like features) and less environmental values in common with Eungella National Park. Field examination of the Broken River, and liaison with local people, suggests that the fish and instream aquatic values are higher at the Mt. Sugarloaf site due to the presence of larger, more productive waterholes.

From the scoping study (DNR 1998) and previous history of the water infrastructure debate in the Burdekin, it is obvious that much attention for water infrastructure development in the Bowen/Broken catchment has been focused on Urannah. The scoping study utilised data supplied from previous investigations. For Mt. Sugarloaf, the only study was in done in 1969, and it only examined this location as a site for a weir, not a dam. The 1969 analysis, which was used in the 1998 scoping study, was based on estimating flows from the annual rainfall/run-off curve.

The Urannah site has historically overshadowed the Mt. Sugarloaf site. However, on environmental grounds, based on the limited information collected so far, Mt. Sugarloaf appears to have several advantages over the Urannah site as a storage for the Bowen/Broken catchment. Further studies (environmental and hydrology/engineering) that update and improve the information base for this site, are considered worthwhile. Only then will sufficient information be available to make an informed decision between the two sites.

7.3.3 Bowen River Irrigation Area

The scoping study (DNR 1998) identified 41,000ha of potentially suitable irrigable soils in the Bowen/Broken catchment. This is 2-3 times the maximum land area that could be served from either dam option. Very little information is presently available on the environmental values of the potential irrigation areas. The availability of suitable soils in excess of water resources suggests some potential for environmentally judicious placement of irrigation plots and land clearing. Unlike for the lower Burdekin where the high turbidity provides a considerable degree of protection from nutrient pollution, the clearer waters of the Bowen River will be more susceptible to impacts from irrigation development, such as nutrient pollution. This sub-catchment discharges below the Burdekin Falls Dam (which may act as a retention basin for irrigation development), and any run-off would quickly be exported to coastal and offshore habitats.

7.4 Lower Burdekin Sub-Catchment

The only storage option being considered in the lower Burdekin is the raising of the existing Burdekin Falls Dam wall. The three different scenarios considered include raising the existing wall by 6, 10 and 14.6m, resulting in storage increases of 2-fold, 3-fold or nearly 5-fold, respectively. The Burdekin Falls Dam inundates parts of several major rivers – the upper

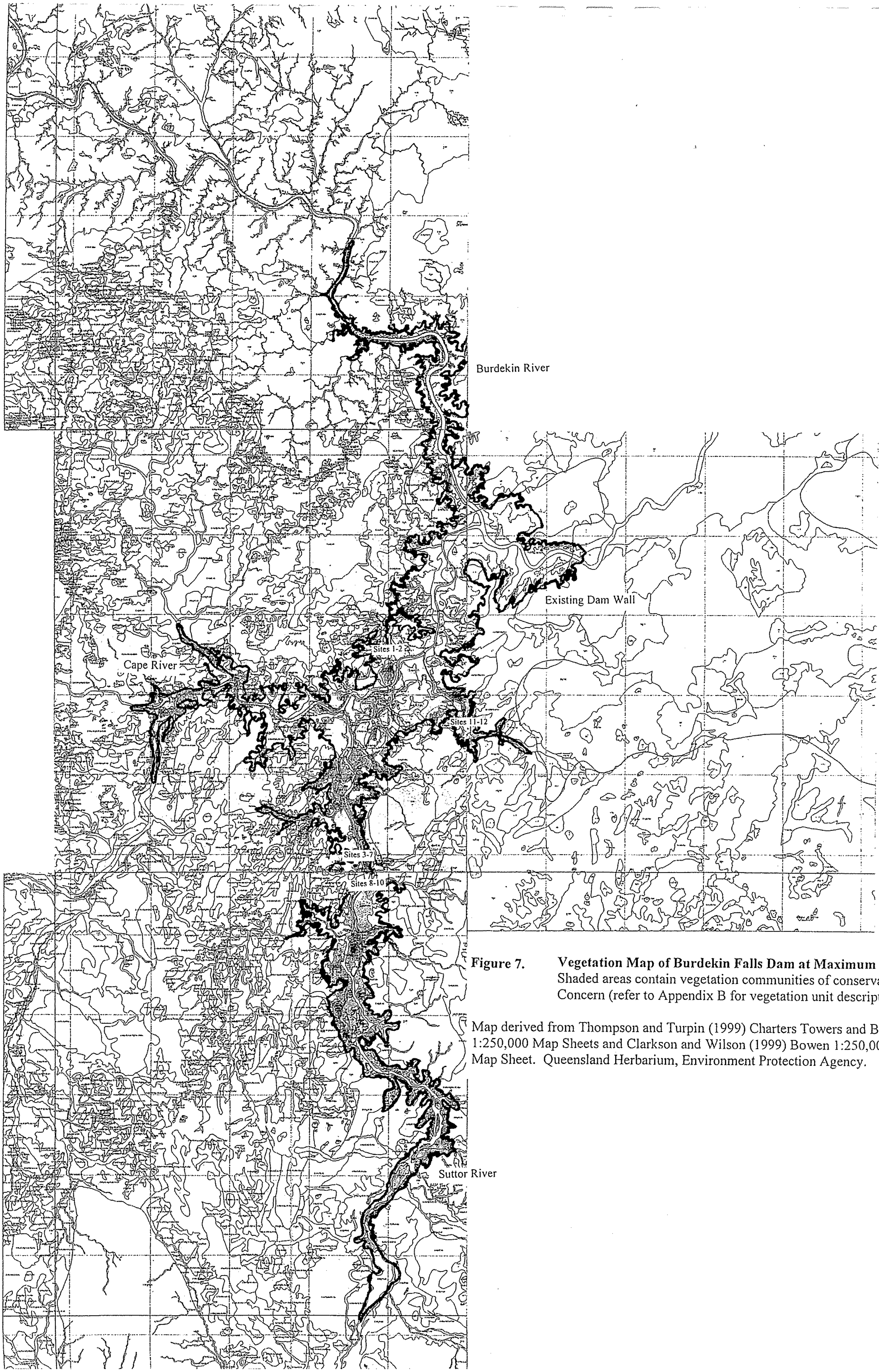


Figure 7. **Vegetation Map of Burdekin Falls Dam at Maximum FSL**
Shaded areas contain vegetation communities of conservation Concern (refer to Appendix B for vegetation unit descriptions)

Map derived from Thompson and Turpin (1999) Charters Towers and Buchanan 1:250,000 Map Sheets and Clarkson and Wilson (1999) Bowen 1:250,000 Map Sheet. Queensland Herbarium, Environment Protection Agency.

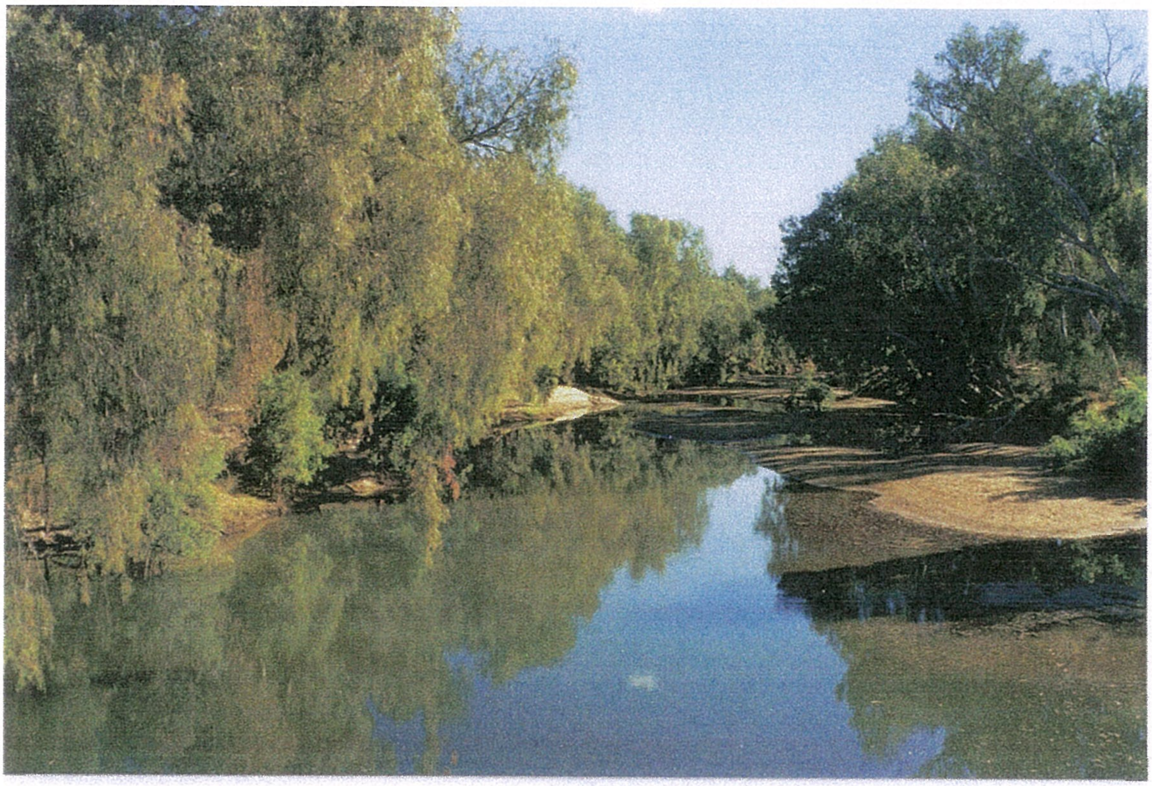


Photo 9 – Cape River at Gregory Development Road bridge.

Photo 10 – anabranch lagoon of lower Cape River

Photo 11 – Suttor River channel at Scartwater crossing. This will be inundated by the raising of the Burdekin Falls Dam.

Photo 12 – Scartwater Lagoon. This large, permanent overflow lagoon of the Suttor River will be inundated by the raising of the Burdekin Falls Dam.

Photo 13 – ***Acacia cambagei*** **(gidgee) woodland on Suttor River flat at Scartwater.**

Photo 14 – ***Corymbia clarksoniana*** **woodland on an elevated bench adjacent to the Suttor**

Burdekin, Cape River, Suttor River and Sellheim River. It is a common perception that raising of the existing Burdekin Falls Dam wall would result in a reduced amount of inundated land compared to the construction of a new dam elsewhere. This is not the case. Due to a relatively flat topography, particularly in the Suttor River arm of the impoundment, the amount of new land inundated is quite large and similar to, or greater than, constructing new storages of equal volume in the upper Burdekin sites. The new area inundated would be 18,000, 33,000 and 53,000ha respectively for the three options. Due to low banks and gradual slope, each raising of the dam wall would inundate a much greater area of the Suttor River channel, than it does for the other rivers, such as the upper Burdekin, which has high banks and greater slope. At the maximum level, the inundation area may extend as far as the Belyando Crossing of the Gregory Developmental Road (ie, virtually to the Mt. Douglas dam site – Figure 7). As was the situation for the Mt. Douglas site, the Suttor River channel of the impoundment includes considerable amounts of vegetation communities of high conservation value, especially on the river channels and overflows, and including extensive stands of coolabah (*Eucalyptus coolabah*) dominated communities. Some occurrences of 'endangered' brigalow communities were also located along the Suttor River and Sellheim River arms. Most of the riverine-associated communities of the Sellheim, Cape and Burdekin River channels and major tributaries also contain regional ecosystems 'of concern'. Indeed, the existing impoundment already inundates a great extent of vegetation communities that would today be recognised as 'endangered' or 'of concern' regional ecosystems.

With a total storage capacity of 8,700,000ML at the maximum level of development (168m FSL), this is by far the largest option being considered in the catchment. This capacity is similar to the total mean discharge from the entire catchment (7-11 x10^6 ML). It would seem unlikely that such a large proposal would gain community acceptance. Such an extraction may also leave little available resources for other sub-catchments such as the upper Burdekin or Bowen/Broken systems, as the water from those areas would be required to maintain environmental flows. An option of this size would provide water far in excess of projected demand. Even raising the Burdekin Falls Dam from its present 154m to 160m (the lowest option considered in the scoping study) would provide more than twice the yield of the next largest site in the entire catchment. There would seem no justification for building a dam larger than this. With implementation of water conservation measures in the coastal plain irrigation areas and in Townsville, even a dam of 160m FSL would seem unnecessary. There is reason to believe that the Elliot Main Channel development, and increased allocation for urban/industrial growth in Townsville could be accommodated by the current dam or a very small increase in its size (as little as 1-2m). The benefits to be gained from water conservation measures have not been investigated, but there are many areas where significant savings could be made. As water is a purchasable commodity, efficiency savings provide win-win situations for both the environment and the water purchasers.

An argument in favour of this site compared to other sites is that many of the downstream impacts that would be likely to accrue from dam development, may have already occurred. This would be true to some extent, although very little effort has been expended assessing the environmental impact of the existing dam. Many of the impacts from the existing dam would be exacerbated, even for a smaller increase in FSL. The potential impacts from a smaller increase in dam size (eg, 2m) mainly differ from the larger options in their severity and likelihood of occurrence. A smaller option would still inundate regional ecosystems of recognised conservation value and would incrementally affect hydrological parameters. Even turbidity would become worse because of greater trapping of turbid, wet season flows, and the already limited euphotic zone would shrink further. It is difficult to determine what impacts might accrue from a small raising of the existing dam, when the impacts of the existing dam have not been studied. For the larger options, additional impacts, not yet realised, may be encountered from the sheer size of the impoundments being considered. This is especially so for coastal environments. Any large dam at this location would have to consider a management regime to allow the passage of flood flows so as to maintain downstream and coastal geomorphological processes. In addition, environmental effects from large dams, especially geomorphological effects, are often not apparent for many years. Such effects may also accrue from the construction of dams elsewhere in the catchment in conjunction with the existing (or a slightly larger) dam.

The Burdekin River discharges to the sea in Upstart Bay through a very large delta up to 40km across (Mabin and Lowry 1996). Evidence suggests that the Burdekin River channel has moved many times throughout its history, including discharging directly into Bowling Green Bay. The present delta has been forming for the last 15,000 years with most development occurring since sea level reached its present height about 6,500 years ago (Mabin and Lowry 1996). At that time, the Burdekin River flowed into Bowling Green Bay. At 4,500 years ago it moved east then south to the Inkerman area then via Sheep Station Creek then into Bowling Green Bay again and at about 2,500 years ago was occupying Kalamia Creek and discharging into Upstart Bay. The Cape Bowling Green sand spit had by now started to form. The recent and rapid formation of Cape Bowling Green indicates just how powerful sediment outflows from the Burdekin River are, and just how vulnerable the Cape would be to any reductions in this process. Despite the mouth of the Burdekin then moving progressively south through Mud Creek, Plantation Creek and the Anabranch, before settling in its present location, the Cape has continued to grow and is now 20km long. The coastline of the delta also has rapidly growing sand spits and barrier bars. The sand spit of Cape Bowling Green protects the extremely valuable coastal habitats of Bowling Green Bay National Park and RAMSAR wetlands. Goh (1992) estimated that Cape Bowling Green is growing at the rate of 1m/yr but noted that it was narrowing at about the middle. Any breach of the sand spit would expose the sheltered habitats of Bowling Green Bay to the south-east winds and cause rapid and extensive environmental changes. Both Cape Bowling Green and the delta coastline, are formed by sand outflow from the Burdekin River but the high wave energy of the coast has strongly affected the development of the coastal features. If the supply of sand is reduced, the strong wave action may cause extensive and relatively rapid erosion of these coastal features.

Very little is known about the effects of Burdekin floods on transport of instream sediment to the coast, other than very large amounts are transported, and these move northwards along the coastline. The lack of data is also complicated by the episodic nature of floods, and that due to the large and varying sub-catchments, the system rarely responds as a simple catchment to run-off generating rain events. Thus there are considerable differences in the hydrograph pattern depending on rainfall pattern and location.

The mean annual flow of the Burdekin River at the existing dam is about 4 times the dam capacity and it is expected that on average, the dam will overflow 3 out of every 4 years (Fleming and Loofs 1991), though this will be variable. During peak flood events, the temporary storage of the dam increases significantly and the ponded area may double (Fleming and Loofs 1991). Flood flows from the upper Burdekin are very sharp whereas flood flows from the Belyando-Suttor are much flatter. Attenuation effects of the dam due to ponded storage would probably be greater for floods from the Belyando-Suttor, than for the upper Burdekin. Under some situations, such as the persistent high rainfall of 1991, the storage of water in the dam may have actually added to the flood height in the lower Burdekin by storing floodwaters from the Cape River just prior to a large flood entering from the upper Burdekin (Fleming and Loofs 1991). The dam greatly extends the flow hydrograph of the recession curve in downstream areas.

Belperio (1978) provided a detailed study of sediment transport in the lower Burdekin River and estimated an average annual load of 450,000t but noted the extremely variable nature of sediment transport ranging from 1,000t in 1969 to 3.7milliont in 1958. Kinhill (1996) recalculated Belperio's estimates using average daily flow, instead of monthly flow, to produce an average of 1.2 million t. This indicates the variability of estimates made so far.

Analysis of pre and post-dam flow data by Kinhill (1996), shows that the downstream of the dam, the frequency of low flows (<2,000ML/day) is greatly increased due to releases for irrigation. Flows from 4,000ML/day up to 100,000 ML/day have been reduced in frequency by the dam. Flows of 200,000ML/day and above appear not to have been affected by the dam, although the amount of data to test this is limited. The vast majority of transported sediment is moved during high flood flows and there has been no determinable effect on the frequency of these large events. However, as the dam will trap all of the bed material load from the 85% of the catchment it captures, this amount of material may have to be entrained from the river bed or banks downstream of the dam, if the total sediment load transported to the coastal areas is to be maintained. Whether there has been any increased erosion downstream of the dam has not been assessed. Other studies have shown that such effects may not occur for many years after dam construction. There may be sufficient available material in the lower reaches of the river to replace the sediment trapped within the dam. If this is the case, it is uncertain for how long this supply will last. Alternatively the sediment may be coming from increased erosion in the Bowen/Broken catchment which discharges into the Burdekin below the dam. There is little sediment transport data for this sub-catchment, but Kinhill (1996) used streamflow data to estimate that sediment transport rates from that system are only 10-25% that of the main Burdekin channel. This limits the ability of this sub-catchment to effectively supplement sediment supply in the Burdekin, although some masking effects may be occurring. A dam in the Bowen/Broken catchment may further reduce any masking effect.

If a significantly enlarged dam at Burdekin Falls, and another dam elsewhere in the Burdekin catchment, does have a measurable attenuation effect on peak flood flows in the lower Burdekin, then sediment transport rates will drop dramatically. This will lead to increased sediment accretion within the lower reaches of the river, increased erosion of the delta coastline, possible reductions in the sand spit that is Cape Bowling Green and reduced sediment deposition in receiving environments such as Bowling Green Bay. Such effects on downstream coastal environments would also occur with the construction of large storages in other parts of the catchment in addition to, or even instead of, raising the Burdekin Falls Dam. In addition, the impacts of reduced freshwater discharge to estuarine environments from a greatly increased water retention in the catchment may be reflected in reduced areal extent and productivity of mangrove forests and reduced fishery productivity, as both of these systems/processes require freshwater inputs to be productive.

The feasibility of building a 130km long irrigation channel (Elliot Main Channel) from the Burdekin River at Clare to Bowen is currently being investigated. This would supply several large irrigation blocks (totalling 23,000ha) in close proximity to the coastal zone. The area served by the proposed Elliot Main Channel contains a myriad of high value habitats, both onshore and in the nearshore receiving environments. The areas served by the Elliot Main Channel have many waterways that discharge directly into the ocean. This, combined with the potential for large storm events, increases run-off potential. The proximity to the good condition coastal and offshore environments restricts the ability to retain and reduce the effects of run-off events. In addition to this, there is the danger that a pipeline south along the coast will enable the spread of exotic or translocated fish, weeds and other organisms, to new catchments where they do not currently occur.

8.0 EVALUATION AGAINST MODSS CRITERIA

As part of the planning process, a Multiple Objective Decision Support System (MODSS) is being used to evaluate the water infrastructure options in the catchment. This will include social, cultural and economic assessments, as well as environmental. This section aims to explain the rationale behind the scores provided in this report for each environmental criterion (Table 7). The ratings will be ratified by the Technical Advisory Panel, and are thus subject to alteration. In many instances, there is an overlap between criteria, with the same issues appearing in more than one place. For instance, loss of species of conservation significance through flooding of impoundment areas, would be included in both Net Biodiversity Change, and Rare and Threatened Taxa. Review of the criteria by the Technical Advisory Panel has found this unavoidable, but also necessary, as such links represent the reality of the situation. For instance, loss of biodiversity or rare taxa would also affect ecological processes (eg, food chains) and the uniqueness of a location. Such links should be maintained.

8.1 Net Biodiversity Change

Net biodiversity change of both flora and fauna elements includes not just losses due to the flooded impoundment area, but also losses in biodiversity in downstream areas affected by the water infrastructure developments (eg, by alteration to flow patterns). The concept of biodiversity also includes considerations such as genetic biodiversity, the uniqueness of the species present, the relative abundances of various taxa and the types of taxa involved. For example, a site with 10,000 insect species would not necessarily be considered more diverse than a site with 20 frog species present. Thus, biodiversity is much more than the number of taxa present. Key data used for evaluating this criterion include:

- diversity of biota known from the site or likely to occur there
- types of biota (eg, insects versus frogs) known from the site or likely to occur there
- variety of habitat types inundated, as this reflects biodiversity values
- size of the inundation area, as larger areas are more likely to flood a greater variety of habitats
- perceived impact of the dam on the diversity of other environments (eg, downstream)

Of the upper Burdekin sites, the Greenvale option would be expected to have the greatest impact on net biodiversity change, due to the higher diversity of habitat types and the higher diversity of aquatic fauna found there. The Mt. Foxton option covers a large area and would also impact strongly upon this parameter, as it would flood part of Running River. Running River drains part of the Wet Tropics World Heritage Area and thus has a strong baseflow and different habitats than the corresponding section of the Burdekin River into which it flows. The differences in net biodiversity change between Mt. Fullstop and Hells Gates are minor, and less than for the other two sites, though Mt. Fullstop has a smaller inundation area, except at the smallest FSL. Although Greenvale has higher quality habitat, it covers less area, which balances the scores to some extent.

The Mt. Douglas site covers a range of vegetation communities and several off-river water bodies. The biodiversity elements represented here have limited occurrences elsewhere. The larger option has a very large inundation area and thus ranks poorly. The raising of the Burdekin Falls Dam would inundate a great variety of habitat types, not only because of the significant area of land inundated, but also because it would flood the lower reaches of several rivers, including the Burdekin, Suttor, Cape and Sellheim rivers. Each of these has distinctly different habitat types, thus impacting on a greater amount of biodiversity.

Table 7. MODSS Scores Evaluated for Each Option Against Ten Assessment Criteria

Scores are relative, not absolute indicators of impact 0= greatest impact 10 = least impact

	Mt. Foxton			Hells Gates			Mt. Fullstop			Greenvale			Mt. Douglas		Mt. Sugarloa	Urannah			BFD	
	335m	345m	364m	365m	375m	385m	365m	375m	389m	430m	439m	445m	182m	192.5m	7.7km	278m	292m	160m	164m	168.6m
Net Biodiversity change	6	5	4	7	6	5	7	7	6	6	5	4	6	1	7	5	4	4	2	0
R&T ecosystems and taxa	6	5	4	7	6	5	7	6	5	6	5	4	1	0	6	5	4	3	2	1
Resilience of Impacted Ecosystems	4	3	2	4	3	2	4	3	2	5	4	3	7	4	6	6	5	3	2	1
Ecological Processes	3	2	1	2	1	0	2	1	0	4	3	2	7	4	7	6	5	3	2	1
Riverine and Coastal Fluvial Dynamics	3	2	1	3	2	1	3	2	1	5	4	3	7	5	6	6	5	2	1	0
Uniqueness of Impacted Area	6	6	5	8	8	7	8	8	7	5	5	4	6	4	5	4	3	5	5	4
Capacity to Manage Impacts	4	4	4	4	4	4	4	4	4	5	5	5	6	5	5	4	3	7	7	7
Downstream Impacts	5	4	3	4	3	2	5	4	3	6	5	4	7	3	6	5	4	4	3	2
Impacts on Aesthetic Values	7	6	5	8	7	6	8	7	6	5	4	3	8	6	4	3	2	6	5	4
On-Farm Effects	4	3	2	4	3	2	4	3	2	7	6	5	7	6	7	7	6	4	3	2

With their smaller impoundment areas, the Mt. Sugarloaf and Urannah dam options would, at first thought, be expected to have the least impact upon net biodiversity change. However, the proximity of the Urannah impoundment to the high biodiversity Eungella National Park, and the presence of mesic floral elements in an otherwise drier environment, would alter that summation. The Mt. Sugarloaf option would be likely to have a lesser impact on biodiversity than the Urannah option, due to its lower elevation and increased distance from the national park and high diversity upland areas, although its values are also still high and its inundation area is larger than for Urannah.

8.2 Rare and Threatened Ecosystems, Habitats and Taxa

This is probably the most straight-forward and readily evaluated criterion. The brief field visits undertaken for this study located few records of significant plant species at any site, although further survey effort would undoubtedly reveal more, as these plants are by definition - rare. Of significance though, was the finding of significant stands of the Vulnerable tree, *Eucalyptus raveretiana* in the Urannah impoundment area. Herbarium records also indicate the presence of this tree in the vicinity of the Mt. Sugarloaf and Burdekin Falls Dam impoundment areas (Table 2). Table 2 indicated the significant plant taxa in the vicinity of each impoundment area, held at the Queensland Herbarium. This data is biased toward certain collection areas and it is unreliable to infer too much from this table due to the paucity of collecting effort at the more inaccessible locations such as Hells Gates and Mt. Fullstop. Table 4 indicates a greater number of significant fauna likely to occur at the upper Burdekin sites. There has been more faunal survey effort in the upper Burdekin, compared to the Bowen/Broken system, and the information is thus interpreted cautiously. Data from the regional ecosystem mapping of the area can be used with reasonable confidence, and contribute to significant discrimination between several of the sites.

Being located in an area containing several regional ecosystems of conservation significance, Mt. Douglas is rated as having the most significant effect for this criterion. For both the 182m and 192m FSL's for this site, almost half the impoundment area includes regional ecosystems that are considered to be of conservation significance. The impoundment area also includes a considerable proportion of a property recently purchased for a national park. For the option of raising the Burdekin Falls Dam, a considerable length of the Suttor River, and some of the Sellheim and Cape Rivers will be inundated. These river arms also contain significant extent of regional ecosystems of conservation significance, including some 'endangered' ecosystems. Concomitant with the presence of regional ecosystems of conservation value, there are often fauna species of conservation values present as their numbers decline in line with loss of their habitat. Thus this options also rates poorly for this criterion.

The distinction between sites in the upper Burdekin for this criterion is limited with the current level of data. The sites are relatively close together and occupy generally similar habitats. Thus, only detailed survey would discriminate between them. Due to its separation from the other sites and its more upstream location and different habitat types, Greenvale may have a slightly greater impact for this criterion, as may Mt. Foxton due to its inundating part of Running River. Faunal data for the Broken River options are very limited.

8.3 Resilience of Impacted Ecosystems

This parameter is difficult to evaluate and requires a detailed understanding and knowledge of the rivers and how they function, that we simply do not possess. In addition, many of the impacts to the systems will come from irrigation development associated with each dam. The extent and severity of any impacts would obviously have a large relevance to the ability of the ecosystems to withstand dam development.

Resilience, the ability of an ecosystem to withstand an impact, is related to sustainability. It can be argued that riverine systems with low and highly variable flows (ie, the Burdekin system), are less able to withstand impacts from regulated flows, than those with higher or less variable flows. This argument follows the line that more consistent, elevated baseflows from releases of water for irrigation, will have a greater impact on the aquatic communities through alteration of the flow pattern, and increases in resource predictability, which favours reduced biotic diversity. This would make the upper Burdekin sites less resilient to change than those of the Bowen/Broken system which has a more predictable flow (comparatively speaking). On the other hand, systems adapted to less variable flows may not be able to withstand reductions in water levels, if the level of extraction is sufficient to lower the normal water levels. In the case of the Bowen/Broken system, reductions in water levels may impact on riffles and rapids and these habitats will be lost if water extraction is too great. Flowing waters are likely to be more resilient to impacts than still waters, especially with regards to fundamental ecological issues such as eutrophication and dissolved oxygen levels. The reception of inflowing water mediates the impacts of contaminants and would suggest that systems with more permanent flow, such as the Bowen/Broken, may be more resilient than those with lesser inflows. The concept of resilience may be dependent on the issues against which resilience is desired. For turbid waters such as in the Belyando-Suttor, the high turbidity greatly mediates the impacts of elevated nutrient levels, thus providing more resilience to the effects of nutrients, compared to waters with greater clarity.

For this criterion, the size of the dam and its effects on flow patterns, downstream habitats, water quality, and the likelihood of ecosystem alteration have been subjectively evaluated. The multiple aspects involved in this criterion, their interactions, and the speculative nature of the effects, have resulted in similar scores for most of the options. The kinds of data and analysis that will be forthcoming from the IQQM models and the WAMP process will be particularly critical in evaluating this criterion. To some extent, that there is already an existing dam at the Burdekin Falls would suggest that the raising of that dam would mean less net impact, compared to construction of a new dam elsewhere, and that many of the impacts that may result from dam construction have already occurred, and the remaining components of the affected ecosystems are resilient to the impact. This has been taken into account, though the significant size of the raising being considered and the potential for threshold impacts on coastal ecosystems of low resilience have resulted in a low rating for this option.

8.4 Ecological Processes

The concept of ecological processes is an integrative one, and quantifying it would require a detailed knowledge of the functioning of ecological processes, a considerable task. Evaluation of this criterion is fairly subjective. Impacts on the pattern of streamflow, and water quality aspects such as water clarity and algal blooms, are considered to be especially relevant, as is the correlation between riverflow and the productivity of coastal fisheries.

Of greatest concern within the upper Burdekin are reduced water clarity and the resultant changes to ecological processes including converting ecosystems from autotrophic to heterotrophic systems. Little information is available that would enable an accurate prediction of limnological performance of the dam options. Data on the limnological performance of the existing Burdekin Falls Dam indicates that high rainfall results in flows of turbid water. Where this turbid water is trapped by the dam, it does settle, but not sufficiently to clarify the water. This process is dependent on the sediment particle size and other processes such as wave action, wind fetch and stratification of the impoundment. Thus, turbid water is released from the dam continuously throughout the year. With the large and in some parts, shallow, upper Burdekin options that are more exposed to wind, the water may remain turbid, especially if the increasing levels of erosion that is occurring there exposes fine clay soil layers. Areas of particularly bad erosion occur in the catchments of the Mt. Foxton, Hells Gates and Mt. Fullstop options. Higher conductivity sub-surface baseflows in the upper Burdekin may promote improved water clarity under some conditions. This is a critical area of research, for it has strong bearing on fundamental ecological processes. At the Mt. Foxton site, much of the erosion is occurring within the inundation area and there may actually be some benefits of reducing erosion by flooding this area. Of the upper Burdekin sites, the Greenvale site may be the least affected by turbidity issues, though there are no data to test this assertion. This prediction is based on the sighting of greater areas of eroding and degrading land downstream of the Greenvale site, but within the catchment areas of the other upper Burdekin sites. Strong dry season groundwater-fed surface flows in the Greenvale section of the catchment may also help in clarifying the impoundment. The significant ecological impacts of converting relatively clear water into turbid water has resulted in very low scores for this criterion where it is considered that this prospect is tangible.

There is currently no data to suggest that the Bowen/Broken options would become turbid. In fact, experience from the existing Eungella Dam just upstream of the sites suggest that the water will mostly remain clear and that blue-green algae may be a management problem when inflows are low. Due to stronger flows from additional incoming tributaries and a more favourable storage to yield ratio, it is suggested that the Mt. Sugarloaf site would be less susceptible than the Urannah site to blue-green algal problems. However, with their deep waterbodies and significant stratification potential, less wind-mixing and large dam sizes (relative to inflow), the occurrence of blue-green algae outbreaks at both sites seems very likely. Management options can reduce the frequency and severity of the blooms, but they will still occur.

The Belyando-Suttor is already very turbid and this water is trapped by the existing Burdekin Falls Dam. Although turbidity can get worse than it currently is, because of its pre-existing condition, ecological processes in relation to turbidity are less likely to be affected by these two proposals. The hydrological impacts of the larger Mt. Douglas option however, would probably significantly alter a number of flood-dependent ecological processes below the dam unless this is ameliorated by the Suttor River entering 10km downstream. The existing Burdekin Falls Dam has already impacted upon many ecological processes, thus reducing some aspects of further increasing the size of this dam. As for other criteria, the large increase in dam size may impact further upon ecological processes not yet affected by the existing dam. A smaller wall raising would greatly reduce the risk and extent of further alteration to ecological processes.

Throughout the world, there are numerous examples of excessive river regulation devastating estuarine and coastal fisheries due to factors such as effects on food chains of reduced nutrient export, and habitat loss due to coastal erosion and hypersalinity in mangroves areas. In Australia, positive correlations between river flow and prawn and/or fish catches have been documented for several areas including northern New South Wales (Ruello 1973, Glaister 1978) Gulf of Carpentaria (Staples and Vance 1985, Blaber *et al.* 1998), Fitzroy River (Platten 1997) and the Logan River (Loneragan and Bunn 1999). Contrary to popular belief, mangrove trees are not entirely marine adapted and usually do best at moderate or low salinities. Thus, supplies of freshwater promotes greater mangrove tree growth and productivity. Reduced freshwater flows increase salinity in mangrove environments, which leads to reduced growth and productivity, plus changes in community composition to species more tolerant of higher salinity. This then affects a variety of ecological processes in coastal environments. The various types of impact on coastal/marine fisheries and mangrove productivity from dam development, are ultimately related to the volume of water extraction and attenuation of flood flows. Generally, larger dam options will have greater effects.

8.5 Riverine and Coastal Fluvial Dynamics

The coastline of the Burdekin delta and other habitats to the north, such as Cape Bowling Green, have been formed relatively rapidly (geologically speaking) by sand emanating from the Burdekin River. Their presence is the result of a balance between the continual processes of erosion and replenishment. The Burdekin delta and adjacent coastline has aggraded quite rapidly to form the complex coastal habitats now present. Their rapid growth also indicates their vulnerability to reduced sand supply, given the powerful coastal erosive forces present. Dams are very effective traps for coarse sediment, retaining virtually all of the supply. If the supply of sand to the coast is constrained by dam development, then the integrity of the complex and valuable coastal habitats would be jeopardised. It is not known to what extent this process has been affected by the existing Burdekin Falls Dam, if at all. While the large flow events that contribute the most to sediment movement have probably not been impacted by the existing dam, the dataset is limited to just a few events. The contribution to sediment movement of medium-sized events, which have been impacted by the existing dam, is not known. As the bedload is already effectively trapped by the existing dam, a larger dam will not have any greater effect in trapping it. However, reductions in flood flows would reduce transport of sediment below the dam to coastal regions. The attenuation of flood flows that have bedload transport capacity can be modelled to determine the effect of reduced transport ability on the delivery of sediment to the coastal regions. However, the assumptions that underlie such models vary and vastly different estimates often result.

The effects of a dam may not be noticed for many years in the coastal regions if sand trapped by the dam is substituted for by sand stored within the lower river reaches, increased erosion from riverbanks below the dam, or by increased erosion from catchments below the dam, such as the Bowen and Bogie catchments. Thus, the effects of the existing dam may not yet be apparent. Flood flows from the relatively unregulated Bowen/Broken system may also be providing some of the sediment-transporting flows, thus masking effects of the existing Burdekin Falls Dam to some extent. If this is the case, then construction of a large dam on the Broken River may affect this compensatory balance. Any dam, regardless of its location, that reduces the power of sediment-transporting flood events, will have an effect on coastal fluvial dynamics. Sediment movement is episodic and variable, making it difficult to study and model. However, the crucial importance of this issue to the integrity, indeed very survival, of the vulnerable coastal environments of the Burdekin delta and coastline, Cape Bowling Green and Bowling Green Bay, make it of the upmost importance.

Riverine fluvial dynamics are also dependent on large flow events, though smaller events also play a greater role. The smaller, more frequent events play a greater role in riverine ecosystems, including for parameters such as channel maintenance. Unlike for coastal systems, the effects will vary with the location of the dam. Generally, the higher a dam is in the catchment, the less frequently it is expected to spill. This is the case for the Burdekin options, and for environmental flow purposes, dams should spill every year. Although dams further up-river spill less frequently, this may have less impact in this situation if there are incoming unregulated tributaries below the dam site. For example, until 1998, when it flowed for most of the year, Eungella Dam had not spilled for 7 years (Dam Ranger pers. comm.). Despite this, the downstream riverine environment would have received substantial water from the unregulated, but more reliable creeks downstream, such as Urannah Creek, Massey Creek and Grant Creek. Releases from Eungella Dam were made during this time to provide water to riverine habitats between the dam wall and the first in-flowing creek (Massey Creek). The likely spill frequency for the Urannah option is very low, especially if built to the maximum level. This dam would probably behave similarly to the existing Eungella Dam and releases to downstream riverine environments would probably often be required. The Mt. Sugarloaf option however, would naturally spill much more frequently, yet provide only a slightly less yield.

For the Greenvale option in the upper Burdekin, the spill frequency is quite low, especially if built to the higher options. Between this site and Mt. Fullstop/Hells Gates, enters the Clarke River, which due to its extensive catchment area, has a high (mean ~ 900,000ML/yr DNR 1998), although variable flow. Tributaries with the highest and most reliable flows in the upper Burdekin, enter the river below all of the dam options, except Running River, which is captured by Mt. Foxton. Thus, although the spill frequency is lower for the Greenvale option, the rivers with the greatest contributions to overall flow will be unregulated. The Greenvale option, would however, need to allow sufficient flows to maintain the main river channel, between the Greenvale site and the Clarke River.

The Mt. Douglas option will impact severely on spill frequency, such that it will trap even large flood flows, even if built to a lower level than the maximum listed in Table 1. Given its position low in the catchment, this is a poor result from an environmental flow viewpoint. However, the length of river between this option and the impoundment of the Burdekin Falls dam is not great compared to the length of the Belyando River. In addition, the Suttor River joins the Belyando 10km downstream of Mt. Douglas and may mask some of the effects of the low spill frequency. Given its low gradient and relatively low flood frequency and volumes, the Belyando-Suttor sub-catchment probably contributes less to coarse sediment transport than do the other major sub-catchments.

The size and shape of a watercourse reflects the size and frequency of the flows it carries, particularly flood events. The low banks and numerous overflow lagoons of the Belyando-Suttor Rivers indicate the lesser flood power of this sub-catchment compared to the high and wide banks of the upper Burdekin, lower Burdekin and Bowen rivers. Reduction of flows that maintain the watercourse channel will result in changes such as sediment accretion, channel contraction, changes in riverine habitat and increase in instream vegetation. Channel maintenance is a critical requirement of riverine fluvial dynamics. In variable catchments such as the Burdekin, channel morphology is a dynamic feature responding to a wide variety of flow events and discharges. Flows with a recurrence interval of 1.5-2 years are required for channel maintenance, as well as larger bankfull flows and the passage of large flood flows. Larger options that trap a greater proportion of riverflow (eg, Urannah and some of the larger upper Burdekin options) will have greater difficulty achieving this goal. Hydrological (IQQM) modelling currently underway will provide further details on this aspect of the assessment.

8.6 Uniqueness of Impacted Area

The uniqueness of an impacted area relates to representativeness, and also includes other concepts such as wilderness values. All of the potential impoundment sites are on existing cattle grazing properties and none are truly wilderness, although the Broken River sites would be the least disturbed by signs of habitation. In terms of representativeness, the vegetation communities of the Mt. Douglas and Burdekin Falls Dam impoundment areas are limited in the extent of their remaining post-European distribution and are poorly represented in existing reserves. The Urannah option contains some spectacular gorge country that has some wilderness values, and is relatively unique. The Mt. Sugarloaf option also has these features but to a lesser degree. Both sites have no public access, limited infrastructure and relatively less grazing impacts. The Hells Gates and Mt. Fullstop sites also have limited access and rugged hills although the signs and effects of land-use are more pronounced. Hogan and Vallance (1998) noted the presence of a set of rapids 3km upstream of Mt. Foxton which is probably an important spawning site for fish such as sooty grunter. Such rapids are relatively unique within the upper Burdekin, though they are more common in the Bowen/Broken sub-catchment and several of the upper Burdekin tributaries. The permanent spring-driven baseflows of the Greenvale site are relatively unique in the Burdekin catchment, as are the numerous overflow lagoons and wetlands of the lower Belyando, Suttor and Cape Rivers which would be inundated by the Mt. Douglas or Burdekin Falls Dam options.

8.7 Capacity to Manage Construction Impacts

For many aspects of the construction process, environmental management plans and other procedures will mean that impacts will be equal across the various options, although some factors are site-specific. The impact of floods can be managed successfully, though they pose a greater environmental risk than no flooding, and should thus be considered as a potential impact. Heavy rainfall during construction is more likely at Mt. Sugarloaf and Urannah, and these sites also have greater slopes and run-off potential. Major floods could affect any of the sites. The existing uses and condition of the surrounding land may affect the ability to manage construction impacts.

The formation of new access roads will create additional environmental impacts. There are no roads to either site on the Broken River or to Hells Gates and Mt. Fullstop. Access to Greenvale consists of unformed tracks. Mt. Douglas is very close to the Gregory Developmental Road and Mt. Foxton is within 1.5 hours drive from Townsville on a very good dirt road. The Burdekin Falls Dam is also easily reached. Many aspects of this criterion do not vary with the size of the impoundment, thus the scores provided are the same for all FSL's at each site.

8.8 Downstream Impacts

This criterion is affected by many factors such as dam size, location, yield, length of river regulated, distance to the irrigation area and location of other major contributing tributaries. The major categories of impact result from alterations to water volumes and flow patterns, and altered water quality from regular dry season releases. This category is linked to fluvial dynamics and ecosystem processes, though is more focused on water flow. Dams high up in the catchment will trap a high proportion of the riverflow at that point and could thus be said to have a larger impact in the area immediately downstream. Incoming tributaries will, especially if they carry large volumes, ameliorate this effect to varying extents. Dams further down the catchment may well have a higher spill frequency even if they are larger, but will also capture a greater number of tributaries and will require larger environmental flow releases.

In the upper Burdekin, the Greenvale site is highest in the catchment. It has the lowest spill frequency as it traps a large proportion of flow from its sub-catchment area. The other upper Burdekin sites will naturally spill more frequently despite being much larger storages. Despite this, the Mt. Fullstop/Hells Gates and Mt. Foxton options will still requires environmental flow releases 2 and 3 times that of Greenvale, respectively (DNR 1998). In the Broken River, both sites capture a relatively larger proportion of total sub-catchment flow than the other options (except the upper Burdekin options at maximum FSL). This is due to their location high up in the catchment and relatively large size, given the flow volumes of their catchment area. This is especially so for Urannah, which has a storage volume up to 4.4 times (at 292m FSL) its mean annual flow (Table 1). A Mt. Sugarloaf impoundment will spill more frequently than a Urannah impoundment and should require less environmental releases, and will regulate a lesser length of river, though it will capture important tributaries such as Grant Creek, which would not be captured by the Urannah option.

A dam at Mt. Douglas will have a significant impact on environmental flows to the lower Belyando River, but the lower Suttor River (only 10km downstream) will still be supplied by this sub-catchment. This is balanced by the lower probability of impact on other downstream environments such as the coastal ecosystems, as the Suttor River has a relatively low flow which is mostly trapped by the existing Burdekin Falls Dam. It produces flood flows of sufficient size to affect the coastal environments much less often. There is legitimate concern that a significant raising of the Burdekin Falls Dam will have serious impacts on coastal environments (discussed in 8.5). This is countered to some extent by reduced instream impacts below that dam, as the lower Burdekin River already has a greatly altered flow pattern from the existing dam.

The approximate length of newly regulated river for each option is listed in Table 1. This is greatest for the Greenvale option followed in order by the other upper Burdekin options and then the Broken River options and Mt. Douglas. If an upper Burdekin dam is only used to supply water to an upper Burdekin irrigation area and not to the Burdekin Falls Dam, then the extent of downstream impacts would be less, especially as major tributaries such as Star River and Keelbottom Creek enter adjacent to the irrigation area. The Broken River options are highly unlikely to be used to supply developments on the coastal plains, thus reducing the extent of their downstream impacts.

One of the most important downstream environments that must be protected from the impacts of new developments is the Great Barrier Reef. Major factors of point here are effects on coastal fisheries and fish habitat, and nutrient and sediment run-off. Impacts on fisheries, and the productivity of coastal habitats, affected by reduced freshwater flow, can be modelled by the IQQM currently in progress by DNR. Nutrient and suspended sediment run-off are complex issues. The nature of the proposed irrigation areas is poorly defined at this stage. The extent of the land, the soil type, the crops grown and the environmental management systems will all affect the potential impacts. The issue of fine suspended sediment is different to that discussed for coarser, bedload sediment. Suspended sediments do settle within impoundments if given sufficient settling time and conditions. The amount of sediment coming from the irrigation areas needs to be balanced against the sediment trapped by the impoundment. Irrigation development that occurs upstream of the Burdekin Falls Dam (ie, in the upper Burdekin) may have reduced contaminant export because of the retention capacity of that impoundment and the other four weirs in the main Burdekin channel. Developments in closer proximity to waterways have a greater chance of run-off related problems.

The upper Burdekin and Bowen/Broken systems have similar-sized irrigation areas (~13,000-16,000ha). The former is limited by the amount of suitable land while the latter is limited by the available water resources. Both are in close proximity to major waterways which increase the risk of run-off. The upper Burdekin irrigation area is in a lower rainfall area (less run-off potential) and is above the Burdekin Falls Dam. The Elliot Main Channel has the largest potential area of irrigation development. It also has a high run-off potential and is in very close proximity to high value coastal and offshore habitats. It is thus expected to have a greater environmental impact than irrigation developments elsewhere.

Irrigation developments in the Belyando-Suttor should have the least downstream effects. Compared to the other locations being considered, an irrigation area here would have less run-off potential and a greater resilience of the receiving waters with respect to nutrient pollution (because of the existing high turbidity). The presence of the Burdekin Falls Dam downstream also provides a retention basin for contaminants. Given that there is a very large area of suitable irrigable soils in the Belyando-Suttor catchment, but limited water resources, there is the potential to restrict development to areas with the most potential and/or least environmental impacts, including utilising already-cleared land for cropping. In fact, such measures would be necessary, given the high conservation value of many of the remaining vegetation communities in the area. In this respect, it is perhaps unfortunate that the environmental effects and hydrological performance of the only potential dam site is very poor and that the preferred site for development are in areas more likely to have environmental impacts. Irrigation in this sub-catchment could be supplied by a channel from the Burdekin Falls Dam, as an alternative to the Elliot Main Channel. The distances and elevational differences are not dissimilar. As for the Elliot Main Channel, such a scheme has the most benefit if it can be supplied from the existing Burdekin Falls Dam, not an enlarged dam.

8.9 Aesthetics

This is a fairly subjective criterion. It is based not on the aesthetic appeal of the resultant impoundment, but on the loss of aesthetic values in the area affected by the impoundment. Aesthetics may be judged by values such as the naturalness or lack of disturbance to the sites (ie, land condition), clarity of the water, attractive swimming holes and recreational areas, and the presence of surrounding hills and sweeping views. Due to their steep topography and lower levels of land disturbance, Mt. Sugarloaf and particularly Urannah, have high aesthetic values. Both have attractive riparian zones and Mt. Sugarloaf has some attractive waterholes. Greenvale also has some hilly topography and attractive riparian zones. Hells Gates, Mt. Fullstop and Mt. Foxton have similar aesthetic values to each other, though Mt. Foxton also includes some rapids and will inundate part of the attractive Running River. For most people, the Mt. Douglas and Burdekin Falls Dam impoundment areas have lesser aesthetic appeal because of the relative dryness and low relief.

8.10 On-Farm Effects

This criterion covers the effects of irrigation area development, including land and water degradation, waterlogging, salinisation, contamination etc within the irrigation areas themselves. Little information is currently available on the potential irrigation areas. In the upper Burdekin, Bowen/Broken and Belyando-Suttor sub-catchments, irrigation development is planned in close proximity to major waterways. This is fraught with prospects for significant run-off and contamination of these waterways. The development of distinct irrigation blocks serviced by channels, and with defined run-off points, provide more control over run-off than a linear development that parallels the river course for a significant distance, and that has numerous contaminant exit points. The Elliot Main Channel development is in close proximity to sensitive and highly valuable coastal habitats. The irrigation areas in the Burdekin catchment may contain vegetation communities that are of limited distribution and thus have high conservation values. This is especially true for the basalt soils in the upper Burdekin, alluvial soils in the lower Burdekin (eg, at Strathalbyn), and the potential irrigation areas of the Belyando River which contain vegetation types of restricted distributions.

The nature of the irrigation areas and the types of crops that may be grown have not been ascertained. Thus it is not possible to fully comment on the on-farm effects. The size of irrigation area capable of being supported by each option, based on their yield, is one criterion for evaluation. Mt. Douglas and the two Broken River options will support similar-sized irrigation areas (Table 1) that are at least half that capable of being supported by any of the other remaining options. In the upper Burdekin, the Greenvale option will support less irrigation development than the other three options, although all four will, even at the lowest FSL's investigated, be able to support the upper Burdekin irrigation area as it is currently defined in DNR (1998). As the Greenvale options will have a lesser ability to supply development in the coastal plains, they have a more favourable score than the other three upper Burdekin options. If none of these options are used to supply water to the coastal plains, then they effectively serve the same size irrigation area. Raising of the Burdekin Falls Dam to the FSL's in the scoping study will also support large areas of irrigation development in riverine and coastal environments. For Mt. Douglas and the Broken River options, the availability of suitable irrigable land greatly in excess of the available water resources, means that there should be some opportunity to reduce on-farm effects through more judicious placement of farms (eg, on better soils or by avoiding higher value habitats). Such advantages are not apparent in the upper Burdekin or the Elliot Main Channel, where water resources greatly exceed the area of suitable irrigable land. Basaltic soils, and alluvial soils along river courses, often contain regional ecosystems of conservation value. The need to protect these areas, and to set aside some of the vegetation communities within irrigation areas for conservation, will further reduce the amount of suitable land available for development in these locations. Further restrictions may come with the need to avoid erosion-prone land. This is especially evident in the upper Burdekin where eroding gullies extend for many hundred of metres from the riverbank.

9.0 CONCLUSIONS

The purpose of this scoping study was to examine in more detail, the remaining options for water infrastructure development in the Burdekin catchment, to provide sufficient information for the Technical Advisory Panel to score these options against the MODSS criteria, and to define the most important environmental issues likely to be associated with each option. This has been done through a combination of desktop study, brief field visits to each site, and liaison with members of the Technical Advisory Panel and other stakeholders. There exists a considerable deal of uncertainty with regards to quantifying the extent of the identified environmental issues, but this is not prohibitive to their evaluation at this stage of the assessment process.

9.1 Terrestrial and Aquatic Flora and Fauna

Mapping of the impoundment areas was undertaken by vegetation communities or where available, regional ecosystems. Mapping of regional ecosystems by the EPA is in progress for all areas, and at the time of preparation of this report, was available (at least in draft form) for all sub-catchments except the upper Burdekin. This mapping confirmed the presence of 'endangered' regional ecosystems within the impoundment area of Mt. Douglas and the Burdekin Falls Dam (raising options). Vegetation communities of the upper Burdekin and Broken Rivers are of a lesser conservation significance compared to the aforementioned sites, though significant areas of riparian communities listed as being 'of concern' are present.

A total of 23 plant species of conservation significance (listed under the Qld Nature Conservation Regulation) within the vicinity of the potential impoundments were extracted from Queensland Herbarium records. Most of these occur in the Burdekin Falls Dam (14) or upper Burdekin (10) areas, with 7 from Mt. Douglas and 5 from the Broken River area. However, the coverage of data is patchy. Our brief field surveys found several additional species of conservation significance, including several records for the Cape River fan palm, *Livistona lanuginosa* (listed as Vulnerable) in the Burdekin Falls dam impoundment area, and a significant stand of *Eucalyptus raveretiana* (listed as Vulnerable) in the Urannah impoundment area.

From a survey of museum data, published and unpublished data, and our own field surveys, a total of 45 terrestrial fauna species of conservation significance are noted as occurring, or likely to be found, within one of the impoundment areas. Each of the sites on the main Burdekin River channel have over 30 species that may be present, while 25 were noted for Mt. Douglas and 22 for the two Broken River sites combined. More survey effort has been undertaken for the upper Burdekin sites than for the other locations, which probably explains the differences noted above.

Our knowledge of the fish fauna of the Burdekin River is greater than that of the terrestrial flora and fauna, although it is also biased toward the upper Burdekin. A total of 37 fish species have been recorded from the Burdekin River catchment, though 7 of these have been translocated into the catchment, or parts thereof. Two species are of high conservation value, being endemic to the Burdekin catchment. The small-headed grunter, *Scortum parviceps* only occurs upstream of Burdekin Falls and the catfish, *Neosilurus mollespiculum* is also found in low numbers in the Bowen River. In addition, the sooty grunter (*Hephaestus fuliginosus*) populations in the Burdekin represent a distinct genotype and evolutionary significant unit. Recent research on the fishes of the Burdekin catchment have revealed the close relationship, and even dependency of many species, with the pattern of river flows. Predicting the outcomes of river regulation and altered flow regime on the aquatic fauna and habitats is complex. There is a wide range of possible artificial flow regimes and the responses to each vary for different species. It is certain to say however, that it is inconceivable that alterations to the flow regime will not have a significant impact on the aquatic fauna of the Burdekin catchment. Stocking and translocations of sportfish species to impoundments is often claimed to be an environmental benefit but this claim is not justified. Such recommendations should be considered very carefully, as even native translocated fish species have already been shown to have had a significant impact upon the fish communities in the Burdekin catchment.

9.2 Environmental Assessment and MODSS Evaluation

Brief descriptions of the arguments used in scoring the development options against each criterion were presented in section 8. The scores were presented in Table 7. These scores are likely to be modified, though not substantially, after further discussion with the Technical Advisory Panel. A summary of the issues considered to be of most relevance for each option is presented below.

Greenvale
- has the highest general habitat values in the upper Burdekin
- inundates less area of land than the other upper Burdekin options
- a very large dam here may impact upon the downstream end of Valley of Lagoons area
- is a hub of fish diversity in the upper Burdekin
- dam wall may prevent fish from more stable upstream environments colonising downstream areas after natural disturbances (eg, prolonged drought)
- more permanent baseflows provide different habitat conditions to that found at other upper Burdekin sites (ie, higher uniqueness value)
- will regulate a greater length of river than any other option in the catchment
- has a lower natural spill frequency than the other upper Burdekin sites but should have a lower requirement for environmental flows than other upper Burdekin sites
- less likely to impact on flood flows and downstream sediment transport compared to other upper Burdekin sites
- less capable of supporting significant irrigation development in addition to that already identified in the upper Burdekin
- may be less likely to cause reduced water clarity compared to the other upper Burdekin sites

Mt. Fullstop
- has similar general habitat and biodiversity values as Hells Gates
- large inundation area (larger than Greenvale but smaller than Hells Gates or Mt. Foxton)
- has less yield than Hells Gates, except for highest FSL
- has greater spill frequency than Hells Gates except for highest FSL
- has potential to significantly reduce water clarity
- can support significant irrigation development in addition to that already identified in the upper Burdekin
- will take several to many years for dam to fill, especially at highest FSL
- large options may impact on flood flows and sediment transport to downstream coastal and offshore environments

Hells Gates
- has similar general habitat and biodiversity values as Mt. Fullstop
- large inundation area (larger than Greenvale but smaller than Mt. Fullstop or Mt. Foxton)
- has greater yield than Mt. Fullstop, except for highest FSL
- has lower spill frequency than Mt. Fullstop except for highest FSL
- has potential to significantly reduce water clarity

- can support significant irrigation development in addition to that already identified in the upper Burdekin
- will take several to many years for dam to fill, especially at highest FSL
- large options may impact on flood flows and sediment transport to downstream coastal and offshore environments

Mt. Foxton
- main inundation area has similar general habitat and diversity values as Hells Gates and Mt. Fullstop but will also inundate part of Running River which has higher habitat values and is a strong flowing tributary
- has the greatest probability of causing reduced water clarity unless submerging eroding land within the inundation area provide some erosion control benefits
- has a large inundation area
- regulates a lesser length of river than the other upper Burdekin options
- inundation area includes a set of rapids that may be a significant fish spawning site
- can support significant irrigation development in addition to that already identified in the upper Burdekin
- large options may impact on flood flows and sediment transport to downstream coastal and offshore environments

Burdekin Falls Dam (raising of the existing wall)
- has a very large new inundation area that will flood up several major rivers, each with significantly different habitat types (ie, higher biodiversity effects)
- inundation area includes significant length of Suttor River channel and regional ecosystems of conservation value, including some considered to be ‘endangered’
- has a very high yield but relatively low spill frequency for its location and inflows
- many impacts, such as altered water quality and flow regime have already occurred though their environmental effects have never been quantified
- an enlarged dam here may create significant problems for vulnerable coastal ecosystems if flood flows and sediment transport power are reduced
- smaller options should be evaluated for this site

Mt. Douglas
- larger option has the greatest extent on inundation for any option in the catchment
- shallow impoundment would have a widely fluctuating shoreline prone to weed invasion and significant evaporative losses
- impoundment area will inundate regional ecosystems of considerable conservation significance, including some considered to be ‘endangered’
- part of a property acquired for a national park will be inundated
- low spill frequency will affect downstream environments, unless the Suttor River (joining only 10km downstream) masks this effect
- water is already turbid so clarity will not be greatly affected
- turbid water provides greater resilience to nutrient pollution
- larger option will take many years to fill

Urannah
- close to Eungella National Park and has high habitat values along the river channels
- includes a significant stand of *Eucalyptus raveretiana*, a tree species of conservation value
- has a relatively small inundation area
- site has a low spill frequency and Eungella Dam, ~30km upstream rarely spills naturally
- clear, deep water, low and less persistent inflows will create blue-green algal problems, as occurs in Eungella Dam

- has a very large storage volume compared to the low flow at this site
- is not capable of supporting irrigation development in addition to that already identified within the Bowen/Broken catchment
- has high scenic/aesthetic values, including gorge-type country
- both options, but especially the larger option, will take many years to fill
- smaller options should be considered for this site

Mt. Sugarloaf
- is only 30km downstream from Urannah and has similar types of values, though many are not rated as highly
- inundation area is relatively small though greater than for Urannah
- higher inflows at this site mean a greater spill frequency than for Urannah, for only a small decrease in yield, from one-half to one-third the storage volume
- higher and more persistent inflows will reduce the potential for blue-green algal problems, though they should still occur
- is reported to have more valuable instream pools and fish habitat than Urannah
- dam should fill quite quickly (1-2 years)

Overall
- new large water infrastructure developments in all sub-catchments would not be sustainable
- in the upper Burdekin, habitat and biodiversity values provide limited discrimination between sites, though habitat values are highest at Greenvale and Mt. Foxton
- all upper Burdekin options at the highest FSL provide water far in excess of currently identified uses and may, in conjunction with the Burdekin Falls Dam, affect flood flows and sediment transport processes to sensitive coastal environments
- in the upper Burdekin, altered flow regimes and reduced water clarity are the issues providing the greatest discrimination between sites, and potentially the greatest environmental impacts. There is little ecosystem resilience against these impacts
- smaller options must be considered in the upper Burdekin
- inundation of ‘endangered’ regional ecosystems and a property recently acquired for a national park, is likely to be a fatal flaw for the Mt. Douglas option
- raising BFD will inundate a large area of land, including regional ecosystems of conservation value. Though some impacts on downstream riverine environments have already occurred, these have not been quantified and further development may exacerbate the situation, especially for critical and vulnerable coastal environments
- the ability of increased irrigation and urban/industrial demand in coastal areas to be met from the existing BFD must be investigated
- the Urannah and Mt. Sugarloaf options have a very high probability of regularly developing blue-green algae problems, especially at the former site
- Urannah and the larger upper Burdekin options may take several to many years to fill, significantly affecting flows to downstream environments in the meantime
- the Urannah option captures a very large proportion of the total river flow at that point and a smaller option should be considered there
- larger dam options will generally have greater impacts on coastal/marine fisheries and habitats, as will irrigation areas in coastal locations and any dam that supports such developments.
- irrigation areas upstream of existing impoundments (ie, upper Burdekin) may be less likely to export nutrients and fine suspended sediment to the Great Barrier Reef due to the retention benefits offered by the downstream impoundment

9.3 Assessing Combinations of Options and Total Catchment Water Extraction

This report has largely dealt with the water infrastructure options individually. Most comparisons have only been made between options within the same sub-catchment. This is because each sub-catchment is essentially a separate catchment and the relevant issues within each sub-catchment differ greatly. Thus it is like comparing ‘apples with oranges’. However, given that the lower Burdekin River and the coastal environments are affected by all of the upstream options, regardless of sub-catchment, it is appropriate to examine combinations of options. This exercise can be simplified by excluding combinations that are not likely to be realised. Assumptions used are that there will be no more than one dam considered in each sub-catchment and that the Mt. Douglas option will not proceed any further (although it is included on the figures for comparison). Water harvesting, serving up to 2,200ha (DNR 1998), is an option for the Belyando-Suttor sub-catchment, although few details are available.

One of the more certain recommendations that can be made, is that water for coastal developments, such as the Elliot Main Channel, should only be sourced from the Burdekin Falls Dam. Then a Broken River dam would only supply a Collinsville/Bowen River irrigation area and an upper Burdekin dam will only supply an irrigation area in that sub-catchment. Thus, the only remaining combinations to be considered are whether to proceed with 1,2 or 3 new dams/irrigation areas.

Sediment transport is one of the major issues for whole catchment management. Even though a Broken River dam would extract less water from the entire catchment than a new upper Burdekin dam, because the existing Burdekin Falls Dam traps all of the bedload sediment, flood flows from the Bowen/Broken system may be required to supply sediment to the lower Burdekin river. How the river is compensating for the entrapment of sediment behind the Burdekin Falls Dam (if it is compensating at all), is at this stage unknown, but a critical area of research. It could be that the upper Burdekin, with its larger flood flows, is supplying the power to transport sediment from the lower river to the coast, but that since construction of the existing Burdekin Falls Dam, the sediment itself has been supplied from the Bowen/Broken River. A dam in that river may reduce the supply of sediment to the lower Burdekin River. Hence, even if the Bowen/Broken system does not generate enough flood flows to transport sediment to the coast, it may be a major supplier of the sediment that is being transported to the coast by floods from the upper Burdekin. In reality, all sub-catchments contribute to sediment transport, but their relative contributions vary at different times. The issue is best dealt with through modelling approaches.

It is currently believed that although the existing dam has impacted on the frequency of small and medium flow events, large events have not been affected (there have however been only a few large events since construction of the dam to test this assertion). However, the issue goes beyond whether large flows have been impacted, because the source of the sediment being transported also needs to be determined. If sediment delivery from any of the sub-catchments is reduced, then the (unimpacted) flood flows may entrain sediment from the lower river ie. cause increased erosion.

The Burdekin catchment has a highly variable flow regime with extended periods of relatively low flow punctuated by extremely large, but infrequent, flood events. Even if large flood events are not seriously impacted by the construction of new dams, the level of extraction taken from the periods of low flow may seriously affect ecological processes within the river and in the coastal and nearshore areas. Reference to Figure 8 shows that in combination with the existing Burdekin Falls Dam, the upper Burdekin options (notionally represented by Hells Gates) will

Figure 8. Cumulative Impact of Development Options on Percentage of River Inundated and Regulated, and Water Extraction From the Total Catchment. Size of Bubble Indicates Combined Area of Water Storage and Irrigation Development
(figure supplied by P. Heaton, DNR)

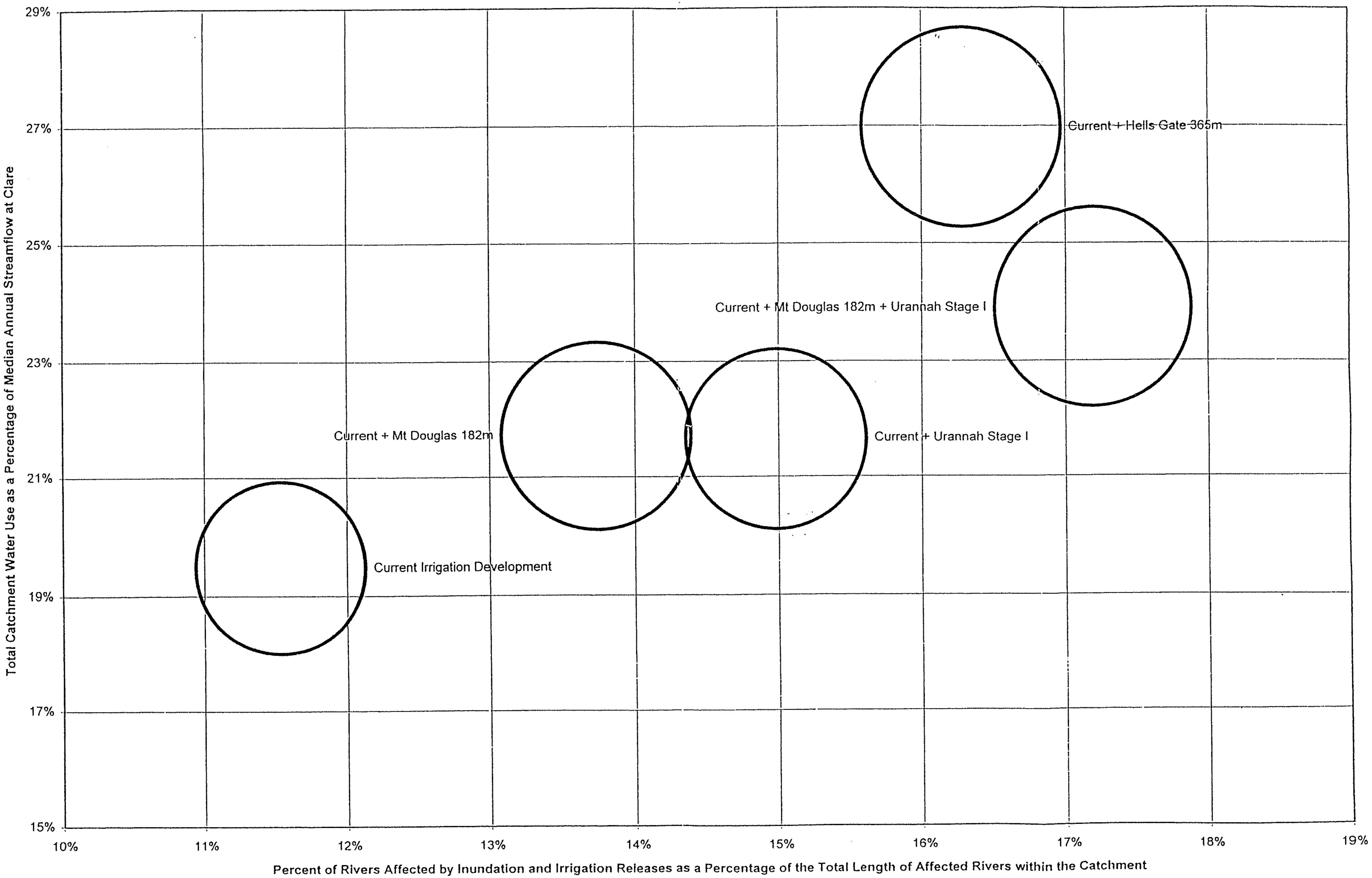
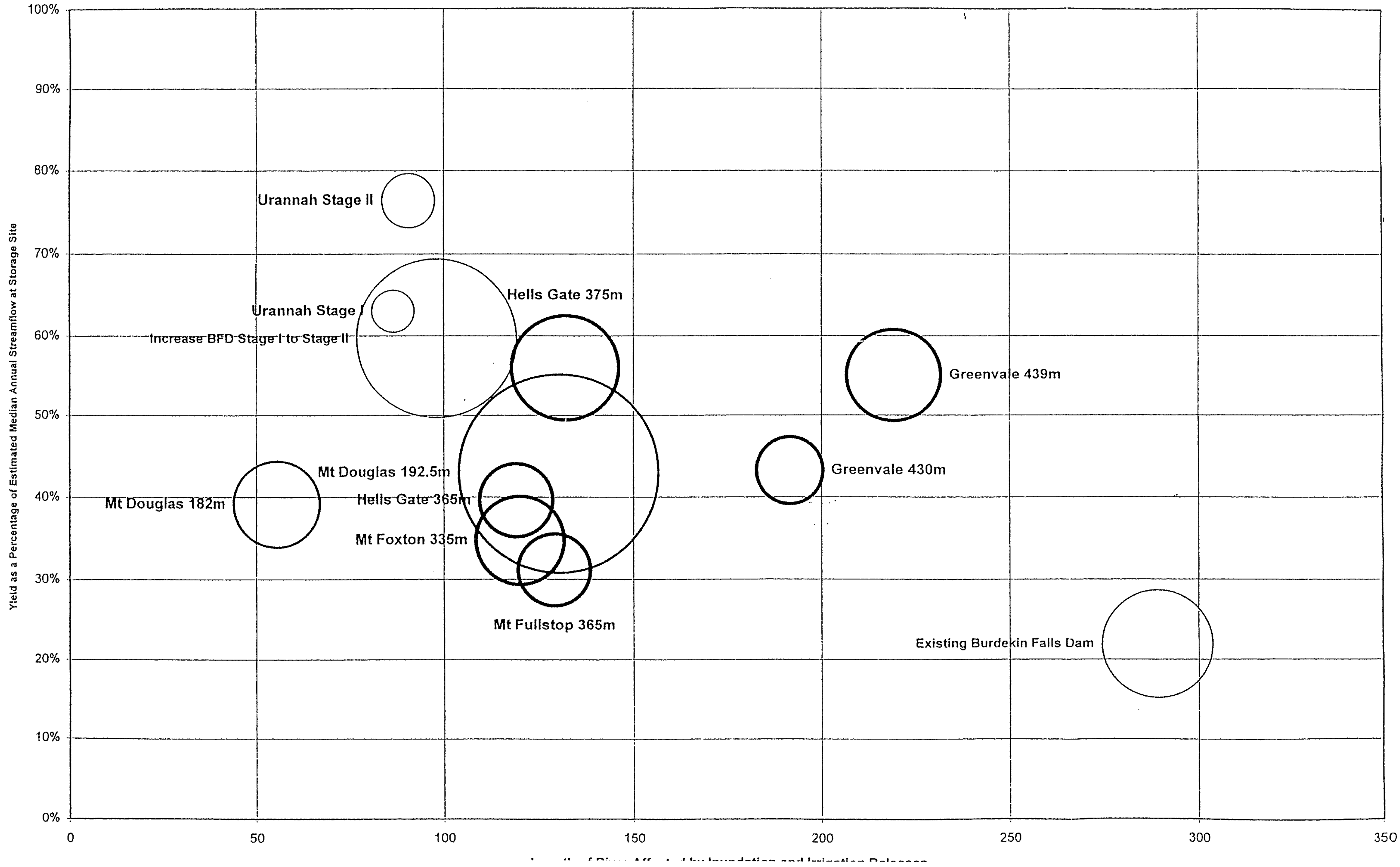


Figure 9. Impact of Each Development Option on Streamflow at Storage Site and Length of River Inundated and Regulated. Size of Bubble Indicates Area Submerged by the Impoundment. (figure supplied by P. Heaton, DNR)



produce the greatest level of water extraction from the total catchment, and will regulate a greater total length of river. In terms of water flow to the lower river and the coast, the Broken River options would be more favourable than the upper Burdekin options. Extracting from Figure 8, a combination of Urannah stage 1, the smallest Hells Gates option and even a small raising of the existing Burdekin Falls Dam, would extract more than 30% of the median annual streamflow of the entire catchment, and inundate or regulate more than 20% of the total river length within the catchment. Such a scenario runs a high risk of significant habitat degradation and disruption of ecological processes.

This discussion relates only to total catchment water extraction and impacts on the lower river and the coastal zone. Impacts within sub-catchments also need to be considered. Figure 9 shows that the relative level of water extraction of the Urannah options from their catchment area within the Bowen/Broken sub-catchment, is greater than the extraction of the upper Burdekin options from their catchment area within that sub-catchment. This demonstrates the large size of the Urannah options, relative to the flow from that part of the catchment. Also of note in Figure 9, is the significantly greater length of river inundated and regulated by the Greenvale options.

The extent of water extraction and impact on environmental flows are among the higher profile areas for assessment of new dams, especially in regard to combining impacts from several storages. Although impacts on the flow regime are very important, other issues also have a catchment-wide effect. For example, in the upper Burdekin, the major environmental concerns relate to water quality (turbidity) and this impact can occur at a level of extraction much less than that which would be estimated for flow-related parameters.

9.4 Management and Mitigation Options

Apart from considering the impacts of each dam option, there needs to be some assessment of the potential of these impacts to be managed or mitigated. In addition, options for restoring currently degraded habitats as compensation for habitats lost from new development, could be considered. A review of the myriad of management options for the numerous potential environmental impacts would be substantial. However, some comments on the potential for managing or mitigating the major environmental issues are warranted. Three Natural Resource Management Strategies are in progress for the Burdekin catchment, covering Townsville-Thuringowa, the Burdekin-Bowen floodplain and the Burdekin rangelands. These provide further details on natural resource management priorities. The draft of the Burdekin-Bowen strategy has recently been released (BIFMAC 1999).

One area of management where much effort is being directed, is that of providing environmental flows. This field is a relatively new area of study and will be included in the IQQM modelling and the WAMP process. The existing communities in the Burdekin catchment are the result of a wide variety of flow regimes and all, or even most, of the processes cannot be replicated authentically. Any selected flow regime will benefit some species whilst negatively impacting on others. The use of a variety of flow regimes, each responding to the prevailing rainfall pattern, is warranted. In such a variable catchment, it is doubtful that flow regimes covering the full range of flow-related impacts, whilst addressing the operational requirements of the water users could be successfully implemented. Key parameters and processes will need to be identified. One area of significant separation for environmental flows is that different flow regimes are appropriate for the different sub-catchments. Generalised flow regimes for the entire catchment will not be appropriate.

One of the most commonly investigated mitigation options for dam developments is that of fish passage. Usually, the issue revolves around fish species that move between freshwater and estuarine/marine waters, although within-river movements are also increasing in prominence. As the Burdekin Falls have been an effective fish passage barrier for at least 10 million years (Pusey *et al.* 1998), this is less of an issue for the Burdekin Falls Dam, the upper Burdekin options and Mt. Douglas. One exception is the apparent loss of long-finned eels from the upper Burdekin, and presumably the Belyando-Suttor, since construction of the dam. These were the only migratory fish species that could negotiate the falls prior to dam construction. Investigation into the source of passage restriction for this species is warranted.

The main fish passage issue in the Burdekin catchment is the barrier provided by Clare Weir, which has greatly reduced the fish species diversity of the Burdekin River and the Bowen/Broken system, above that point. Hogan *et al.* (1997) investigated means of providing fish passage at Clare Weir. Fish passage at this point, and at the Collinsville Weir on the Bowen River, must be re-established. Numerous smaller, but no less significant, fish passage barriers exist on the Burdekin floodplain. These include irrigation drop-boards, culverts, bund walls, artificial channels, and hydrological modifications such as reduced flooding, loss of movement pathways and connections between habitats. This has reduced fish access to important wetland nursery grounds. Many of the physical barriers are unnecessary and can be removed, whilst connectivity between isolated wetlands could be reinstated. Fish stocking could be used as a mitigation option within impoundments and upstream riverine environments. However, to date, it has only been used as a means of improving recreational fishing opportunities. The use of stocking to mitigate loss of fish passage, should involve all species affected, in appropriately balanced numbers.

Even though increased land degradation may have contributed significantly to the turbidity of the existing Burdekin Falls Dam, essentially, its turbidity is a function of the location and size of the dam. The Burdekin River naturally runs turbid in the wet season and the dam captures this flow, as well as flow from the permanently turbid Belyando-Suttor sub-catchment. Thus, there is little that can be done to clarify the dam. Extensive investment in measures to improve land condition in the catchment would be valuable environmental improvements, and may aid in reducing the turbidity, but it is questionable whether they would clarify the waters to any noticeable degree. Thus, for any new dams in the upper Burdekin sub-catchment, it may not be possible to prevent them from becoming turbid and from rendering the downstream riverine environment turbid. Their mere existence may be sufficient for this to occur. Allowing passage of as much of the wet season flows as possible, would reduce the effect. Smaller options would also have greater water clarity, due to reduced trapping of turbid flows. Options with greater water clarity, or options that alternate between turbid and clear water, will be susceptible to blue-green algae problems. However, these would be smaller options, and would have greater flushing capacities, which should alleviate the problem somewhat. Allowing elevated river turbidity is not an acceptable means of managing algal and nutrient issues.

There is a very high probability of blue-green algae outbreaks within the Broken River options. Like turbidity in the upper Burdekin, although increased nutrient run-off from human impacts can exacerbate the situation, the problem is largely a function of the size and location of the dams. The factors that promote blue-green algal outbreaks are complex, but several management options seem appropriate. In the upper Broken River, most of the additional nutrients that supply the outbreaks will come from large storm events. Sediment-bound nutrients from a large storm event may remain within an impoundment for many years, thus continually supplying the blue-green algae. Allowing the large storm events to pass should reduce the retained nutrient supply, and hopefully the severity of outbreaks (although there may be enough nutrients present within the soils of the impoundment area at the time of inundation, to supply the algae for many years). The higher natural spill frequency of the Mt. Sugarloaf option thus provides more benefits in this regard. Chemical or physical means of immobilising the sediment-bound nutrients are available, but are not generally practical, unless the need is very strong. Blue-green algae are also favoured by the development of stratification in still water bodies. Deep impoundments such as the Broken River options will develop strong stratification for most of the year. Breaking down this stratification, or increasing its depth, will require physical mixing of the water column. Destratification mechanisms include mechanical stirrers, use of multi-level off-takes to unsettle water layers when releasing water, and selective releases from the dam to disturb the water. The first option can be expensive and inefficient. The second and third options may conflict with downstream environmental objectives as water from deep layers will contain no oxygen (eg, could cause fish kills) and selective releases may not match with environmental flow requirements. The most realistic option is to have a regular, strong inflow of water to prevent/reduce the development of stratification within the dam. The Mt. Sugarloaf option will have a greater level of persistent inflow than the Urannah option, and will exchange its water more often. The Burdekin Falls Dam (and the Mt. Douglas option) is too turbid to develop blue-green algae problems, though they are present and would most likely bloom if the water clarified.

One of the more obvious impacts from development of the Burdekin Falls Dam and the Burdekin River Irrigation Area, is that turbid water from the dam/lower Burdekin is used on farms, and ultimately ends up in the ecologically valuable coastal wetlands. This has tremendously affected these habitats, especially as most wetlands have a significant submerged macrophyte community, which are vulnerable to prolonged turbidity. Restoring these valuable coastal wetlands to their former condition should be a priority for catchment management. The water clarity of these wetlands cannot realistically be restored by reducing the turbidity of the Burdekin Dam but it can be achieved by preventing release of sediments into the wetlands. This can be by water recycling systems that reduce tailwater run-off into wetlands, or where water is still going to be released into the wetlands, passing it through sediment retention ponds beforehand to reduce the fine sediment load. Mechanisms for promoting flocculation of suspended sediments within the wetlands should be treated cautiously, as rapid build-up of benthic sediments with high nutrient loads would be detrimental to natural wetlands and is best used in artificial retention ponds. Restoration of the coastal wetlands should be examined on a case-by-case basis, as the requirements for each will vary. The management of tailwater and storm run-off, control of aquatic and riparian weeds, use of buffer zones, designation and protection of conservation areas, maintenance of habitat connectivity and local water quality are among the many factors required to manage new irrigation areas.

Fencing is one of the most powerful tools available for riparian management in tropical rangelands, where cattle are the predominant land use. The predominant environmental benefits of riparian fencing is the protection of riverbanks from erosion (a significant issue along many watercourses in the catchment), improving water quality in riverine waterholes, and reducing weed infestations and improving habitat values of riparian zones. Identification of priority areas that would benefit from fencing, and allocation of funds to undertake this work, would provide substantial benefits to the riverine environments, and alleviate land degradation, erosion and turbidity issues in the catchment. Weed control, and revegetation and erosion control work, would also be of substantial benefit, especially in areas that are already degraded or are most likely to benefit from protective works. The environmental impacts of erosion and turbidity are exacerbated by dams, so fencing and erosion control works would alleviate to some extent, the effects of dams.

The most obvious management/mitigation option that would engender the highest level of environmental protection, would involve the least research and management costs, would reduce capital construction costs and is the most reliable, is to identify and implement water conservation measures in all aspects of water usage. This way, the smallest possible impoundments required to meet the identified demands can be considered. It is not realistically achievable to manage even a reasonable percentage of the wide variety of environmental impacts that result from water infrastructure developments. Environmental restoration is very expensive and difficult. Preventing impacts is the best way to manage them. By far, the most important factor affecting the environmental sustainability of dams is their size. Consideration of all measures possible to increase water use efficiency and reduce water demand is of paramount importance and will make the most significant difference to the capacity to manage environmental impacts resulting from new water infrastructure developments.

9.5 Overall Conclusions

After a more detailed assessment of environmental issues associated with the Mt. Douglas dam site, Burrows *et al.* (1999) recommended that this option would not be suitable as a dam site. Although a dam at this site is not without other environmental problems, this recommendation was based on the large extent of regional ecosystems considered to be ‘endangered’ or ‘of concern’ within the impoundment area, and more importantly, the acquisition of Nairana (a property within the impoundment area) for a national park. Further advice can be sought from the Queensland Herbarium, EPA on the importance of the vegetation communities within the impoundment area, and their level of representation in other parts of the state.

There are also significant issues associated with the raising of the Burdekin Falls Dam. Several regional ecosystems of conservation value (‘of concern’ and ‘endangered’) are present within the increased impoundment area, especially within the Suttor River arm, which because of its topography, is where the greatest area of increased inundation would occur. Probably of most concern, are the hydrological and downstream impacts of such a large reservoir. The flow regime in the 159km of river downstream of the existing dam has already been altered for over 10 years, and the imposition of new impacts on this length of river would be less compared to the imposition of a new flow regime on an unregulated river. However, the coastal environments are of greater concern. The significant geomorphological features of the Burdekin delta, coastline and Cape Bowling Green, are supplied by sand from the Burdekin River. Reductions in delivery of sand, largely through reductions in the frequency of medium-large flow events may pose a serious threat to these coastal features. The impact of such a large dam on sediment transport processes and coastal environments is a critical point, as is its impact on coastal/marine fisheries. An option for a smaller raising of the dam wall at this site would be evaluated more favourably and should still meet future water demand.

In the upper Burdekin, the Greenvale site has the highest general terrestrial and aquatic values and at the highest full supply level, may even impinge on the downstream part of the Valley of Lagoons area and Reedy Brook Creek. Mt. Foxton at full supply level would inundate Running River up to the base of the falls/gorge area. This river has high environmental values and its source in Wet Tropics World Heritage Area ensures a relatively high quality water flow. In the upper Burdekin, the four options have many similar characteristics, though the Greenvale site would be considered to have the highest general environmental values and a dam here would regulate a greater length of river than the other sites. However, it is believed that altered flow regimes and the prospects for reduced water clarity will be the most impactful aspects of new dams in this sub-catchment. On these grounds, and the smaller size of the dam options available, the Greenvale option has ranked most preferred within this sub-catchment. Further research into the turbidity issues may ultimately be a major deciding factor though.

In the Broken River, the Urannah option has a number of disadvantages compared to the Mt. Sugarloaf option, most notably the proximity to Eungella National Park, the higher habitat and aesthetic qualities of the impoundment area, the lower spill frequency and increased problems with blue-green algae outbreaks. The storage capacity of the larger Urannah option is 4-5 times the mean annual flow and 7-8 times the median annual flow at that point, and would take many years to fill. As the Urannah catchment area captures approximately 40% of the total Bowen River flow, this would be a significant imposition on the downstream riverine environments. Both Urannah options are considered too large for a site this far up a catchment that has few other downstream sources of water. To date, most water storage investigations in the Broken River have focused on the Urannah site. The Mt. Sugarloaf site has only been investigated as a site for a weir in 1967 but is worthy of an updated and more detailed assessment. The two sites are close enough that they could, in a cost-effective manner, be further investigated together to ensure that informed decisions are made.

One important and highly relevant conclusion that is applicable across all of the different potential dam sites, is that the size of the proposed dam has a significant impact on its environmental evaluation. At the Burdekin Falls, and in the upper Burdekin, the options evaluated are all much greater than required by the uses identified for the near future. The Urannah options are very large for the level of water flow that passes that point. Smaller options at these sites would be evaluated more favourably and would provide a more realistic view of environmental impacts. For example, in the upper Burdekin, the Hells Gates, Mt. Fullstop and Mt. Foxton options are all significantly larger than the Greenvale option, and as would be expected, have been scored less favourably. Evaluation of comparable-sized options at these sites have more merit and would allow assessment of the actual sites, free from the bias of dam size. In fact, the further down river the sites are, the smaller the storage area needs to be to supply the same required yield. Thus, options at the downstream sites that actually have a lesser storage capacity than that at more upstream sites should be considered. The appropriate parameter for comparison is the size of dam required to provide a given yield. The descriptive evaluations in this report have tried, where possible, to evaluate the merits of each site and the full range of FSL's that might be possible at each rather than the specific FSL's currently proposed. This is of course done in the absence of data on smaller options, but these can be inferred from the existing data for the larger options. The MODSS evaluations however, are strictly based on the FSL's supplied from DNR.

New water infrastructure developments of the size currently being evaluated in each of the major sub-catchments (upper Burdekin, lower Burdekin and Bowen/Broken) would not be ecologically sustainable. All of the options evaluated will cause significant environmental changes, including changes that cannot be effectively managed. The preferred scenario is to make better use of the existing Burdekin Falls Dam.

On balance, environmentally preferable scenarios for progression to the next stage of assessment would be along the lines of the following:

1) Do not proceed further with the Mt. Douglas option. However, water harvesting is an option for the Belyando-Suttor catchment that can still be pursued.
2) Only raise the existing Burdekin Falls Dam by the amount required after full water conservation measures for existing and future users have been investigated. With increased water conservation measures (eg, tailwater recycling in the BRIA), it should be possible to supply much of the projected new developments (eg, Elliot Main Channel) from the existing dam. There seems little justification at this stage for the large options considered in this study. The environmental impacts from these would be considerable, potentially even catastrophic, particularly on coastal environments, and in all likelihood, they would be

practically irreversible. The environmental impacts of a smaller option could be readily evaluated under the same MODSS simulations currently being conducted.

3) In the Bowen/Broken sub-catchment, the Mt. Sugarloaf option may has several environmental advantages over the traditionally more-fancied Urannah option. Both options are in a similar location and have similar yields, though the Mt. Sugarloaf option has only half the storage volume of the Urannah option and would fill many years before a dam at Urannah. It should also have less environmental flow requirements and less blue-green algae problems. The Urannah options investigated here are very large for the catchment location and flow, and a smaller option should be considered. These options are located very close to each other and should be further investigated together.
4) In the upper Burdekin sub-catchment, the Greenvale option, despite having higher general habitat values and regulating a greater length of river, is considered more favourable due to a perceived lesser impact from reduced water clarity, compared to the other sites there. If further investigation into the turbidity issue reveals that it is not as problematic as indicated in this report, then either Hells Gates or Mt. Fullstop may be more preferable. Comparisons between the upper Burdekin sites are confounded by unequal size of the options, even though they will all supply the same needs.
5) Water for development in the coastal plains should be sourced from the Burdekin Falls Dam, not an upper Burdekin dam. Such uses would utilise a greater length of the upper Burdekin as a water delivery channel and thus significantly increase environmental impacts. This being the case, there is little justification for the large dams being considered within the upper Burdekin. Even the smallest option at each site will supply a great excess of water above that required to service the entire irrigation area identified in the scoping study as being within an economically commandable distance of the upper Burdekin River. In addition, the larger options may take many years to fill and may impact on flood flows and sediment transport processes to the coastal plains.

10.0 RESEARCH NEEDS AND FURTHER WORK

There are numerous environmental issues associated with water infrastructure development, and many of these involve complex process-type interactions that are not easily evaluated, especially in isolation from other potential impacts, or over short time frames. This study has attempted to identify some of the major environmental issues and knowledge gaps (listed below in no particular order) that will be relevant to water infrastructure development in the Burdekin. Topics 5 and 6 would more accurately define the water infrastructure needs, and whether enlarging the Burdekin Falls Dam is even necessary, while topic 7 will provide more information for a large part of the developments that have not been evaluated. The most fertile areas for further work in the Burdekin catchment include; assessments of the effects of altered flow regimes; sediment delivery to downstream environments; the potential limnology of the impoundments and its impacts on water quality; and impacts of the existing dam (topics 1,2,3 and 4). Topics 1-4 will provide essential predictive capabilities for issues that will need to be addressed as part of any development, but for which several years of investigation are required. Several of these issues are also generic enough to have a high degree of relevance to water infrastructure developments elsewhere.

1) Effects of Altered Flow Regimes on Riverine Environments

Many of the hydrological changes related to the extent of water abstraction and alterations to the flow regime can be answered by simulations of the IQQM process currently in progress. The biological consequences of the modelled hydrological regimes, and the possible existence of threshold effects, remain to be determined but are the relevant criteria for assessment. Environmental flow techniques such as benchmarking, are being undertaken in other catchments (eg, Pioneer) prior to decisions on further water extraction. There is an existing dataset on the relationship between freshwater fish communities and flow regimes in the upper Burdekin River that can be compared to various modelled flow scenarios. Such data does not exist for the Bowen River but is an appropriate area of inquiry, especially given the different flow pattern there. There are also techniques that estimate the flow pattern required for riverine parameters such as channel maintenance.

2) Effects on Sediment Transport

The existing Burdekin Falls Dam probably traps all of the bedload entering its impoundment. The effect of this, and any new dam, on sediment availability, and the effect of increased water storage on flood flows capable of sediment transport, is of critical importance. Such investigations will determine impacts on the valuable and vulnerable coastal environments, and the patterns of deposition and erosion within the river channels below any impoundment.

3) Impoundment Limnology

A comparative study of the limnology of existing impoundments, and the likely limnology of potential new impoundments, is required in order to provide a predictive capacity of their performance. Where water is released downstream for any purpose, the limnology of the impoundment (along with the flow regime) has a very strong effect on the downstream impacts within the riverine environments. Impoundment limnology will be particularly important for assessing the potential for blue-green algae problems at the Broken River sites and assessing the potential for reduced water clarity in the upper Burdekin.

Central to water clarity in the upper Burdekin is the source and grain size of the suspended sediment, the erosion potential of the catchment area for each site and the relationship of turbidity to expected flow. This will determine the potential for each site to remain turbid or to clarify as the dry season progresses. Such investigations should also be able to determine where land improvement programs (eg, as mitigation options) would best be targeted. The other aspect of research on this topic is whether the upper Burdekin options are sufficiently large (trap a sufficient volume of turbid wet season flows) that they will become turbid, regardless of the erosion potential within their catchment areas. Data from the existing gauging stations can be combined with regular turbidity/suspended solids measurements, including over the course of storm event hydrographs, to indicate the potential for this to occur. Such studies may require several years of baseline measurement, as several large events need to be measured, as well as the dry season progression of improved water clarity.

4) Assess Impacts of the Existing Burdekin Falls Dam

The effects of the existing Burdekin Falls Dam have never been evaluated, but would provide key data on the likely effects of any new dam developments, including enlargement of this dam. There are a few opportunities for before and after comparisons using datasets collected prior to the dam construction. These include reviewing water clarity records for DNR gauging stations and the South Burdekin Water Board. Aerial photographs, survey data and other historical records will provide before and after data for coastal and riverine geomorphological processes. For other riverine parameters where before and after comparisons are not possible, above and below dam comparisons can be made.

5) Investigate Improved Water Conservation Measures

Given the scarcity of water resources in Australia, water conservation efforts receive surprisingly little attention, and are not usually included in future demand scenarios. The opportunities for water savings are seen as significant, especially in the urban/industrial areas and in the Burdekin River Irrigation Area. Investigation of the potential water savings and mechanisms for motivational, governmental and institutional support for such schemes, would better determine the future water demand scenarios and the infrastructure required to support them. One specific question is whether improved water conservation measures can make available some of the water resources from the Burdekin Falls Dam that are currently fully committed, and reduce, delay or negate, the need for raising this dam.

6) Evaluation of Smaller Water Storages

While the above studies are necessary to evaluate the relative impacts of various impoundment options, there are several key areas of the evaluation process that can be altered to provide alternative outcomes in the assessment process. Many of the options presented for evaluation (eg, upper Burdekin dams and raising BFD) are much larger than is required by the presently identified water uses. Larger dams will nearly always be rated as more environmentally damaging than smaller dams. Evaluation of options that supply only the currently identified demand would provide improved comparability across sites throughout the catchment.

7) Further Assessment of the Likely Irrigation Developments

The impacts of irrigation area development resulting from construction of new water storages are a considerable component of the overall impact of any water infrastructure development. Appropriate evaluation of the water storage options in the Burdekin catchment requires more detailed directions on the likely configurations of irrigation areas that will be served from each of the proposed storages. Important issues include likely crop mix, environmental values of the irrigation areas, proximity to riverine and coastal environments, salinity potential, erosion and run-off potential.

8) Baseline Studies of the Burdekin River

The most important issue in determining the existence of environmental changes and to devise appropriate management regimes, is to quantify the change that has occurred. Developing baseline datasets of water quality, habitat and flow requirements of instream flora/fauna, riverine and coastal geomorphology allows this to occur.

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APPENDIX A Summary of regional ecosystems identified from each of the prospective dam sites. Information presented includes conservation status, occurrence at each site and a qualitative assessment of extent that the regional ecosystems of conservation significance are affected. The lists presented are indicative only, and are represented only as the results of a review of existing mapping and brief field visits. The assessment is based on the mapping as it currently stands. The most advanced mapping is available for the Burdekin Falls Dam and Mt. Douglas options. The least advanced is for the upper Burdekin options.

UPPER BURDEKIN OPTIONS

VEGETATION UNIT	CORRESPONDING REGIONAL ECOSYSTEM	CONSERVATION STATUS	EXTENT OF OCCURRENCE			
			GREENVALE	MT. FULLSTOP	HELLS GATES	MT. FOXTON
1. Low flood-pruned woodland to tall forest in channels and on bank of rivers and larger creeks.	9.3.1	**Of Concern**	Common along main river channels	Common along main river channels	Common along main river channels	Common along main river channels
2. Woodland on river levees, terraces, minor back-channels and backswamps with a sparse or absent mid-stratum and grassy ground stratum	On levees – 9.3.2 On terraces – 9.3.3 Backchannels/swamps - 9.3.4	No Concern **Of Concern** **Of Concern**	Abundant	Abundant	Abundant	Abundant
3. Woodland on stony hills on Mt. Fullstop Range and north side of Hells Gates	No corresponding ecosystem	May Be **Of Concern**	Probably not present	Limited	Limited	Limited
4. Woodland on smaller creeks. Including banks and minor levees and terraces	9.3.1	**Of Concern**	Common on creeklines	Common on creeklines	Common on creeklines	Common on creeklines
5. Woodland on flat to low hilly areas	9.11.5	No Concern	Abundant	Abundant	Abundant	Abundant
6. Open to low open woodland from gentler slopes to steep rocky hills	No corresponding ecosystem	May Be **Of Concern**	Not located	Not located	Not located	Common along Running River arm
7. Semi-evergreen vine thicket on limestone outcrops	9.11.8	**Of Concern**	Not located	Rarely located	Rarely located	Not located
8. Evergreen vine thicket on basalt, in mosaic with vine forest and wetlands	9.8.3	**Of Concern**	Rarely located	Not located	Not located	Not located
9. Woodland on hills	No corresponding ecosystem	May Be **Of Concern**	Rarely located	Not located	Not located	Not located

DESCRIPTION OF VEGETATION UNITS FOR THE UPPER BURDEKIN (by Russell Cumming, EPA)

1. Low flood-pruned woodland to tall forest in channels and on banks of rivers and larger creeks.

In channels; *Melaleuca fluviatilis* with minor *Casuarina cunninghamiana, Callistemon viminalis, Lophostemon grandiflorus* and *Melaleuca linariifolia*. Some *Melaleuca leucadendra* and *Acacia aulacocarpa* in higher rainfall areas (eg. upper Running River). Mid and ground strata mostly absent.
On banks; *Eucalyptus tereticornis, E. camaldulensis* and/or *E. camaldulensis / tereticornis* intergrades, with *Corymbia tessellaris* and a sparse or absent mid stratum and grassy ground layer.

2. Woodland on river levees, terraces, minor back-channels and backswamps with a sparse or absent mid stratum and grassy ground stratum.

On levees; *Eucalyptus crebra, Corymbia. tessellaris* and *C. erythrophloia.* Minor *E. confertiflora* occurs north of Lucky Downs.
On terraces; *Eucalyptus crebra, E. brownii, E. platyphylla* and *Corymbia clarksoniana. Eucalyptus leptophleba* occurs in the northernmost part of the Greenvale inundation area, near Reedy Brook.
On back-channels and fringing swamps; *Eucalyptus tereticornis, E. camaldulensis*, intergrades, *E. platyphylla* and/or *E. brownii.*

3. Woodland on stony hills on Mt Fullstop Range and north side of Hells Gates.

Mosaic of *Acacia shirleyi, Corymbia leichhardtii, E. persistens, E. lamprophylla* and various mid stratum species such as *Alphitonia excelsa, Erythroxylum australe, Acacia nuperrima, Lamprolobium fruticosum, Bursaria incana,* etc. Ground stratum grassy.

4. Woodland on smaller creeks, including banks and minor levees and terraces.

From largest to smallest creeks, dominant species include; *Eucalyptus tereticornis, E. camaldulensis, Melaleuca fluviatilis, Lophostemon grandiflorus* and *Melaleuca bracteata.*

5. Woodland on flat to low hilly areas.

Mosaic of *Eucalyptus crebra, E. persistens* and *E. melanophloia.* Minor *E. brownii* on flats. Mid stratum sparse to absent. Ground layer grassy.

6. Open to low open woodland from lower gentle slopes to steep rocky hills.

Lower slopes with *Eucalyptus drepanophylla* and *Corymbia dallachiana.* Hills with *C. leichardtii, E. lamprophylla, E. shirleyi, Cochlospermum gillivraei*. Mid stratum sparse or absent. Ground stratum mostly with *Triodia* sp.

7. Semi-evergreen vine thicket on limestone outcrops.

Species include *Pleiogynium timorense, Gyrocarpus americanus, Pouteria cotinifolia, Drypetes deplanchei, Grewia scabrella* and many others. Canopy and mid stratum not differentiated. Ground stratum sparse to absent.

8. Evergreen vine thicket on basalt, in mosaic with vine forest and wetland areas (not examined). Actual thickets unable to be accessed for species list description.

9. Woodland on hills (not examined).

Eucalyptus howittiana (probably), *E. persistens, Acacia burdekenensis* and ?*E. trachyphloia*. Mid stratum sparse to moderate. Ground stratum sparse to moderate, sometimes with *Triodia* sp.

BURDEKIN FALLS DAM OPTIONS

REGIONAL ECOSYSTEM	CONSERVATION STATUS	PROBABLE OCCURRENCE IN IMPOUNDMENT AREA
9.3.1 *Eucalyptus camaldulensis* or *E. tereticornis* woodlands in channels and on alluvial flats and levees of larger watercourses.	**Of Concern**	Common along Burdekin and Sellheim River channels and on many tributaries
9.3.3 Mixed eucalypt woodland on alluvial terraces of larger watercourses. Includes *Eucalyptus platyphylla* and *Corymbia tessellaris*.	**Of Concern**	Common along Burdekin River and Sellheim River channel
9.3.5 *Eucalyptus brownii* woodland on sand plains	No Concern	Along river channels in upper parts of impoundment
9.3.6 *Eucalyptus platyphylla* woodland on yellow podzolics in gentle drainage depressions of tertiary plateaus.	No Concern	Common in Lornesleigh area of impoundment
9.5.3 *Eucalyptus crebra* and *Corymbia dallachiana* woodland on yellow earths of tertiary plains.	**Of Concern**	Limited occurrence in Cape River area of impoundment
9.5.4 *Eucalyptus melanophloia* woodland on yellow earths of tertiary plains	**Of Concern**	On undulating terrain near the river channel.
9.7.1/9.11.5/11.7.3/11.11.12 *Eucalyptus persistens* +/- *Triodia mitchelli* +/- *Corymbia lamprophylla* low open woodland on stripped margins of Cainozoic sand plains.	No concern at present	Very common within impoundment area
9.7.2 *Acacia shirleyi* open forest on skeletal soils and red earths	**Of Concern**	Along Suttor River arm of impoundment
9.8.1 Open woodland of *Eucalyptus crebra* with sparse tussock grass ground layer.	No Concern	On hilly terrain, mostly within highest impoundment option
9.11.1 *Eucalyptus melanophloia* +/- *E. shirleyi* low open woodland.	No Concern	Limited occurrence in impoundment area near Burdekin-Suttor junction
9.11.2 *Eucalyptus crebra* and *Corymbia dallachiana* woodland	No Concern	Found on undulating low hills, mostly in upper part of impoundment area
9.12.1 Woodland of *Eucalyptus crebra*, bloodwoods and deciduous softwood species on undulating to hilly terrain.	No Concern	Dominates woodland areas away from the river channel
9.12.4 *Eucalyptus shirleyi* low open woodland with sparse tussock grass ground layer.	No Concern	Limited occurrence near Burdekin-Suttor junction and mostly only affected by highest impoundment option.
9.12.5 *Corymbia* spp. woodland on gently sloping terrain	No Concern	Moderately common in impoundment area
11.3.1 *Acacia harpophylla* woodland often with *Geijera parviflora* and *Eremophila mitchellii* +/- emergent eucalypts.	**Endangered**	Limited occurrence
11.3.4 Tall woodland or open forest of *Eucalyptus tereticornis* or *E. camaldulensis* on alluvial plains.	**Of concern**	Moderately common along river channels

11.3.7 *Corymbia clarksoniana* and *C. tessellaris* woodland sometimes with *C. dallachiana*. Sparse understorey of forbs and grasses.	**Of Concern**	Limited occurrence
11.3.9 *Eucalyptus platyphylla* woodland with *Corymbia clarksoniana* and *C. tessellaris* and a sub-canopy and shrub layer of *Petalostigma pubescens*. Ground layer of forbs and grasses.	No Concern	Woodland of alluvial plains and lower parts of hills.
11.3.10 Grassy woodland of *Eucalyptus brownii* on Cainozoic alluvial plains.	No concern at present	On undulating terrain near the river channel.
11.3.12 *Melaleuca viridiflora* woodland, often with *Eucalyptus platyphylla*, *Corymbia clarksoniana* and *C. dallachiana* emergents.	**Of Concern**	Limited occurrence
11.3.25 Fringing woodland of *Eucalyptus tereticornis* or *E. camaldulensis*, generally with *Casuarina cunninghamiana*, *Callistemon viminalis* and *Angophora floribunda* on alluvial plains.	**Of concern**	Moderately common occurrence of woodland and fringing forest of stream channels.
11.5.3 Shrubby woodland of *Eucalyptus populnea* and/or *E. melanophloia* +/- *Corymbia clarksoniana* +/- *C. dallachiana*.	No concern at present	On undulating terrain near the river channel.
11.11.1 Low woodland of *Acacia rhodoxylon* with sparse tussock grass ground cover.	No concern	Limited occurrence on skeletal sandstone-derived soils near Burdekin-Suttor junction. May already be flooded by existing impoundment
11.11.1 *Eucalyptus crebra* +/- *Acacia rhodoxylon* woodland with sparse grass ground layer.	No concern	Limited occurrence on hills, mostly above impoundment area
11.11.8 *Eucalyptus shirleyi* woodland on low hills	No Concern	Common on north side of existing impoundment.
11.11.10 *Eucalyptus melanophloia* grassy or shrubby low woodland +/- *E. crebra*, *Corymbia dallachiana* or *C. erythrophloia*.	No Concern	Common in existing impoundment and in new areas to be flooded
11.11.15 *Eucalyptus crebra* +/- *Corymbia erythrophloia* +/- *E. populnea* +/- *E. melanophloia* +/- *C. tessellaris* +/- *C. clarksoniana* woodland. Understorey often shrubby.	No concern at present	Found on undulating low hills, mostly in upper part of impoundment area
11.12.1 Woodland of *Eucalyptus crebra* +/- *Corymbia erythrophloia*, often with a sparse and variable substratum and a grass ground layer.	No Concern	Common around lower areas of existing impoundment
11.12.2 *Eucalyptus crebra* and/or *E. melanophloia* +/- *Corymbia dallachiana* open woodland.	No Concern	Mostly on low hills around existing impoundment area
11.12.5 Open woodland of *Corymbia leichhardtii* with *Eucalyptus crebra* and sparse tussock grass ground layer.	No concern	On hilly terrain, mostly within highest impoundment option
11.12.7 *Eucalpytus crebra* woodland with patches of semi-evergreen vine thicket.	No Concern	Limited occurrence on rocky hills
11.3.3 Grassy woodland to open woodland of *Eucalyptus coolabah* on Cainozoic alluvial	**Of concern**	Extensive along Suttor River channel and over much of the

plains. Sometimes as a grassland (e.g. *Astrebla lappacea*) with emergent *E. coolabah*. Other tree spcies present e.g. *Melaleuca bracteata* and *Acacia pendula*.		alluvial plain
11.3.8 Woodland of *Acacia argyrodendron* on Cainozoic alluvial plains.	**Of concern**	Along Suttor River in upstream area of impoundment
11.3.9 *Eucalyptus platyphylla* woodland with *Corymbia clarksoniana* and *C. tessellaris* and a sub-canopy and shrub layer of *Petalostigma pubescens*. Ground layer of forbs and grasses	No Concern	Common in Lornesleigh area of impoundment
11.3.15 Fringing woodland of *Eucalyptus coolabah* with *Acacia stenophylla* and *Meuehlenbeckia cunninghamii* on Cainozoic alluvial plains. Stream channels with heavy soils that remain swampy for long periods.	**Of concern**	Extensive along Suttor River channel and over much of the alluvial plain
11.4.5 *Acacia argyrodendron* woodland +/- understorey of *Terminalia oblongata* and *Eremophila mitchellii* on Cainozoic clay plains.	**Endangered**	Along Suttor River in upstream area of impoundment
11.4.8 *Eucalyptus cambageana* +/- *Acacia harpophylla* +/- *A. argyrodendron* woodland on Cainozoic clay plains.	**Of concern**	Along Suttor River in upstream area of impoundment and near Harvest Home on the Cape River arm
11.5.3 Shrubby woodland of *Eucalyptus populnea* and/or *E*. *melanophloia* +/- *Corymbia clarksoniana* +/- *C*. *dallachiana* on Cainozoic sand plains. Understorey includes *Eremophila mitchellii*, *Geijera parviflora* and *Ventilago viminalis*.	No concern at present	Limited occurrence in Cape River area
11.5.12 *Corymbia clarksoniana* +/- *Corymbia* spp. woodland on colluvial lower slopes of Cainozoic sand plains	No Concern	Common in Cape River arm but often away from impoundment area
11.7.2 Monospecific stands of *Acacia* forest/woodland on lateritic duricrusts. Species include *Acacia shirleyi*, *A*. *catenulata*, *A*. *burrowii*, *A*. *sparsifolia*, *A*. *crassa*, *A*. *blakei* and *A*. *microsperma*. Emergent eucalypt species may be present e.g. *Eucalyptus thozetiana*, *E*. *decorticans* and *E*. *exserta*.	No concern at present	Found in Suttor arm of impoundment
11.7.3 *Eucalyptus persistens* and *Triodia mitchellii* low open woodland on stripped margins of Cainozoic sand plains.	No concern at present	Moderately common in lower Suttor River arm
11.11.2 *Acacia shirleyi* or *Acacia catenulata* low open forest +/- emergent eucalypts	No Concern	Limited occurrence on hills in Cape River arm and lower Suttor area of impoundment
11.11.9 *Eucalyptus brownii* open woodland/woodland on moderately to strongly deformed metamorphosed sediments and interbedded volcanics	No Concern	Mostly in lower reaches of the Suttor River arm
11.11.13 *Acacia harpophylla* +/- *Acacia argyrodendron* shrubby low open forest or woodland.	**Of Concern**	On low hills around Cape River and Suttor River part of impoundment

MT. DOUGLAS OPTION (from Burrows *et al.* 1999)

REGIONAL ECOSYSTEM	CONSERVATION STATUS	AFFECTED BY 182 m PROPOSAL	POTENTIAL AFFECT (182 m)	AFFECTED BY 192 m PROPOSAL	POTENTIAL AEFFECT (192m)
9.12.4 *Eucalyptus shirleyi* low open woodland on skeletal soils on hilly acid or intermediate volcanic and igneous rocks	No concern at present	No	n/a	yes	n/a
11.3.1 Open forest of *Acacia harpophylla* and/or *Casuarina cristata* with low trees *Geijera parvifolia*, *Eremophila mitchelli* +/- emergent *Eucalyptus* spp. e.g. *E. coolabah*, *E. populnea*, *E. pilligaensis* on Cainozoic alluvial plains. Cracking clay soils.	**Endangered**	Yes	High	yes	High
11.3.3 Grassy woodland to open woodland of *Eucalyptus coolabah* on Cainozoic alluvial plains. Sometimes as a grassland (e.g. *Astrebla lappacea*) with emergent *E. coolabah*. Other tree spcies present e.g. *Melaleuca bracteata* and *Acacia pendula*.	**Of concern**	yes	High	yes	High
11.3.4 Tall woodland or open forest of *Eucalyptus tereticornis* or *E. camaldulensis* on Cainozoic alluvial plains. Other species that may be present include *Corymbia tessellaris*, *E. coolabah*, *C. clarksoniana*, *E. populnea* or *E. brownii*, *E. melanophloia*, *E. platyphylla*, *Angophora floribunda*, *Lophostemon suaveolens*.	**Of concern**	yes	High	yes	High
11.3.5 Low woodland or open forest of *Acacia cambagei*, sometimes clumped, on Cainozoic alluvial plains.	**Of concern**	yes	High	yes	High
11.3.7 Tall woodland of *Corymbia clarksoniana*, *C. tessellaris* and *C. dallachiana* on Cainozoic alluvial plains. Sandy soils.	**Of concern**	yes	Medium	yes	Medium
11.3.8 Woodland of *Acacia argyrodendron* on Cainozoic alluvial plains.	**Of concern**	yes	High	yes	High
11.3.10 Grassy woodland of *Eucalyptus brownii* on Cainozoic alluvial plains.	No concern at present	no	n/a	yes	n/a

REGIONAL ECOSYSTEM	CONSERVATION STATUS	AFFECTED BY 182 m PROPOSAL	POTENTIAL AFFECT (182 m)	AFFECTED BY 192 m PROPOSAL	POTENTIAL AEFFECT (192m)
11.3.15 Fringing woodland of *Eucalyptus coolabah* with *Acacia stenophylla* and *Meuehlenbeckia cunninghamii* on Cainozoic alluvial plains. Stream channels with heavy soils that remain swampy for long periods.	**Of concern**		High	yes	High
11.3.25 Fringing woodland of *Eucalyptus tereticornis* or *E. camaldulensis*, generally with *Casuarina cunninghamiana*, *Callistemon viminalis* and *Angophora floribunda* on Cainozoic alluvial plains. Fringing forest and woodland. Stream channels especially in eastern parts of bioregion.	**Of concern**	No	Low	yes	Low
11.3.27 Freshwater wetlands with aquatic vegetation (lagoons) associated with Cainozoic alluvial plains.	**Of concern**	No	Low	yes	Low
11.4.5 *Acacia argyrodendron* woodland +/- understorey of *Terminalia oblongata* and *Eremophila mitchellii* on Cainozoic clay plains.	**Endangered**	yes	Medium	yes	Medium
11.4.6 *Acacia cambagei* woodland +/- understorey of *Terminalia oblongata* and *Eremophila mitchellii* on Cainozoic clay plains.	**Of concern**	yes	Medium	yes	Medium
11.4.8 *Eucalyptus populnea*, *Acacia harpophylla* +/- *Casuarina cristata* and *Eremophila mitchellii* on Cainozoic clay plains.	**Of concern**	yes	Medium	yes	Medium
11.4.9 *Acacia argyrodendron* woodland +/- understorey of *Terminalia oblongata* and *Eremophila mitchellii* on Cainozoic clay plains.	**Endangered**	yes	High	yes	High
11.5.3 Shrubby woodland of *Eucalyptus populnea* and/or *E. melanophloia* +/- *Corymbia clarksoniana* +/- *C. dallachiana* on Cainozoic sand plains. Lowlands. Deep red earths. Understorey includes *Eremophila mitchellii*, *Geijera parviflora* and *Ventilago viminalis*.	No concern at present	no	n/a	yes	n/a

REGIONAL ECOSYSTEM	CONSERVATION STATUS	AFFECTED BY 182 m PROPOSAL	POTENTIAL AFFECT (182 m)	AFFECTED BY 192 m PROPOSAL	POTENTIAL AEFFECT (192m)
11.5.9 *Eucalyptus crebra* and/or *Corymbia citriodora* woodland on Cainozoic sand plains. Plateaus and broad crests. Deep red earths. Other species may include *Corymbia clarksoniana* or *C. intermedia*, *C. dallachiana*, *C. lamprophylla*, *Eucalyptus tenuipes*, *E. exserta*, *E. cloeziana*, *E. acmenoides*, *Lysicarpus angustfolius* and patches of *Callitris glaucophylla* and *Acacia shirleyi*. *Eucalyptus moluccana* or *C. citriodora* sometimes locally common especially on colluvial lower slopes. Understorey grassy or shrubby depending on fire history.	No concern at present	no	n/a	yes	n/a
11.7.2 Monospecific stands of *Acacia* forest/woodland on Cainozoic lateritic duricrusts. Species include *Acacia shirleyi*, *A. catenulata*, *A. burrowii*, *A. sparsifolia*, *A. crassa*, *A. blakei* and *A. microsperma*. Hill slopes and scarp retreat zones. Emergent eucalypt species may be present e.g. *Eucalyptus thozetiana*, *E. decorticans* and *E. exserta*.	No concern at present	no	n/a	yes	n/a
11.7.3 *Eucalyptus persistens* and *Triodia mitchellii* low open woodland on stripped margins of Cainozoic sand plains.	No concern at present	no	n/a	yes	n/a
11.11.12 *Eucalyptus persistens* +/- *Corymbia lamprophylla* low open woodland on Mesozoic to Proterozoic moderately to strongly deformed and metamorphosed sediments and interbed volcanics. Lowlands.	No concern at present	no	n/a	yes	n/a
11.11.15 *Eucalyptus crebra* +/- *Corymbia erythrophloia* +/- *E. populnea* +/- *E. melanophloia* +/- *C. tessellaris* +/- *C. clarksoniana* woodland on Mesozoic to Proterozoic moderately to strongly deformed and meatmorphosed sediments and interbedded volcanics. Undulating lowlands and low hills often with distinct strike patterns. Understorey often shrubby *Eucalyptus exserta*, *E. platyphylla* present in central coastal part of bioregion.	No concern at present	no	n/a	yes	n/a

BOWEN/BROKEN OPTIONS

REGIONAL ECOSYSTEM	CONSERVATION STATUS	POTENTIAL OCCURRENCE IN MT. SUGARLOAF OPTION	POTENTIAL OCCURRENCE IN URANNAH OPTION
11.12.1 Woodland of *Eucalyptus crebra* +/- *Corymbia erythrophloia* often with a sparse and variable shrub layer and a grassy ground layer	No Concern	Most common ecosystem away from creeklines	Most common ecosystem away from creeklines in the areas around Urannah Creek and Dicks Creek
11.3.12 *Allocasuarina leuhmannii* woodland often with *Melaleuca viridiflora*, *Casuarina cristata* and *Corymbia clarksoniana* or with *Eucalyptus crebra* and *C. erythrophloia* emergents. Shrub stratum is dominated by *Petalostigma pubescens* and *Eremophila mitchellii*. Sparse ground cover includes forbs and grasses.	**Endangered**	Not sighted in field inspection. May occur along Emu Ck and north side of Broken River	Probably not present
11.3.30 *Eucalyptus crebra* and *Corymbia dallachiana* open woodland/woodland with a ground layer often dominated by *Bothrochloa pertusa* (Indian blue grass)	**Endangered**	Not sighted in field inspection. May occur along Emu Ck and north side of Broken River	Probably not present
11.3.10 *Eucalyptus brownii* open woodland/woodland with a sparse shrub stratum including *Petalostigma pubsecens* and now often introduced grasses.	No Concern	Common away from creeklines in Emu Creek and Broken River areas	Probably on lower part of Broken River arm
11.3.9 *Eucalyptus platyphylla* woodland with *Corymbia clarksoniana* and *C. tessellaris* and a sub-canopy and shrub layer of *Petalostigma pubescens*. Ground layer of forbs and grasses	No Concern	Only present at dam wall	Not present
11.11.9 *Eucalyptus brownii* open woodland/woodland with occasional *Corymbia dallachiana* and *Grevillea striata*. Sparse shrub stratum includes *Grewia retusifolia* and *Carissa ovata*.	No Concern	Not located at present	Only present in upper reaches of Urannah Creek impoundment area
5a *Eucalyptus tereticornis* or *Eucalyptus camaldulensis* tall woodland/open forest with *Corymbia tessellaris* and *Eucalyptus platyphylla* and/or *C. clarksoniana*, *E. brownii* and *Lophostemon suaveolens*. Variable shrub layer often dominated by *Planchonia careya*.	**Of Concern**	Not located at pesent	Present on alluvial plains and levees of Broken River arm of impoundment
11.12.3 Woodland of *Eucalyptus crebra*, *E. tereticornis*, *E. platyphylla* and *Corymbia tessellaris*.	No Concern	Not located at present	Minor occurrence in upper reaches of Dicks Creek area

11.12.7 *Eucalyptus crebra* woodland with patches of semi-evergreen vine thicket	No Concern	Not located at present	Higher elevation areas of Broken River and Urannah Creek
11.3.29 *Eucalyptus crebra*, *E. exserta* and *Corymbia dallachiana* woodland with low understorey of *Melaleuca viridiflora* and *M. nervosa*.	No Concern	Not lcoated at present	Common on alluvial plains of Broken River in lower part of impoundment
11.3.25 *Eucalyptus tereticornis* or *E. camaldulensis* woodland/open forest usually with *Casuarina cunninghamiana* and *Callistemon viminalis*.	**Of Concern**	Not located at present	Common on stream channels within the impoundment
11.11.5 Microphyll rainforest and/or semi-evergreen vine thicket with *Araucaria cunninghamii* emergents at some locations.	No Concern	Not located at present	Limited occurrence within impoundment on high hills

APPENDIX B PLANT SPECIES LOCATED DURING FIELD SURVEY OF THE POTENTIAL DAM SITES ON THE UPPER BURDEKIN RIVER (by Russell Cumming, EPA)

Scientific name	Common name	*weed	# rare or threatened	Mt Foxton	Hells Gate	Mt Fullstop	Greenvale
AMARANTHACEAE							
Alternanthera ficoidea		*		Y	Y	Y	
Deeringia amaranthoides					Y	Y	
ANACARDIACEAE							
Pleiogynium timorense	Burdekin plum			Y	Y	Y	
APOCYNACEAE							
Carissa lanceolata	currant bush, conkleberry			Y	Y	Y	Y
Carissa ovata	scrub currant bush				Y	Y	
ASCLEPIADACEAE							
Asclepias curassavica	milkweed	*		Y	Y	Y	
Calotropis procera	rubber bush	*			Y		
ASTERACEAE							
Ageratum houstonianum	bluetop, billygoat weed	*		Y	Y	Y	
Parthenium hysterophorus	parthenium	*		Y	Y	Y	Y
Pterocaulon serrulatum				Y	Y	Y	
Tagetes minuta	stinking roger	*			Y	Y	
Xanthium pungens	noogoora burr	*			Y	Y	
BIGNONIACEAE							
Dolichandrone heterophylla					Y	Y	Y
BORAGINACEAE							
sp indet		*		Y			

CAESALPINIACEAE						
Bauhinia ?carronii	bauhinia			Y	Y	
Bauhinia hookeri	bauhinia		Y	Y	Y	Y
Cassia brewsteri				Y	Y	Y
Erythrophleum chlorostachys	Cooktown ironwood					Y
Parkinsonia aculeata	parkinsonia	*		Y	Y	
CAPPARACEAE						
Capparis lasiantha			Y	Y	Y	
Capparis umbonata			Y			
CASUARINACEAE						
Casuarina cunninghamiana	river sheoak		Y	Y	Y	Y
CELASTRACEAE						
Maytenus cunninghamii			Y	Y	Y	Y
CONVOLVULACEAE						
Argyreia nervosa		*				Y
EBENACEAE						
Diospyros humilis	ebony			Y	Y	
ERYTHROXYLACEAE						
Erythroxylum australe	native cocain		Y	Y	Y	Y
EUPHORBIACEAE	euphorbs					
Antidesma parvifolium	black currant					Y
Briedelia leichhardtii	scrub turpentine			Y	Y	
Croton phebalioides	croton			Y	Y	
Petalostigma banksii	quinine bush		Y	Y	Y	Y
Petalostigma pubescens	quinine tree			Y	Y	Y
FABACEAE						
Crotalaria novaehollandiae	rattlepod		Y	Y	Y	

Crotalaria pallida	rattlepod	*	Y	Y	Y	
Crotalaria verrucosa	mauve-flowered rattlepod		Y			
Macroptilium atropurpureum	siratro	*	Y	Y	Y	
Sesbania cannabina	sesbania pea		Y	Y	Y	
HERNANDIACEAE						
Gyrocarpus americanus	helicopter tree			Y	Y	
LAMIACEAE						
Glossocarya hemiderma				Y	Y	
Ocimum sp. indet				Y	Y	
Plectranthus sp. indet				Y	Y	
LECYTHIDACEAE						
Planchonia careya	cocky apple		Y			
LORANTHACEAE						
Amyema bifurcatum	mistletoe		Y			Y
Amyema ?sanguineum	mistletoe		Y			
MALVACEAE						
Abutilon oxycarpum				Y	Y	
Abutilon sp.				Y	Y	
Gossypium australe	native cotton		Y			
Malvastrum americanum	malvastrum	*	Y	Y	Y	
Sida cordifolia	flannel weed		Y	Y	Y	Y
Sida subspicata	flannel weed		Y			
Urena lobata	urena burr	*	Y	Y	Y	
MELIACEAE						
Owenia acidula	emu berry		Y			
MIMOSACEAE						
Acacia aulacocarpa	wattle		Y			

Acacia sp aff aulacocarpa (disparrima ms)	wattle			Y	Y	Y	
Acacia bidwillii	corky wattle			Y	Y	Y	Y
Acacia burdekenensis	Burdekin wattle						Y
Acacia farnesiana	mimosa bush	*					Y
Acacia holosericea	silver wattle				Y	Y	
Acacia salicina	willow wattle				Y	Y	
Acacia victoriae	gundabluey						Y
MORACEAE							
Ficus opposita	sandpaper fig			Y	Y	Y	Y
Ficus platypoda	large-leaved rock fig				Y	Y	
Ficus racemosa	cluster fig			Y			
Ficus virens	white fig				Y	Y	
MYOPORACEAE							
Eremophila mitchellii	false sandalwood			Y	Y	Y	Y
Myoporum acuminatum	boobialla			Y			
MYRSINACEAE							
Rapanea variabilis					Y	Y	
MYRTACEAE	MYRTLES						
Callistemon viminalis	bottlebrush						
Corymbia clarksoniana	grey bloodwood			Y	Y		
Corymbia dallachiana	Dallachy gum			Y	Y	Y	Y
Corymbia erythrophloia	red bloodwood			Y	Y	Y	Y
Corymbia tessellaris	Moreton Bay ash			Y	Y	Y	Y
Eucalyptus brownii	Reid River box			Y	Y	Y	Y
Eucalyptus camaldulensis	river red gum			Y	Y	Y	
Eucalyptus camaldulensis / tereticornis	blue gum - river red gum intergrade / hybrid			Y	Y	Y	
Eucalyptus confertiflora							Y
Eucalyptus crebra	narrow-leaved ironbark			Y	Y	Y	Y
Eucalyptus howittiana	Howitts box		#				Y

Eucalyptus leptophleba	Molloy red box					Y
Eucalyptus melanophloia	round-leaved ironbark		Y	Y	Y	Y
Eucalyptus persistens	grey box		Y	Y	Y	Y
Eucalyptus platyphylla x tereticornis	poplar gum - blue gum hybrid					Y
Eucalyptus platyphylla	poplar gum		Y	Y	Y	Y
Eucalyptus tereticornis	blue gum		Y	Y	Y	Y
Lophostemon grandiflorus	northern swamp box		Y	Y	Y	Y
Melaleuca bracteata	black tea tree		Y	Y	Y	Y
Melaleuca fluviatilis	river tea tree		Y	Y	Y	Y
Melaleuca leucadendra	weeping tea tree		Y			
Melaleuca linariifolia	tea tree					
Melaleuca nervosa	small-leaved tea tree		Y			
Melaleuca viridiflora	broad-leaved tea tree		Y			
ONAGRACEAE						
Ludwigia octovalvis	native fuchsia		Y	Y	Y	
ORCHIDACEAE						
Cymbidium canaliculatum	black orchid		Y	Y	Y	Y
PANDANACEAE						
Pandanus whitei	pandanus		Y			
PAPAVERACEAE						
Argemone ochroleuca	Mexican poppy	*		Y	Y	
PITTOSPORACEAE						
Bursaria incana	mock orange		Y	Y	Y	Y
POACEAE	GRASSES					
Aristida calycina	three-awn grass		Y			
Aristida sp. indet	three-awn grass		Y			
Arundinella nepalensis						Y
Bothriochloa pertusa	Indian bluegrass	*	Y			
Chionachne cyathopoda	river grass			Y	Y	Y

Chloris inflata	Rhodes grass	*		Y	Y	
Cynodon dactylon	couch		Y	Y	Y	Y
Enneapogon pubescens	nine-awn grass			Y	Y	
Eragrostis ?interrupta	love grass			Y	Y	
Heteropogon contortus	black speargrass		Y	Y	Y	Y
Melinis repens	red Natal grass		Y	Y	Y	
Panicum maximum	Guinea grass	*		Y	Y	
Themeda quadrivalvis	grader grass	*				Y
Themeda triandra	kangaroo grass					Y
Triodia sp.	spinifex, porcupine grass					Y
Urochloa mosambicensis	urochloa	*	Y	Y	Y	Y
PROTEACEAE						
Grevillea parallela	grevillea		Y			
Grevillea parallela x sp. aff parallela	grevillea		Y			
Grevillea sp aff parallela	grevillea		Y	Y		
Grevillea striata	beefwood		Y	Y	Y	Y
Hakea arborescens	hakea					Y
Persoonia falcata	geebung		Y			
RHAMNACEAE						
Alphitonia excelsa	red ash		Y			
Ventilago viminalis	vine tree					Y
Ziziphus mauritianus	chinee apple	*	Y			
RUBIACEAE						
Canthium attenuatum						Y
Canthium ?buxifolium				Y	Y	
Canthium ?sp. Charters Towers				Y	Y	Y
Gardenia ochreata						Y
RUTACEAE						
Flindersia dissosperma	leopardwood		Y	Y		Y

SAPINDACEAE					
Alectryon connatus			Y	Y	
Alecryon oleifolius	bullocks bush		Y	Y	
Atalaya hemiglauca	whitewood	Y	Y	Y	Y
Dodonaea lanceolata	native hop	Y			
Dodonaea viscosa sp. spatulata	native hop	Y			Y
SAPOTACEAE					
Pouteria cotinifolia			Y	Y	
STERCULIACEAE					
Waltheria indica			Y	Y	
TILIACEAE					
Grewia scabrella			Y	Y	
VITACEAE					
Cissus oblonga	grape		Y	Y	
Cissus reniformis	grape		Y	Y	
XANTHORRHOEACEAE					
Lomandra hystrix	river mat rush				
Lomandra longifolia	mat rush				Y

APPENDIX C Plant Species Recorded at Sites Inspected Within Proposed Burdekin Falls Dam, Mt. Sugarloaf and Urannah Impoundment Areas (by Garry Werren and Kerry Walsh)

(Note: entries of special conservation interest – ie, plants that are considered rare - and/or threatened and/or those of moist forest (mesic) affinity within a dry (xeric) environmental context – are shaded; relative abundance is indicated by the following symbols: ν=dominant/co-dominant, λ=abundant/frequent, +=occasional/rare)

Scientific Name	**Common Name**	***Status***[1]	***Sites Inspected***																			
			Burdekin Falls Dam Uplift												*Mt Sugarloaf*			*Urannah*				
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
AMARANTHACEAE																						
Alternanthera nodiflora									+											
ANACARDIACEAE																						
Euroshinus falcatus																			+			
Pleiogynium timorense	Burdekin plum		λ	+													+	+	λ	+	λ	
ANNONACEAE																						
Polythalia nitdissina																			+			
APOCYNACEAE																						
Alstonia scholaris	milky pine																				+	
Carissa ovata	scrub currant bush				λ									+		λ						
Parsonsia eucalyptophylla																	+		+			
Parsonsia lanceolata	"bush banana"																			+		
APONOGETONACEAE	pond lilies																					
Aponogeton sp.								λ														
ARECACEAE	Palms																					
Livistona lanuginosa	Cape River fan palm	V	λ	+	+																	
ASCLEPIADACEAE	milkweeds																					
Asclepias curassavica	red-head cotton bush	*															+		+			
Asclepias sp.	(white flower)																				λ	

[1] "Status" refers to whether a native taxon is regarded as rare and/or threatened and employs the conventional system of E=endangered, V=vulnerable, R=rare/restricted, and P=poorly known or status pending. The designation 'C' applies to common plants that are "collectable" and subject to legislative controls to ensure that populations are not over exploited. This system is used in the Schedules of the Wildlife Regulations that accompany the *Nature Conservation Act (1992)*. An asterisk (*) indicates that a species is exotic and a probable weed.

Scientific Name	Common Name	Status[1]	Sites Inspected																			
			Burdekin Falls Dam Uplift												Mt Sugarloaf			Urannah				
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Hoya australis	common wax plant																		+			
Sarcostemma australe	caustic vine															+						
ASTERACEAE	daisies																					
Ageratum houstonianum	Bluetop, billygoat weed	*																			+	+
Helichrysum sp.	an everlasting daisy					+												+				+
Xanthium pungens	Noogoora burr	*			λ						λ											
BORAGINACEAE																						
Trichodesma zeylanicum															+							
Sp. indet.	false cornflower	*							+						+							
CACTACEAE	cacti																					
Opuntia ?stricta	prickly pear	*					+	+	+				+									
CAESALPINIACEAE																						
Lysiphyllum hookeri	white bauhinia				+						+		λ	λ		λ						
Parkinsonia aculeata	parkinsonia	*				+										+						
Senna surattensis															+							
CAPPARACEAE																						
Capparis canescens																		+				
Capparis lasiantha				+					+													
Capparis umbonata									λ													
Capparis sp.					+																	
CASUARINACEAE																						
Casuarina cunninghamiana	river she-oak																+		λ	+	+	
CELASTRACEAE																						
Cassine melanocarpa																		+				
Maytenus disperma																		+				
COMBRETACEAE																						
Terminalia oblongata						+							+									
COMMELINACEAE																						
Commelina sp.	wandering jew											+									+	

Scientific Name	Common Name	Status[1]	Sites Inspected																			
			Burdekin Falls Dam Uplift												Mt Sugarloaf			Urannah				
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
CYPERACEAE	sedges																					
Cyperus involucratus	tall sedge		+					+		+	+	+				+			+			
Scirpus sp. aff. *mucronatus*	clubrush										+	+										
EBENACEAE																						
Diospyros geminata	scaly ebony															λ		+	+			
ERYTHROXYLACEAE																						
Erythroxylum australe			+						+													
EUPHORBIACEAE																						
Alchornea thozetiana																			+			
Antidesma parvifolium	black currant		+																			
Drypetes deplanchei	yellow tulip/grey boxwood															λ		+	+			
Glochidion apodagynum																			+			
Petalostigma pubescens	quinine tree			λ					λ									+				
Phyllanthus sp.																	+					
Macaranga tanarius	blush macaranga																+		+		λ	
FABACEAE	peas																					
Abrus precatorius	gidee gidee																		+			
Aeschynomene indica	budda pea	*															+					
Indigofera pratense					+										+			+				
Sesbania cannabina	sesbania pea											+										
Tephrosia sp.	pea						+										+					
FLACOURTIACEAE																						
Scolopia braunii	flintwood																+		+		+	
HERNANDIACEAE																						
Gyrocarpus americanus	helicopter tree																	+				
HYDROCHARITACEAE																						
Hydrilla vertivillata	water thyme																		+		ν	
Vallisneria ?gigantea	ribbonweed																		λ	λ		
JUNCACEAE																						
Juncus usitatus										+												

Scientific Name	**Common Name**	***Status***[1]	***Sites Inspected***																			
			Burdekin Falls Dam Uplift												*Mt Sugarloaf*			*Urannah*				
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
LAMIACEAE																						
Hyptis suaveolens	hyptis	*				+																
Plectranthus sp. indet																			+			
Unknown	white flowered mint					+							+			λ	+		+	+	+	+
LECYTHIDACEAE																						
Planchonia careya	cocky apple		λ				λ								+	+	+	λ	+			
LORANTHACEAE																						
Amyema ?sanguineum	mistletoe									+												
MALVACEAE																						
Hibiscus heterophyllus	native rosella										+							+				
Malvastrum americanum	malvastrum	*									λ		+									
Sida cordifolia	flannel weed		λ	+	λ	+			ν		+	+	λ			+	λ		+	+		+
Sida subspicata	flannel weed			+	+	+					+											
Urena lobata	urena burr	*										+										
MARSILEACEAE	nardoos																					
Marsilea sp. aff. mutica	nardoo							λ				λ										
MELIACEAE	teak & cedar family																					
Melia azederach var. *australisica*	white cedar																		+			
Owenia acidula	emu berry				+				+													
MENYANTHACEAE																						
Nymphoides indica	water snowflake							+											+	+		
MIMOSACEAE																						
Acacia aulacocarpa	wattle		+	+																		
Acacia cambagei	gidgee					ν					ν											
Acacia farnesiana	mimosa bush	*									+		+	+								
Acacia harpophylla	brigalow													λ								
Acacia holosericea	silver wattle		+	λ							+	+										
Acacia leptostachya	Townsville wattle		λ	λ														+	+			
Acacia longispicata			+																			
Acacia salicina	willow wattle		λ							λ	λ		λ	λ		+		+	+			
Acacia shirleyi			+																			
Acacia stenophylla												+										

Scientific Name	Common Name	Status[1]	Sites Inspected																			
			Burdekin Falls Dam Uplift												Mt Sugarloaf			Urannah				
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Acacia torulosa			+																			
Pararchidendron pruinosum	tulip siris																		+			
Paraserianthes toona	Mackay/acacia cedar																		λ		+	
MORACEAE																						
Ficus opposita	sandpaper fig		+													+						
Ficus platypoda	large-leaved rock fig																	λ	λ			
Ficus racemosa	cluster fig																+		+		+	
Ficus virens	white fig																		+			
MYRSINACEAE																						
Rapanea variabilis	muttonwood																		+		+	
MYRTACEAE	myrtles																					
Callistemon viminalis	bottlebrush																ν		ν	λ	ν	+
Corymbia clarksoniana	grey bloodwood		λ	λ		ν			λ													
Corymbia dallachiana	Dallachy gum			ν		ν	λ		+					+		+						
Corymbia erythrophloia	red bloodwood				λ									+	ν			+				
Corymbia tessellaris	Moreton Bay ash						+				+			+	+	λ		λ				
Eucalyptus brownii	Reid River box													λ								
Eucalyptus camaldulensis	river red gum		λ		ν		+			λ	λ	ν				+						
Eucalyptus camaldulensis / tereticornis	blue gum - river red gum intergrade / hybrid												ν									
Eucalyptus citriodora	lemon-scented gum																	λ				
Eucalyptus coolabah	Coolibah				ν	ν	ν			λ	ν	+					+		λ			
Eucalyptus crebra	narrow-leaved ironbark						+							+	ν	λ		λ				
Eucalyptus persistens	grey box		λ	ν																		
Eucalyptus platyphylla	poplar gum		λ						ν				+									
Eucalyptus raveretiana		V															ν		ν	λ	ν	λ
Eucalyptus tereticornis	blue gum																		λ			
Lophostemon grandiflorus	Northern swamp box														λ	ν	ν	+	ν	+	λ	+
Melaleuca bracteata	black tea tree		λ							+			λ			+	+		+			
Melaleuca fluviatilis	river paperbark		λ								λ		λ		λ	ν	λ					
Melaleuca leucadendra	Weeping paperbark				ν					ν		λ					λ					
Melaleuca linariifolia	snow in summer									λ			λ				ν	+	+			
Melaleuca nervosa	small-leaved tea tree				λ						+											

Scientific Name	Common Name	Status[1]	Sites Inspected																			
			Burdekin Falls Dam Uplift												Mt Sugarloaf			Urannah				
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Syzygium australe	creek cherry																		λ		λ	
Syzygium sp. aff. wilsonii																					+	
NYMPHACEAE																						
Nymphaea violacea	purple waterlily																			λ		
ONAGRACEAE																						
Ludwigia peploides	water primrose											+								+		
ORCHIDACEAE	orchids																					
Cymbidium canaliculatum	black orchid	C			λ						λ				+			+				
PANDANACEAE	pandans																					
Pandanus whitei	pandanus		λ	λ																		
PAPAVERACEAE	poppies																					
Argemone ochroleuca	Mexican poppy	*			λ	λ							λ							+		+
PHILESIACEAE																						
Geitnoplesium cymosum	scrambling lily																		+		+	
PITTOSPORACEAE																						
Bursaria incana	mock orange			λ																		
Citriobatus pauciflorus	orange thorn																	+	+			
POACEAE	grasses																					
Aristida calycina	three-awn grass			λ										λ								
Aristida sp indet	three-awn grass						λ															
Chloris inflata	Rhodes grass	*					λ				+											
Cynodon dactylon	couch		+		+						+		λ			λ	λ					
Eragrostis ?interrupta	love grass		+																			
Heteropogon contortus	black speargrass						+	λ	λ				λ									
Heteropogon tritaceus	speargrass		+		+						+											
Melinis repens	red Natal grass					+									+		+	λ				
Oplismenus sp.	a waterfall grass																				+	
Panicum maximum	Guinea grass	*			λ					+						λ						

Scientific Name	Common Name	Status[1]	Sites Inspected																			
			Burdekin Falls Dam Uplift												Mt Sugarloaf			Urannah				
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Themeda triandra	kangaroo grass		λ		λ										+							
POLYGONACEAE	smartweeds																					
Muehlenbeckia ?cunninghamii	lignum							+		+												
Persicaria lapathifolia	willow smartweed											+	+				λ			+		
PROTEACEAE																						
Grevillea sp. aff *parallela*	grevillea		λ	λ	+													+				
RHAMNACEAE																						
Alphitonia excelsa	red ash		+																+			
RUBIACEAE																						
Canthium attenuatum																+						
Canthium coprosmoides	coast canthium																		+		+	
Morinda sp. aff. jasminoides																	+					
Nauclea orientalis	Leichhardt tree																+		+	+	+	
Timonius timon	swizel bush																+		+		+	
POTOMAGETONACEAE																						
Potomageton crispus	curly pond weed											+							+	λ	+	+
Potomageton javanicus								λ				λ					λ				λ	
Potomageton tricarinatus												+										
RUTACEAE																						
Geijera parviflora	scrub wilga																	+	+		+	
SANTALACEAE																						
Santalum lanceolatum	sandlewood		+															+				
SAPINDACEAE																						
Alectryon oleifolius	bullocks bush		+																			
Atalaya hemiglauca	whitewood				+		+							λ								
Cupaniopsis anacardioides	tuckeroo																	+	+			
Ganophyllum falcatum	scaly ash																		+		+	
STERCULIACEAE																						

Scientific Name	Common Name	Status[1]	Sites Inspected																			
			Burdekin Falls Dam Uplift												Mt Sugarloaf			Urannah				
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Brachychiton australis	kurrajong															+						
TYPHACEAE	bullrushes																					
Typha domingensis	bullrush							λ														
ULMACEAE																						
Aphananthe philippinensis	native elm/axehandle																		+		+	
Trema tomentosa	poison peach		+																			
VERBENACEAE																						
Lantana camara	lantana	*																+	λ	+	+	λ
VITACEAE																						
Tetrastigma nitens	shining grape																	+	+			
XANTHORRHOEACEAE																						
Lomandra hystrix	river mat rush		λ		+						+											
Lomandra longifolia	mat rush																λ		+	+	λ	

The sites, and their AMG coordinates, are as follows:

Burdekin Falls Dam Raising (Sellheim and Belyando-Suttor Rivers, sites 1-12)

Site 1 (04848 77093) – Boundary Creek– Cranbourne – gallery forest along shallow sandy creek line with minor lateral channels;
Site 2 (04848 77094) – Boundary Creek flats – Cranbourne – medium grassy layered woodland on flat to gently undulating bench;
Site 3 (04847 76695) – Suttor River causeway – Scartwater – gallery forest within medium grassy open woodland on channel flanks and terraces;
Site 4 (04862 76705) – Gidgee community on Suttor River floodplain – Scartwater – medium grassy open woodland on gently sloping floodplain bench;
Site 5 (04860 76726) – elevated bench on Suttor River floodplain – Scartwater – low grassy open woodland on levées;
Site 6 (04860 76726) – elevated depression on Suttor River floodplain – Scartwater – medium grassy open woodland on gently sloping elevated terrace with billabongs;
Site 7 (04871 76736) – back terrace of Suttor River – Scartwater – low sparse grassy open forest on gently sloping alluvial back terrace;
Site 8 (04860 76650) – Suttor River – St Annes/Hanging Rock (below caretaker's residence) – gallery forest along channel flank and terrace;
Site 9 (04839 76594) – Creek on Scartwater/Hanging Rock boundary – low to medium open woodland along flanks of slightly incised sandy channel;
Site 10 (04842 76592) – Blackwater Lagoon – Scartwater – medium grassy open forest/woodland surrounding a major billabong;
Site 11 (05005 76959) – Sellheim River, above Rutherford Ck confluence (Mt. McConnell) – riverine forest/medium grassy open forest on sandy channel flank and flood terrace;
Site 12 (49999 76949) – Rutherford Creek upstream of confluence with Sellheim River (Mt. McConnell) – low-medium grassy open woodland on undulating alluvial bench.

Mt Sugarloaf Impoundment (Broken River, sites 13-15)

Site 13 (06211 76940) – approach road to Beckford section of Urannah holding - low-medium grassy open woodland on dissected bench of colluvial piedmont slope;
Site 14 (06215 76939) – stream below Beckford homestead – Urannah holding - low riverine forest along small ephemeral stream and adjacent alluvial terraces;
Site 15 (06280 78947) – Broken River Crossing – Urannah holding – tall (to 35m) gallery forest along intermittent stream.

Urannah Impoundment (Broken River, Massey and Urannah Creeks, sites 16-20)

Site 16 – flanks of Broken River – Cloverly holding – medium grassy open woodland on lower piedmont slopes;
Site 17 – Broken River – Cloverly holding – medium riverine forest along a bouldery permanent stream channel;
Site 18 – Broken River crossing – Cloverly holding – medium open forest on flood terraces with billabong;
Site 19 – Massey Creek pool – Cloverly holding – tall (to 40m) gallery forest/riverine open forest along banks and terraces of a semi-incised permanent stream; and
Site 20 – Broken River flanks south of homestead – Urannah holding – medium-tall layered open forest on alluvial bench and side channels.

APPENDIX D Fauna Recorded From Potential Burdekin Dam Sites and Held at the Queensland Museum

FAMILY	GENUS	SPECIES	SUB-SPECIES	LOCALITY	SOURCE
UPPER BURDEKIN OPTIONS					
AMPHIBIANS					
HYLIDAE	*Cyclorana*	*brevipes*		Clarke R, S of Greenvale	QM
HYLIDAE	*Litoria*	*lesueuri*		New Moon Stn	QM
REPTILES					
AGAMIDAE	*Diporiphora*	*australis*		Spyglass Stn	QM
BOIDAE	*Morelia*	*spilota*		New Moon Stn	QM
COLUBRIDAE	*Tropidonophis*	*mairii*		New Moon Stn	QM
GEKKONIDAE	*Gehyra*	*dubia*		New Moon Stn	QM
GEKKONIDAE	*Gehyra*	*dubia*		Spyglass Stn	QM
GEKKONIDAE	*Oedura*	*rhombifer*		New Moon Stn	QM
SCINCIDAE	*Carlia*	*jarnoldae*		New Moon Stn	QM
SCINCIDAE	*Carlia*	*jarnoldae*		Spyglass Stn	QM
SCINCIDAE	*Carlia*	*munda*		New Moon Stn	QM
SCINCIDAE	*Carlia*	*munda*		Spyglass Stn	QM
SCINCIDAE	*Carlia*	*mundivensis*		Spyglass Stn	QM
SCINCIDAE	*Ctenotus*	*spaldingi*		New Moon Stn	QM
SCINCIDAE	*Egernia*	*frerei*		Christmas Creek Stn	QM
SCINCIDAE	*Eulamprus*	*brachysoma*		Spyglass Stn	QM
SCINCIDAE	*Morethia*	*taeniopleura*		Spyglass Stn	QM
VARANIDAE	*Varanus*	*tristis*		Spyglass Stn	QM
BIRDS					
CUCULIDAE	*Cacomantis*	*flabelliformis*	*prionurus*	Spyglass Stn	QM
MELIPHAGIDAE	*Lichenostomus*	*plumulus*	*plumula*	Lake Lucy	QM
MAMMALS					
EMBALLONURIDAE	*Taphozus*	*georgianus*		Christmas Ck, Greenvale	QM
EMBALLONURIDAE	*Taphozus*	*georgianus*		Spyglass Stn	QM

MURIDAE	*Hydromys*	*chrysogaster*		Christmas Creek	QM
PSEUDOCHEIRIDAE	*Petauroides*	*volans*		Christmas Creek	QM
PTEROPODIDAE	*Pteropus*	*conspicillatus*		Christmas Creek	QM
RHINOLOPHIDAE	*Rhinolophus*	*megaphyllus*		Christmas Creek	QM
SCOLOPACIDAE	*Gallinago*	*hardwickii*		New Moon Stn	QM
VESPERTILIONIDAE	*Miniopterus*	*australis*		Christmas Creek	
VESPERTILIONIDAE	*Miniopterus*	*australis*		Spyglass Stn	QM
VESPERTILIONIDAE	*Miniopterus*	*schreibersii*		Christmas Creek	QM
VESPERTILIONIDAE	*Scotorepens*	sp.		New Moon Stn	QM
BURDEKIN FALLS DAM OPTIONS					
AMPHIBIANS					
HYLIDAE	*Cyclorana*	*novaehollandiae*		Mt. Cooper	QM
HYLIDAE	*Litoria*	*alboguttata*		Cranbourne	QM
HYLIDAE	*Litoria*	*alboguttata*		Lornesleigh	QM
HYLIDAE	*Litoria*	*inermis*		Cranbourne	QM
HYLIDAE	*Litoria*	*inermis*		Mt. Cooper	QM
HYLIDAE	*Litoria*	*latopalmata*		Mt. Cooper	QM
HYLIDAE	*Litoria*	*leseueri*		Mt. Cooper	QM
HYLIDAE	*Litoria*	*nasuta*		Cranbourne	QM
HYLIDAE	*Litoria*	*rothii*		Cranbourne	QM
HYLIDAE	*Litoria*	*rubella*		Cranbourne	QM
MYOBATRACHIDAE	*Lymnodynastes*	*ornatus*		Mt. Cooper	QM
MYOBATRACHIDAE	*Lymnodynastes*	*ornatus*		Cranbourne	QM
MYOBATRACHIDAE	*Lymnodynastes*	*tasmaniensis*		Cranbourne	QM
MYOBATRACHIDAE	*Lymnodynastes*	*terraereginae*		Mt. Cooper	QM
REPTILES					
AGAMIDAE	*Diporiphora*	*australis*		Mt. Cooper	QM
COLUBRIDAE	*Dendrelaphis*	*punctulata*		Mt. Cooper	QM
ELAPIDAE	*Cacophis*	*harriettae*		Mt. Cooper	QM
ELAPIDAE	*Demansia*	*torquata*		Mt. Cooper	QM
ELAPIDAE	*Rhinoplocephalus*	*boschmai*		Mt. Cooper	QM
ELAPIDAE	*Rhinoplocephalus*	*nigrostriatus*		Mt. Cooper	QM
ELAPIDAE	*Suta*	*suta*		St. Pauls	QM

GEKKONIDAE	*Diplodactylus*	*vittatus*		Mt. Cooper	QM
GEKKONIDAE	*Gehyra*	*dubia*		Mt. Cooper, Spring Creek Hut	QM
GEKKONIDAE	*Gehyra*	*dubia*		St. Pauls Stn	QM
GEKKONIDAE	*Heternotia*	*binoei*		Mt. Cooper	QM
GEKKONIDAE	*Heternotia*	*binoei*		Lornesleigh	QM
SCINCIDAE	*Carlia*	*munda*		Cranbourne	QM
SCINCIDAE	*Carlia*	*munda*		Lornesleigh	QM
SCINCIDAE	*Carlia*	*mundivensis*		Mt. Cooper	QM
SCINCIDAE	*Carlia*	*pectoralis*		Mt. Cooper	QM
SCINCIDAE	*Carlia*	*pectoralis*		St. Pauls	QM
SCINCIDAE	*Carlia*	*schmeltzii*		Cardigan	QM
SCINCIDAE	*Carlia*	*schmeltzii*		Mt. Cooper	QM
SCINCIDAE	*Ctenotus*	*hebetior*		Mt. Cooper	QM
SCINCIDAE	*Ctenotus*	*robustus*		Mt. Cooper	QM
SCINCIDAE	*Ctenotus*	*taeniolatus*		Mt. Cooper	QM
SCINCIDAE	*Egernia*	*rugosa*		Mt. Cooper	QM
SCINCIDAE	*Eremiascincus*	*richardsoni*		Mt. Cooper	QM
SCINCIDAE	*Eulamprus*	*brachysoma*		Cardigan	QM
SCINCIDAE	*Eulamprus*	*quoyii*		Mt. Cooper	QM
SCINCIDAE	*Glaphyromorphus*	*punctulatus*		Mt. Cooper	QM
SCINCIDAE	*Lerista*	*cinerea*		Mt. Cooper	QM
SCINCIDAE	*Lerista*	*cinerea*		Warrawee	NSR
SCINCIDAE	*Lerista*	*vittata*		Mt. Cooper	QM
SCINCIDAE	*Lygisaurus*	*foliorum*		Mt. Cooper	QM
SCINCIDAE	*Menetia*	*greyii*		Mt. Cooper	QM
SCINCIDAE	*Morethia*	*boulengeri*		Lornesleigh	QM
SCINCIDAE	*Morethia*	*taeniopleura*		Mt. Cooper	QM
SCINCIDAE	*Morethia*	*taeniopleura*		St. Pauls	QM
SCINCIDAE	*Notoscincus*	*ornatus*		Mt. Cooper	QM
SCINCIDAE	*Tiliqua*	*scincoides*		Mt. Cooper	QM
SCINCIDAE	*Menetia*	*greyii*		Burdekin Falls Dam	QM
PYGOPODIDAE	*Pygopus*	*nigriceps*		Mt. Cooper	QM
TYPHLOPIDAE	*Ramphotyphlops*	*ligatus*		Mt. Cooper	QM

MAMMALS					
MURIDAE	*Pseudomys*	*desertor*		Mt. Elsie	QM
TACHYGLOSSIDAE	*Tachyglossus*	*aculeatus*		Mt. Cooper	QM
VESPERTILIONIDAE	*Chanilobus*	*gouldii*		St. Anns	QM
VESPERTILIONIDAE	*Chanilobus*	*nigrogriseus*		Cranbourne	QM
VESPERTILIONIDAE	*Chanilobus*	*nigrogriseus*		Mt. Cooper	QM
VESPERTILIONIDAE	*Miniopterus*	*schreibersii*		Mt. Cooper	QM
VESPERTILIONIDAE	*Scoteanax*	*rueppellii*		Mt. Cooper	QM
VESPERTILIONIDAE	*Scotorepens*	sp.		Lornesleigh	QM
VESPERTILIONIDAE	*Scotorepens*	sp.		Mt. Cooper	QM
BROKEN RIVER OPTIONS					
BIRDS					
ACANTHIZIDAE	*Acanthiza*	*pusilla*	*mcgilli*	Broken River, Clarke Range	QM
ACANTHIZIDAE	*Sericornis*	*frontalis*	*leavigaster*	Broken River, Clarke Range	QM
ACANTHIZIDAE	*Sericornis*	*magnirostris*	*magnirostris*	Broken River, Clarke Range	QM
CRACTICIDAE	*Strepera*	*graculina*	*graculina*	Broken River, Clarke Range	QM
MONARCHIDAE	*Rhipidura*	*fuliginusa*	*alisteri*	Broken River, Clarke Range	QM
PETROICIDAE	*Eopsaltria*	*australis*	*chrysorrhoa*	Broken River, Clarke Range	QM
PITTIDAE	*Pitta*	*versicolor*	*versicolor*	Broken River, Clarke Range	QM
PODARGIDAE	*Podargus*	*strigoides*	*strigoides*	Broken River, Clarke Range	QM
PSITTACIDAE	*Platycerus*	*elegans*	*filewoodi*	Broken River, Clarke Range	QM

APPENDIX E Birds Recorded From the Upper Burdekin Brief Field Survey – September 1999 (by Dr. Martin Cohen, EPA)

Common Name	Scientific Name
Emu	*Dromaius novaehollandiae*
Australian Wood Duck	*Chenonetta jubata*
Cotton Pygmy-goose	*Nettapus coromandelianus*
Pacific Black Duck	*Anas superciliosa*
Grey Teal	*Anas gracilis*
Hardhead	*Aythya australis*
Australian Darter	*Anhinga novaehollandiae*
Little Pied Cormorant	*Phalacrocorax melaleucos*
Little Black Cormorant	*Phalacrocorax sulcirostris*
Australian Pelican	*Pelecanus conspicillatus*
White-faced Heron	*Egretta novaehollandiae*
Little Egret	*Egretta garzetta*
White-necked Heron	*Ardea pacifica*
Great Egret	*Ardea alba*
Intermediate Egret	*Ardea intermedia*
Glossy Ibis	*Plegadis falcinellus*
Australian White Ibis	*Threskiornis molucca*
Straw-necked Ibis	*Threskiornis spinicollis*
Royal Spoonbill	*Platalea regia*
Black-necked Stork	*Ephippiorhynchus asiaticus*
Osprey	*Pandion haliatus*
Pacific Baza	*Aviceda subcristata*
Black Kite	*Milvus migrans*
Whistling Kite	*Haliastur sphenurus*
White-bellied Sea-Eagle	*Haliaeetus leucogaster*
Brown Goshawk	*Accipiter fasciatus*
Wedge-tailed Eagle	*Aquila audax*
Australian Hobby	*Falco longipennis*
Peregrine Falcon	*Falco peregrinus*
Nankeen Kestrel	*Falco cenchroides*
Brolga	*Grus rubicunda*
Australian Bustard	*Ardeotis australis*
Red-backed Button-quail	*Turnix maculosa*
Little Button-quail	*Turnix velox*
Red-chested Button-quail	*Turnix pyrrhothorax*
Sharp-tailed Sandpiper	*Calidris acuminata*
Comb-crested Jacana	*Irediparra gallinacea*
Bush Stone-curlew	*Burhinus grallarius*
Black-winged Stilt	*Himantopus himantopus*
Black-fronted Dotterel	*Elseyornis melanops*
Masked Lapwing	*Vanellus miles*
Whiskered Tern	*Chlidonias hybridus*
Rock Dove *	*Columba livia*
Crested Pigeon	*Ocyphaps lophotes*
Squatter Pigeon	*Geophaps scripta*
Peaceful Dove	*Geopelia placida*
Bar-shouldered Dove	*Geopelia humeralis*
Red-tailed Black Cockatoo	*Calyptorhynchus banksii*
Galah	*Eolophus roseicapillus*
Sulfur-crested Cockatoo	*Cacatua galerita*
Rainbow Lorikeet	*Trichoglossus haematodus*
Pale-headed Rosella	*Platycercus adscitus*
Northern Rosella	*Platycercus venustus*

Pallid Cuckoo	*Cuculus pallidus*
Brush Cuckoo	*Cacomantis variolosus*
Channel-billed Cuckoo	*Scythrops novaehollandiae*
Pheasant Coucal	*Centropus phasianinus*
Southern Boobook	*Ninox boobook*
Tawny Frogmouth	*Podargus strigoides*
Australian Owlet-nightjar	*Aegotheles cristatus*
Azure Kingfisher	*Alcedo azurea*
Laughing Kookaburra	*Dacelo novaehollandiae*
Blue-winged Kookaburra	*Dacelo leachii*
Sacred Kingfisher	*Todiramphus sanctus*
Rainbow Bee-eater	*Merops ornatus*
Red-backed Fairy-wren	*Malurus melanocephalus*
Red-browed Pardalote	*Pardalotus rubricatus*
Striated Pardalote	*Pardalotus striatus*
Weebill	*Smicrornis brevirostris*
White-throated Gerygone	*Gerygone olivacea*
Silver-crowned Friarbird	*Philemon argenticeps*
Noisy Friarbird	*Philemon corniculatus*
Little Friarbird	*Philemon citreogularis*
Blue-faced Honeyeater	*Entomyzon cyanotis*
Noisy Minor	*Manorina melanocephala*
Yellow-throated Minor	*Manorina flavigula*
White-throated Honeyeater	*Melithreptus albogularis*
Brown Honeyeater	*Lichmera indistincta*
Grey-crowned Babbler	*Pomatostomus temporalis*
Rufous Whistler	*Pachycephala rufiventris*
Figbird	*Sphecotheres viridis*
Leaden Flycatcher	*Myiagra rubecula*
Magpie-lark	*Grallina cyanoleuca*
Northern Fantail	*Rhipidura rufiventris*
Willie Wagtail	*Rhipidura leucophrys*
Spangled Drongo	*Dicrurus bracteatus*
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*
White-bellied Cuckoo-shrike	*Coracina papuensis*
White-winged Triller	*Lalage suerii*
Varied Triller	*Lalage leucomela*
White-breasted Woodswallow	*Artamus leucorynchus*
Black-faced Woodswallow	*Artamus cinereus*
Grey Butcherbird	*Cracticus torquatus*
Pied Butcherbird	*Cracticus nigrogularis*
Australian Magpie	*Gymnorhina tibicen*
Pied Currawong	*Strepera graculina*
Australian Raven	*Corvus coronoides*
Torresian Crow	*Corvus orru*
White-winged Chough	*Corcorax melanorhamphos*
Apostlebird	*Struthidea cinerea*
Great Bowerbird	*Chlamydera nuchalis*
Richard’s Pipit	*Anthus novaeseelandiae*
House Sparrow *	*Passer domesticus*
Zebra Finch	*Taeniopygia guttata*
Double-barred Finch	*Taeniopygia bichenovii*
Mistletoebird	*Dicaeum hirundinaceum*
Welcome Swallow	*Hirundo neoxena*
Fairy Martin	*Hirundo ariel*
Common Myna*	*Acridotheros tristis*

* = non-native (human assisted) introduction

APPENDIX F Bird Species Recorded at Sites Inspected Within Proposed Burdekin Falls Dam, Mt. Sugarloaf and Urannah Impoundment Areas (by Garry Werren)

(Note: taxa of special conservation interest are indicated by shaded entries, with relative abundance of records indicated by ν=abundant records, λ=frequently recorded, and +=occasionally recorded)

Scientific Name	Common Name	Status[2]	Sites Inspected																			
			Burdekin Falls Dam Uplift												Mt Sugarloaf			Urannah				
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Phalacrocorax melanoleucos	Little Pied Cormorant																			+	+	
Phalacrocorax sulcirostris	Little Black Cormorant				+							+										
Pelecanus conspicillatus	Australian Pelican											+								+		
Egretta alba	Great Egret				+							+										
Ardea novaehollandiae	White-faced Heron																			+		+
Ardea pacifica	Pacific Heron				+																	
Nycticorax caledonicus	Nankeen Night-heron											+										
Cygnus atratus	Black Swan				+																	
Dendrocygna eytoni	Plumed Whistling-duck				λ																	
Chenonetta jubata	Wood Duck				λ							+										
Anas superciliosa	Pacific Black Duck											+								+		
Accipiter fasciatus	Brown Goshawk																	+				
Milvus migrans	Black Kite				+																	
Haliastur sphenurus	Whistling Kite				+		+															
Haliastur indus	Brahminy Kite							+														
Hieraaetus morphnoides	Little Eagle									+												
Aquila audax	Wedge-tailed Eagle					+															+	
Falco subniger	Black Falcon														+							
Coturnix pectoralis	Stubble Quail					λ																
Gallinula ventralis	Black-tailed Native Hen																			+		
Charadrius melanops	Black-fronted Dotterel																			+		+
Geophaps scripta scripta	Squatter Pigeon	V			λ									+								
Ocyphaps lophotes	Crested Pigeon														+							
Phaps calchoptera	Common Bronzewing													+								
Geopelia placida	Peaceful Dove					+	+									+						
Cacatua roseicapilla	Galah						λ		+													
Cacatua galerita	Sulphur-crested Cockatoo											+									+	

[2] "Status" refers to whether a native taxon is regarded as rare and/or threatened and, as for the plants, employs the conventional system of E=endangered, V=vulnerable, R=rare/restricted, and P=poorly known or status pending. This system is used in the Schedules of the Wildlife Regulations that accompany the *Nature Conservation Act (1992)*.

Scientific Name	**Common Name**	***Status***[2]	***Sites Inspected***																				
			Burdekin Falls Dam Uplift												*Mt Sugarloaf*			*Urannah*					
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Calyptorhynchus magnificus	Red-tailed Black Cockatoo				+																	
Trichoglossus haemotodus	Rainbow Lorikeet		+	+				λ		λ	+	+	ν		+		λ			+	+	
Trichoglossus chlorilepidotus	Scaly-breasted Lorikeet			+																		
Aprosmictus erythropterus	Red-winged Parrot		λ		+						+	ν	+									
Platycercus adscitus	Pale-headed Rosella				+		+					+										
Cuculus pyrrhophanus	Fan-tailed Cuckoo															+						
Cuculus pallidus	Pallid Cuckoo																		+			
Chrysococcyx lucidus	Shining Bronze Cuckoo				+																	
Centropus phasianus	Pheasant Coucal				+																	
Dacelo leachi	Blue-winged Kookaburra				+	+																
Dacelo gigas	Laughing Kookaburra				+					+		+	λ	+		λ		+		+	+	
Todirhamphus sanctus	Sacred Kingfisher				+																	
Todirhamphus macleayi	Forest Kingfisher																	+				
Ceyx azurea	Azure Kingfisher																+				+	
Merops ornatus	Rainbow Bee-eater			+	+				+											+	+	
Eurostopodus guttatus	Spotted Nightjar				+																	
Aegotheles cristatus	Owlet Nightjar				+																	
Anthus novaeseelandiae	Australian Pipit																					
Coracina novaehollandiae	Black-faced Cuckoo-Shrike			+	λ	λ												+			+	
Microeca leucophaea	Brown Flycatcher (Jacky Winter)		+																			
Pacycephala rufiventris	Rufous Whistler				+				+		+				+						+	
Colluricincla harmonica	Grey Shrike-thrush										+	+										
Myiagra rubecula	Leaden Flycatcher															+			+		+	
Pomatostomus temporalis	Grey-crowned Babbler		+								+											
Malurus assimilis	Variegated Fairy-wren			+																		
Malurus melanocephalus	Red-backed Fairy-wren														+							
Gerygone fusca	Western Gerygone (Warbler)				+												+					
Gerygone oliacea	White-throated Gerygone (Warbler)		+	+	λ				+		+	+					+		+	+		
Smircrornis brevirostris	Weebill			+											+							
Daphoenositta chrysoptera	Varied Sittella (white-headed form)														+							

Scientific Name	Common Name	Status[2]	Sites Inspected																			
			Burdekin Falls Dam Uplift												*Mt Sugarloaf*			*Urannah*				
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Philemon cireogularis	Little Friarbird		+										+									
Philemon corniculatus	Noisy Friarbird		ν	ν	ν								λ	+			λ	+	λ	+	+	
Entomyzon cyanotis	Blue-faced Honeyeater		λ		+		ν				+	ν	λ				λ			+	+	
Manorina flavigula	Yellow-throated Miner										λ	λ										
Melithreptus albogularis	White-throated Honeyeater				+			λ				+				λ	λ				+	
Meliphaga lewinii	Lewin's Honeyeater																		+		+	
Meliphaga notata	Yellow-spotted Honeyeater				+											+					+	
Meliphaga unicolor	White-gaped Honeyeater				+																	
Lichenostomus flavus	Yellow Honeyeater		+	λ													λ			+	+	
Lichmera indisctincta	Brown Honeyeater																		ν			
Nectarinia jugularis	Yellow-bellied Sunbird								+										+		+	
Diceaum hirundinaceum	Mistletoebird				+														+	+	+	
Pardalotus striatus	Striated Pardalote				+			+	+		+		+		+	+	+	+	+	+	+	
Poephila bichenovii	Double-barred Finch			+											+							
Aidemosyne modesta	Plum-headed Finch														+							
Oriolus sagittatus	Olive-backed Oriole				+												+		+	+	+	
Dicrurs megarhynchus	Spangled Drongo															+	+			+	+	
Grallina cyanoleuca	Pied Mudlark		λ		ν						+	+	+				+	+		+	+	
Corcorax melanorhamphos	White-winged Chough																λ	+				+
Struthidea cinerea	Apostlebird			λ								λ										+
Artamus cinereus	Black-faced Woodswallow														+							
Cracticus nigrogularis	Pied Butcherbird		ν	+	λ	λ	+			+		+		+				+				+
Cracticus torquatus	Grey Butcherbird			+																		
Strepera graculina	Pied Currawong			+														+			+	
Gymnorhina tibicen	Australian Magpie				+	+							+				λ	+				
Clamydera nuchalis	Great Bowerbird					+	+															
Corvus bennetti	Little Crow				+			λ			+		+		+							
Corvus coronoides	Australian Raven						+	+	+			+				+	+	+				

APPENDIX G

ASSESSMENT OF FAUNAL HABITAT AT BFD, MT. SUGARLOAF AND URANNAH
(by Garry Werren)

Since the current investigations contribute to a preliminary assessment of a range of impoundment options, there was no provision for extensive faunal assessment of the various sites. Instead, habitat elements such as (1) the incidence of hollows and (2) the occurrence of fallen and standing dead timber were noted, as was the occurrence of bird cup and platform nests. Incidental records of the more conspicuous vertebrate group, the birds, were undertaken during the course of the vegetation assessment. Opportunistic sightings of other diurnal vertebrates and indirect evidence such as tracks and scats were also made. Spotlighting was conducted at one site only (site 3) but this was abandoned since it revealed few records of anything other than stock.

Frequency of Hollows/Standing and Fallen Timber/Bird Nests

The prevalence of hollow breeding, particularly within Australian bird assemblages, is well documented. It is also apparent that both standing and fallen timber provides shelter and foraging resources for a range of vertebrates and can be used as an indicator of habitat complexity. In addition, bird cup and platform nests provide another relatively useful measure of reproductive use of habitat and a surrogate of habitat value. Results of site inspections with regarded to these indicators of faunal habitat value are set out in Table 3 below.

The incidence of hollows is particularly high within many of the sites inspected, especially within the proposed Burdekin Falls Dam uplift impoundment extension area. This reflects the occurrence of mature trees throughout the system, but may also result from land management such as fire regimes and stock pressures that may promote tree senescence. The consistent occurrence of both standing and fallen dead timber may similarly reflect such processes.

Incidence of faunal habitat components recorded at various sites inspected within proposed impoundment areas

(Relative frequency of habitat elements is indicated by the following symbols: ν=high, λ=medium, +=low – in the case of bird nest the frequency categories used are >5, 5-3, <3 respectively)

	Sites Inspected																			
	Burdekin Falls Dam Uplift												*Mt Sugarloaf*			***Urannah***				
Attribute	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Hollows	λ	ν	ν	ν	+	ν	+	ν	ν	ν	ν	+	ν	+	+	+	+	λ	λ	λ
Standing/fallen timber	λ	+	λ	ν	+	λ	+	ν	ν	ν	λ	ν	λ	λ	ν	ν	ν	λ	λ	λ
Bird nests	λ	+	+	+		+		+	λ	λ	ν		+	+		+	λ	+		+

No particular patterns are evident in the bird nest frequencies apart from the relatively high numbers recorded in the well developed riverine forest of the Sellheim River. Moderate numbers within fringing forests of Blackwater Lagoon and its tributary creek, and in gallery forest at Cranbourne and at site 17 along the Broken River.

Bird Species Richness

A total of 85 species were recorded during the site inspections. This is likely to be a significant proportion of the district bird assemblage that may be depressed at this time of the year (ie, early spring, prior to the advent of seasonal migrants). Most (64 of 85) were recorded at sites within the proposed impoundment extension area associated with the Burdekin Falls Dam uplift option compared with the other options (30 and 37 at Mt Sugarloaf and Urannah sites respectively). This is presumably an artefact of the sampling intensity (better access at BFD) rather than biological reality. Of more pertinence is the comparatively high numbers of birds within the riverine forests threatened with inundation when compared with those in the widespread open woodlands, including aggregations of species such as Red-winged Parrot (*Aprosmictus erythropterus*), Noisy Friarbirds (*Philemon corniculatus*) and Blue-faced Honeyeaters (*Entomyzon cyanotis*). Of additional importance is the occurrence of birds such as Lewin's Honeyeater (*Meliphaga lewini*) and Yellow-bellied Sunbird (*Nectarinia jugularis*) that are more commonly associated with rainforest and moister eucalypt forests. These are likely at the western edge of their ranges in riverine forests of the proposed Urannah impoundment.

Rare/Threatened Bird Species

Only one species listed as vulnerable (the southern subspecies of the Squatter Pigeon – *Geophaps scripta scripta*) were recorded during the brief site inspections. These are birds of the open woodlands and are unlikely to be significantly affected by any of the impoundment proposals.

Other vertebrate records

No attempt has been made to exhaustively document the other vertebrate groups. It was evident through direct sightings and from the incidence of scats, however, that medium to large macropods are in good numbers throughout the district. These include the Rufous Bettong (*Aepyprymnus rufesens*), Northern Nailtail Wallaby (*Onychogalea unguifera*), Unadorned Rock Wallaby (*Petrogale inornata*), Whiptail Wallaby (*Macropus parryi*), Black-striped Wallaby (*M. dorsalis*), Agile Wallaby (*M. agilis*), Eastern Grey Kangaroo (*M. giganteus*) and Wallaroo (*M. robustus*). Of some significance is the fact that a single individual Spectacled Hare-wallaby (*Lagorchestes conspicillatus*) was flushed from site 12 (Rutherfurd Creek). This represents a species of some conservation interest since one of its congeners is now extinct and its range has contracted significantly since European settlement, although it purportedly persists in good populations within Queensland (Burbidge and Johnson 1983:197).

Several other mammals (Little Red Flying-fox, *Pteropus scapulatus* – site 12), Water Rat (*Hydromys chrysogaster* – middens at site 10), Dingo (*Canis familiaris dingo* – scats at several sites), Rabbit (*Oryctolagus cuniculus* – pellets at several sites) and Feral Pig (*Sus scrofa* – sightings, diggings and tracks at several site on the Scartwater holding) and one monotreme (the Echidna, *Tachyglossus aculeata* – site 11) were recorded. No reptiles apart from an Eastern Water Dragon (*Physignathus leseueri* – site 17) could be identified to species level. Exotic Cane Toads (*Bufo marinus*) appears to be well established within the area. No native anurans were recorded during the survey, although there is likely to be a sizeable assemblage of widespread open country species present. Frogs are likely to be advantaged by impoundments although such modifications would also advantage the Cane Toad that acts as both a competitor and predator.

Other Considerations

The great importance of riparian systems as drought refuges and wildlife corridors, particularly in semi-arid areas such as the upper Burdekin, is well documented. These systems furnish vital foraging, shelter and reproductive resources to a vast array of vertebrates. They also are important to invertebrates, particularly to aquatic species and to those with aquatic larval stages. Of note were the large aggregations of butterflies (particularly *Danaus* spp.) recorded at several sites within all proposed impoundment areas.