Chapter 10 Conclusions

10.1 General conclusions for each chapter

Chapter 1: Introduction

Study introduction only

Chapter 2: Background information

- Peter Faust Dam in the Proserpine River catchment area has drastically altered the flow patterns of the Proserpine River.
- There are no major storages located in the O'Connell and Andromache river catchment, and water use from these rivers is primarily for irrigation purposes.
- A significant feature of the plan area is the Goorganga Plain wetland, which is of national significance.
- There are potentially problems of salinisation and of groundwater window loss as a consequence of over-utilisation of groundwater from the older fractured bedrock or Tertiary terrace aquifers in all parts of the plan area.
- There has been a run of dry years since approximately 1979.
- There is some debate in the available literature relating to whether the shoreline of Repulse Bay is eroding or prograding.

Chapter 3: Approach and methods

- The reach breakdown adopted for this study is shown in
- Figure 3-1 and presented in Appendix 2.

Chapter 4: Condition of Proserpine, O'Connell and Andromache river catchments

Hydrology, hydrogeology, geomorphology

- Base flows are more persistent in the Andromache and O'Connell rivers than the Proserpine River (pre-dam).
- Interactions between surface and groundwater for the plan area are generally poorly understood, but higher base-flow rates for the O'Connell and Andromache river system probably result from greater hydraulic connectivity between the aquifer systems and the surface drainage network.
- Peter Faust Dam has had a major effect on the flow characteristics of most of the length of the Proserpine River and the current flow regime bears little resemblance to the natural flow regime, evidenced by:
  - significant reduction in the duration of zero flows
  - truncation of flows significant for sediment transport and channel maintenance (nominally specified at > 100 m^3s^{-1})
  - reduction in flow variability
  - significant change in seasonality of flows
  - increased duration of low to medium flows.
- A large number of farm dams and overland-flow storages were noted during the catchment flyover, particularly in the O'Connell catchment.
- In the O'Connell and Andromache rivers summer and autumn were the most important times of the year for sediment transport, flushing and filling of waterholes, wetting of benches and terraces and floodplain recharge events, and the number of zero flow days was much higher for the spring– summer period than autumn–winter. The rate of zero-flow days was low for the Andromache River. This analysis highlighted the importance of zero flow events to the flow regime and the dramatically altered frequency of these events for the Proserpine River.
- Releases to the Proserpine River have maintained a balance between extraction and recharge from the recent alluvium aquifers.

- Potential salinisation due to irrigation-induced groundwater rise has been recognised in the Kelsey Creek and Lethe Brook area and this may be related to an ancient seawater intrusion into this area.
- There is direct communication between surface water and groundwater of the Proserpine River channel and recent alluvium, extending to about 200 metres away from the channel banks.
- In the O'Connell and Andromache subcatchments, groundwater resources are restricted by the limited Tertiary terrace cover over the older bedrock. However, little is known about the yield and quality of these groundwaters because existing development is unregulated and the interactions between groundwater and surface waters have not been systematically studied.
- In the Proserpine River below Peter Faust Dam there has been channel contraction, the formation of in-channel benches and vegetation encroachment across the flood channel due to the truncation of larger flows.
- The volumes of sand in the Andromache and O'Connell rivers are elevated compared with natural conditions. Further, the transport rate of the sand load would have been relatively low during the low flow years of the last two decades. However, it is also likely that the rate of land erosion has also been low.
- The dominant discharge flow band was ~ 250 to 600 m^3s^1 for the O'Connell River and ~ 100 to 400 m^3s^1 for the Proserpine River (pre-dam). These values correspond to approximately the two-year to five-year ARI flow events in each case.

Water quality

- The available water quality data are patchily distributed both geographically and temporally. In particular, sites are lacking for some key tributaries, such as Thompson Creek and Goorganga Creek, and very limited in extent in most catchments, particularly the Andromache.
- The surface water quality of the Proserpine River catchment is impacted by nutrient loadings from the Proserpine STP, by below-thermocline waters from Peter Faust Dam and by more diffuse nutrient and salinity inputs into Kelsey Creek and Lethe Brook, with at times high nutrient loading in Myrtle Creek.
- As most stream surface waters are shallow, elevated nutrient concentrations have not led to general dissolved oxygen suppression, except in lower Lethe Brook and Myrtle Creek, but the data available are limited and may have missed reaches and/or times with suppressed oxygen.
- Water quality for the O'Connell River subcatchment sites was generally within the ANZECC/ARMCANZ (2000) trigger values, but the water quality in the Andromache and O'Connell catchment was characterised by common occurrence of high nitrogen concentrations, and increasing conductivity in Boundary Creek at least between 2000 and 2002.

Aquatic biota

- Overall the macroinvertebrate sampling results indicated generally healthy assemblages in the upper reaches of the Proserpine River and Saltwater Creek, moderate to good health in middle Lethe Brook and the Proserpine River below Peter Faust Dam, but poor health in lower Lethe Brook and the Proserpine River below Proserpine. The overall pattern of taxonomic richness and SIGNAL scores were consistent with nutrient impacts below Proserpine and in lower Lethe Brook.
- The macroinvertebrate sampling results for the Andromache and O'Connell catchment were indicative of generally adequate health, but there were signs of impact, probably from agriculture, in the O'Connell, particularly for the lower reaches, and generally harsh conditions or agricultural impacts at the two Andromache River sites
- A feature of the aquatic macrophyte assemblages of the Proserpine catchment was that generally there was a low incidence of weed species except for aquatic grasses. There existed a good diversity of native macrophyte species in the catchment and the assemblage structure was generally healthy.
- Overgrowth of aquatic vegetation, particularly exotic grasses, was found in

some sections of the Proserpine River, and was probably associated with managed stable flows, the absence of flushing flows, elevated nutrient concentrations and the absence of riparian shading of the stream.

- In the Andromache and O'Connell catchment there was also good diversity of native macrophytes, low abundance of exotic species and generally good assemblage health. These features suggest that the aquatic flora of the catchment has substantial environmental values.
- The only exotic fish species found in the plan area were the guppy and gambusia, found in the Proserpine River and Lethe Brook catchments. Despite more detailed sampling in the Andromache and O'Connell by QDPI, as well as TAP visual observations across that catchment, these exotic species were not located.
- Two translocated species also occur in the Proserpine River catchment, sooty grunter and sleepy cod.
- Several migratory fish species are known to occur in the area, and at least two such species were observed just below Peter Faust Dam.
- The barramundi population in the Goorganga Creek wetlands is abundant and dominated by first-year class juveniles, indicating its importance as a nursery and early stage refuge for this species.
- A number of fish passage barriers were observed in the catchment and, although small, with the largely artificial flow regime now imposed in this catchment, the impacts of such barriers are exacerbated.
- The recorded distributions of the migratory fish species appear correlated with their ability to surmount passage barriers, with the more agile species being recorded further upstream than the less agile species.

Flow-linked regional ecosystems

- The flow-linked regional ecosystems found in the plan area are diverse (8.1.1; 8.1.2; 8.1.3; 8.1.4; 8.1.5; 8.3.1; 8.3.1a; 8.3.2; 8.3.3; 8.3.3a; 8.3.5; 8.3.6; 8.3.6a; 8.3.11; 8.3.12; 8.3.13a; 8.3.13b; 8.3.13c; and 8.3.13d).
- The majority of REs persist along the coast and on the ranges along the western rim of the study catchment. This reflects the pattern of historic vegetation clearing for agriculture. In the O'Connell and Andromache catchment REs also persist on a tongue of dissected lowlands that extends from the south-western ranges north-east towards the confluence of the Andromache and O'Connell rivers.
- Atypically, the very upper catchment of the O'Connell River has also been extensively cleared for pastoral development.
- The Proserpine catchment riparian zone has been estimated at 23 142 hectares of which 60 per cent currently retains natural vegetation (although not necessarily remnant vegetation).
- Aerial imagery and RE mapping clearly indicate a denuded riparian strip along the mid to lower Proserpine River. With directed management a more diverse riparian vegetation community representative of the original gallery forest could be re-established in the longer term.
- The Goorganga Plain wetlands are recognised to have values of national significance and are listed in the *Directory of Important Wetlands in Australia*. However, extensive areas of the Goorganga Plain, particularly east of the highway, is now dominated by introduced pasture species.
- Riparian vegetation along the mid and upper reaches of Lethe Brook and Kelsey, Goorganga and Albert creeks (i.e., LE-1, LE-2 and G-1) has fared better than mid reaches of the Proserpine, with a more or less continuous narrow corridor persisting.
- Fauna usage of riparian communities in some areas is limited by:
  - the relative isolation of the riparian corridor from other natural habitats as a result of extensive clearing of adjacent alluvial and non-alluvial plains
  - poor condition of riparian areas due to invasion of the ground stratum by weeds such as guinea grass and elephant grass, and the water margins by para grass
  - poor condition of ground habitat due to the effects of cattle activity

(primarily only lower reaches and floodplain areas)
    - poor habitat condition due to frequent hot fires often promoted by introduced grasses such as guinea grass.
- Exotic aquatic grasses or 'ponded pasture' species are causing significant ecological condition impacts in infested areas, including loss of native emergent vegetation communities, smothering and organic loading of surface waters with resulting water quality impacts (particularly DO depletion), and increased sediment trapping efficiency within stream channels and floodplain drainage depressions.
- A feature of the mid O'Connell River (OC-3) is pockets of dense riparian vegetation comprising weeping paperbark and rainforest species that occur in association with seepage from Tertiary terrace aquifers.
- Extensive areas of denser moist riparian forest occur along the upper reaches of the Andromache (AND-1, AND-2), including Mares Nest Creek, and the O'Connell River (OC-1 and OC-2, although many areas now cleared) where the streams intersect fractured bedrock aquifers.
- Both the Proserpine River and the O'Connell and Andromache catchments are largely free of significant canopy weeds.

Chapter 5 Key ecological and geomorphological values

Geomorphic processes

- Geomorphic processes that maintain ecological values include:
    - lower flood flows above the sediment transport threshold for maintaining small-scale habitats (e.g., riffles)
    - low to moderate flood flows (two- to five5-year ARI) for the O'Connell River to maintain long-term flux of sediment to Repulse Bay
    - moderate to high flows (including floodplain flows) for resetting larger scale habitats, and bed scour, flushing of colonising vegetation from medial bars, floodplain recharge and episodic delivery of sediment to Repulse Bay
    - 'catastrophic' flows for estuary flushing (O'Connell River) and large-scale resetting of landforms.

Key ecological values

- None of the fish species currently known to occur in the plan area are threatened.
- Thirteen of-concern and three endangered flow-dependent REs occur in the plan area: 8.3.1; 8.3.1a; 8.3.6; 8.3.6a; 8.3.5; 8.3.13a; 8.3.13c; 8.3.13d; 8.3.2; 8.3.11; 8.3.13b; 8.3.12; 8.1.2; 8.1.3; 8.1.4; and 8.1.5
- A total of 29 rare or threatened fauna species have been recorded from the Proserpine and O'Connell catchments or adjacent areas; 17 of these species have a significant association with flow dependent ecosystems.
    - The Wildnet database has records of one rare or threatened plant species in the plan area, *Eucalyptus raveretiana* (black ironbox), associated with riparian areas. The seasonally inundated freshwater wetlands of the Goorganga Plain may support the rare *Aponogeton queenslandicus*. there are currently no records of that species from the Mackay–Whitsunday area.
- High-value areas with flow dependence include:
    - Proserpine–Goorganga Plain wetlands
    - intact riparian ecosystem patches
    - aquatic refugia and other high conservation value stream reaches
    - coastal and marine ecosystem complex, including Fish Habitat Areas, Dugong Protection Areas and the Great Barrier Reef Marine Park.

Key flow-dependent ecological processes

- In-stream processes, overbank processes, groundwater processes (recharge, depletion, groundwater windows), and coastal and estuarine processes have been identified.

Chapter 6 Ecological assets and required flow

Ecological assets

- High-integrity low order stream reaches of upper catchments
- Deepwater habitats of middle reaches of Proserpine River
- Riffles and refugial waterholes in middle reaches of all other streams

characteristics

- Goorganga Plain wetland habitat complex
- Proserpine and O'Connell river estuarine and coastal marine habitat complex
- Diverse and native-dominated macrophyte communities
- Fish fauna without exotic species and good representation of migratory species
- At-risk fringing regional ecosystems [RE 8.3.1 & 8.3.1a]
- At-risk frontage regional ecosystems [RE 8.3.5, 8.3.6, 8.3.6a]
- At-risk frontage regional ecosystems in near-coastal areas [RE 8.3.13a,c,d]
- At-risk frontage regional ecosystems incorporating wetlands [RE 8.3.2, 8.3.11]
- At-risk frontage regional ecosystems incorporating wetlands in near-coastal areas [RE 8.3.13b]
- At-risk grasslands on alluvium regional ecosystems [RE 8.3.12]
- At-risk estuarine regional ecosystems [RE 8.1.2, 8.1.3, 8.1.4, 8.1.5]
- Wetland birds
- Waders and shorebirds, marine fauna, Great Barrier Reef Marine Park and Northern Repulse Bay Dugong Protection Area
- Black ironbox (*Eucalyptus raveretiana*)

Flow components supporting these assets

- Base flow, surface runoff flows, flood flows, groundwater level, groundwater inflows, tidal flow and salinity gradient, Tertiary terrace aquifers

Chapter 7 Potential indicators and monitoring

High-integrity low-order stream reaches of upper catchments

- Timing of first filling of channel pools
- Duration of base flow beyond wet season
- Recession rate of pools
- Riffle presence or persistence
- Depth of pools and channel bed form

Deepwater habitats of middle reaches of the Proserpine River

- Dissolved oxygen and nutrient status of selected pools
- Extent of coverage of channel by macrophytes
- Pool depth
- Organic composition of sediments

Riffles and waterholes in middle reaches of other streams

- Number, distribution, depth and drawdown rates of waterholes
- Riffle distribution, extent and persistence
- Groundwater levels in fluvial and Tertiary aquifers

Goorganga Plain wetland

- Recession rates and aerial extent of perennial freshwater pools
- Flow volumes of tributary streams
- Flow height and duration in channels
- Channel depth and form near-natural and allowed to naturally alter
- Seasonal macrophyte cover and composition
- Groundwater depth and salinity
- Tide-induced water level variation in lower stream reaches
- Salinity of lower stream reaches of floodplain habitat complex

Proserpine and O'Connell river estuarine and coastal complex

- Seasonal salinity profile within estuarine reach
- Mangrove community composition and structure
- Flood hydrograph in upper estuary and channel
- Geomorphology within estuary
- Landward extent of tidal inflows

Diverse and native-dominated macrophyte communities

- Distribution, abundance and assemblage structure of macrophytes
- Groundwater levels, base flows and baseflow periods
- Number, distribution, depth fluctuation or recession of perennial pools

Fish fauna without exotics and with migratory species

- Absence of exotic fish
- Distribution and abundance of migratory fishes

- Persistence of pools greater than one metre deep

At-risk regional ecosystems

- Wet season flows
- Seasonal salinity regimes and level fluctuations in near coastal aquifers
- Vegetation mapping

Wetland birds

- Wet season flows in the lower catchments
- Regular mapping of coastal ecosystems using aerial imagery
- Wetland bird congregations in key coastal wetlands

Receiving marine ecosystems

- Mapping via aerial imagery
- River discharge and salinity profile monitoring

Black ironbox

- Direct monitoring of individuals and populations

Relatively extensive riparian habitat corridors

- Base flow and overbank flow
- Periodic monitoring (every five years) of riparian habitat corridor condition

Springs and seepage areas fed from Tertiary terrace aquifers

- Discharge characteristics of springs
- Groundwater levels

Chapter 8 Research requirements

Many areas of data deficiency were identified. Many were not directly flow related, but were essential background information to provide a basis for water resource use management, including:

- effects of current water resource development on downstream wetlands
- effects of current water resource development on the estuarine and marine habitats of Repulse Bay
- distribution, abundance and assemblage structure of macrophytes
- distribution, abundance, age structure and variability of fish assemblages
- clarification of phosphate concentrations across the plan area
- clarification of dissolved metal concentrations, particularly downstream of Proserpine and in Dryander Creek
- general lack of measurements of temporal variability for aquatic ecosystems
- aquatic ecological data for the estuarine and coastal waters
- mapping and bypass flood height determination of fish passage barriers
- mapping of the status, extent and distribution of perennial aquatic habitats
- evaluation and mapping of high conservation value stream reaches
- geomorphological implications associated with flow regulation and modified riparian vegetation condition of Proserpine River
- implications of Proserpine basin flow regulation for in-stream ambient water quality and ecological values
- implications of O'Connell catchment surface water resource extraction for in-stream ambient water quality
- relationship between groundwater resources and surface water habitats
- assessment of existing groundwater data.

Chapter 9 Summary of water resource management issues

The Proserpine River catchment is a highly modified and regulated system, albeit one that retains some high ecological value assets, and could be managed for improved ecological value outcomes. Issues that warrant consideration in water resource management include:

- the implications of existing regulated flow regimes within the Proserpine River catchment for in-stream ambient water quality and ecological values, including the possible merits of regulated 'environmental flows'
- the geomorphological implications of existing flow regulation and modified riparian vegetation condition for river channel form, in-stream habitat values, flooding and downstream estuarine processes
- the impact of existing and future tributary and overland flow capture on downstream flow characteristics and channel geomorphology
- the interactions between surface water habitats and groundwater aquifers of floodplain areas and the implications for 'sustainable use'
- the existing impact of surface water use on floodplain water quality and ecological values
- the existing and future prospect of climate change, which will deliver reduced and or more variable rainfall patterns.

The O'Connell and Andromache catchment is a system under ecological stress. This stress is associated with a decade of below-average rainfall and the extent and intensity of catchment development and surface and groundwater use.

The key water resource management issue for the catchment is limiting any further resource development in a system that appears to have reached or exceeded sustainable extraction levels, particularly with respect to:

- best management practice for surface water extraction from perennial pools that provide important aquatic refugia functions
- the impact of existing catchment development, including vegetation clearing and tributary and overland flow capture on landscape water balance, flows, groundwater recharge and the development of salinity problems
- the lack of understanding of fractured rock, shallow aquifer and surface-water interactions and yield in terms of both volume and quality characteristics and the management implications of such interactions for maintaining in-stream ecological values
- insufficient data on the diurnal and seasonal fluctuations of ambient water quality characteristics and their response to flows and water-extraction activities
- the existing and future prospect of climate change, which may result in reduced and/or more variable rainfall patterns.

It was noted during the study flyover and field investigations that there has been considerable development of overland flow capture infrastructure in the plan area. This is of such an extent that it may be having significant (measurable) effects on rainfall-runoff patterns, thereby affecting flood flow hydrographs, and on fluvial and Tertiary terrace aquifer recharge, thereby affecting base flows. The extent of these impacts is not presently quantified, but will require assessment and accounting for in any water resource planning for the plan area.

As previously mentioned, the existing groundwater data have not been fully interpreted or understood. There has been a long history of individualistic water resource utilisation in areas not subject to licensing and regulation. It should be noted that the rules applying to the recent alluvial aquifers of the Proserpine River may not apply to those of the O'Connell and Andromache rivers.

10.2 Hydrographic flow parameters and key ecological dependencies

Flow parameter	Ecological dependency
Base flow or groundwater level	• Maintenance of riffle and pool habitats by base flow in perennial reaches • Adequate recharge of fluvial aquifer and large, non-groundwater dependent perennial pools to provide refugia during the dry season in intermittent reaches
Lower floods (one to two years ARI)	• Regular elevated flows (not just major flood events but also lesser flows during below-average rainfall years) to allow fish and other aquatic organism passage past natural and low-level artificial passage barriers • Regular substantial freshwater inflows to estuaries to trigger recruitment or migration of estuarine organisms (e.g., prawns)
Moderate to high floods (more than three to five years ARI)	• Flushing flows to reset vegetation cover and macrophyte assemblage composition, providing habitat variability needed by other organisms • Regular elevated flows (not just major flood events but also lesser flows during below-average rainfall years) to allow fish and other aquatic organism passage past natural and low-level artificial passage barriers • Lack of peak flows in Proserpine River resulting in habitat degradation, vegetation overgrowth and reduced habitat and hydraulic linkage values of the river channels • Delivery of sediments and associated nutrients to estuarine and coastal habitats to provide sediment replenishment and nutrient sources for dry season marine productivity • Regular substantial freshwater inflows to estuaries to trigger recruitment or migration of estuarine organisms (e.g., prawns)

10.3 General conclusions

As a broad simplification, the flows in the Proserpine River below Peter Faust Dam and associated sections of Kelsey Creek and Lethe Brook are totally allocated to irrigation, drinking water and industrial water needs, and there is little capacity in the system for allowance for environmental flow allocation. Nonetheless, there are locations and reaches of high ecological value remaining, and with some additional management effort further ecological value could be gained. This additional management effort may not relate to water resource usage management but more to management of the in-channel and riparian vegetation degradation that is associated with current water and land-use practices. Where this management relates to removal of exotic vegetation that is clogging the channel, some additional water transport efficiency in the Proserpine River may be gained that in effect could constitute environmental flow allocations.

The situation in the O'Connell and Andromache catchment differs from that of the Proserpine catchment. In these systems there are no major water storages, so there is comparatively little flow regulation. Nevertheless, the current water resource use patterns appear to be approaching critical environmental thresholds. Water quality in the O'Connell is degraded by nutrient loading, although dissolved oxygen depression is not currently a feature. While not fully quantified at this stage, it does appear that current water use pressures on base flows are approaching, or in some reaches may have surpassed, ecologically tolerable levels. This has been exacerbated in the last two decades by increased agricultural development and associated water needs, when below-average rainfall has heightened natural environmental stress. At present many reaches retain high ecological values, but the systems may not be able to tolerate any additional water use pressures without substantial loss of those values.

The considerations of flow linkages in this study have identified ecosystem reliance of most categories of flood flows as well as base flows. There may well be opportunities to make more efficient usage of the recessional, post-flood peak flows. Note that the peak flows are typically the key trigger for biological response, although the recessional hydrograph limb is important for event duration and wetting requirements.

The Goorganga Plain wetland and adjacent coastal and marine ecosystems are of national significance. At present these systems appear to be maintaining their environmental values in the face of existing water resource demands, but the linkages between upstream flows and ecological responses and response times for these systems are not understood.

This latter point is indicative of a general lack of background data for the plan area. For a region with such extensive and intensive water resource demands and stakeholder appreciation of the local environmental values, including intimate reliance on the environmental values such as from recreational fishing and environmental tourism, it is striking that the available datasets are so limited in temporal and geographic coverage and, in the case of much of the groundwater dataset, there has been such limited interpretation of the data to date. This has been a substantial hindrance to this study.

References

Accad, A., Neldner, V.J., Wilson, B.A. and Niehus, R.E. (2003), *Remnant Vegetation in Queensland: Analysis of remnant vegetation 1997-1999-2000-2001, including regional ecosystem information,* Queensland Herbarium, Environmental Protection Agency, Brisbane.

ACTFR (2003), Coast and Clean Seas Project, *Water Quality in the Whitsunday Rivers Catchments: Surface Water Quality, December 2000 to August 2002*, ACTFR Report No. 02/13, Australian Centre for Tropical Freshwater Research (ACTFR), Townsville.

ACTFR (2004), *Mackay Whitsunday Region State of the Waterways Report 2004*, ACTFR Report No. 02/03, Australian Centre for Tropical Freshwater Research (ACTFR), Townsville.

ANZECC/ARMCANZ (2000), *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ).

Australian Groundwater Consultants Pty Ltd (1984), *Groundwater Investigations for Condor Oil Shale Project Management Group*, Report 824/1.

Aylward, C. and Trendell, P. (1999), *Proserpine and Gregory Rivers Erosion and Vegetation Condition Assessment*, Report prepared for the Whitsunday Rivers Integrated Catchment Management Association.

Blackman, J.G., Perry, T.W., Ford, G.I., Craven, S.A., Gardiner, S.J. and De Lai, R.J. (1999), *Characteristics of Important Wetlands in Queensland*, Environmental Protection Agency, Brisbane.

Brodie, J., McKergow, L.A., Prosser, I.P., Furnas, M., Hughes, A.O. and Hunter, H. (2003), *Sources of Sediment and Nutrient Exports to the Great Barrier Reef World Heritage Area*, ACTFR Report No. 03/11, ACTFR, Townsville.

Brown & Root (2001), *Fluvial Supply of Sediments to the Queensland Coast*, Consultant's report to Environmental Protection Agency, Brisbane.

Capon, S. (2001), *Flood for Thought: Relationships between flow and vegetation dynamics in large arid floodplains*, in I. Rutherford et al. (eds), Proceedings, Third Australian Stream Management Conference, Brisbane, August 2001.

Clarke, D.E. (1971), *Geology of the Proserpine 1:250 000 Sheet area, Queensland*, Geoscience Australia Report.

Clayton, P.D. and Skull, S.D. (1994), *Kelsey Creek Irrigation Scheme Environmental Impact Study: Hydrological, biological and water quality environmental survey - final report*, Australian Centre for Tropical Freshwater Research (ACTFR), Townsville.

Coles, R., Mellors, J., Bilbby, J. and Squire, B. (1987), *Seagrass Beds and Prawn Nursery*

Grounds between Bowen and Water Park Point, Information Series No. Q187021, Queensland Department of Primary Industries, Brisbane.

Coutts, A. and Hardy, S. (2001), *Soils and Land Suitability of the Clarke Range Area, Central Queensland*, Whitsunday Shire Council.

Coventry, R.J., Hopley, D., Campbell, J.B., Douglas, I., Harvey, N., Kershaw, A.P., Oliver, J., Phipps, C.V.G. and Pye, K. (1980), 'The Quaternary of Northeastern Australia', in R.A. Henderson and P.J. Stephenson (eds), *The Geology and Geophysics of Northeastern Australia*, Geological Society of Australia Incorporated, Queensland Division, pp. 375–417.

DEH (2001), *A Directory of Important Wetlands in Australia*, 3rd edn, Department of Environment and Heritage (DEH), Canberra(http://www.deh.gov.au/water/wetlands/database/directory/).

DEH (2005), *Great Barrier Reef Catchment Water Quality Action Plan*, Department of Environment and Heritage (DEH), Canberra (http://www.gbrmpa.gov.au/corp_site/key_issues/water_quality/action_plan/).

Driscoll, P.V. (1995), *Survey of Wader and Waterbird Communities along the Central Queensland Coast*, Report to Queensland Department of Environment and Heritage and Australian Heritage Commission.

EPA (2004), *Draft Queensland Water Quality Guidelines 2004*, Environmental Protection Agency (EPA), Brisbane.

Duke, N.C. (1985), 'Data on mangrove distribution in north-eastern Australia and some other areas', unpublished data report, Australian Institute of Marine Science.

Fisher Stewart & IDA (FSI) (1999), *Whitsunday Region Riverine Quarry Material Management Plan*, Consultant's report to Department of Natural Resources, Mines and Water, Brisbane.

Gutteridge Hastings and Davey (GHD) (2001), O'Connell River Weir: Environmental Impact Study.

Gordon, I and Shaw, R (1997), *The Potential for Development of Salinity and Watertable Problems under Irrigation in the Koolachu Area, Proserpine*, Salinity and Contaminant Hydrology Group, Natural Resource Management Group, Department of Natural Resources and Mines, Brisbane.

Grimes, K.G. (1980), 'The Tertiary Geology of North Queensland', in R.A. Henderson and P.J. Stephenson (eds), *The Geology and Geophysics of Northeastern Australia*, , Geological Society of Australia Incorporated, Queensland Division, pp. 329–47.

Hardy, S.M. (2003), *Soils and Land Suitability of the Whitsunday Coast Area*, Whitsunday Shire Council Report.

Hardy S.M. (2004), *Central Queensland Coast Bioregion Riparian Mapping Project*, Project Report, Mackay Whitsunday Natural Resource Management Group, Mackay.

Hardy, S. M. (2004a), *A Pedogeomorphological Analysis of Goorganga Wetlands to Assist with Managing the Areas Ecosystems*, ISCO 2004, 13th International Soil Conservation Organisation Conference, Brisbane, July 2004.

Houston, W.A. and Duivenvoorden, L.J. (2002), 'Replacement of Littoral Native Vegetation with the Ponded Pasture Grass Hymenachne amplexicaulis: Effects on plant, macroinvertebrate and fish biodiversity of backwaters in the Fitzroy River, Central Queensland, Australia', *Marine and Freshwater Research*, vol. 53, pp. 1235–44.

Hyland, S.J. (2002), *An Investigation of the Impacts of Ponded Pastures on Barramundi and Other Finfish Populations in Tropical Coastal Wetlands*, Project No. 97/20, Department of Primary Industries, Queensland.

Jensen, A.R. (1963), *The Geology of the Southern Half of the Proserpine 1:250 000 Sheet Area, Queensland*, Geoscience Australia Record.

Lobegeiger, J. and Otto, L. (1999), *Andromache and O'Connell Rivers Erosion and Vegetation Condition Assessment*, Report for Whitsunday Rivers Integrated Catchment Management Association Inc.

Mackay, S.J. and Thompson, C.T. (2000), 'Flow Requirements of Submerged Aquatic Macrophytes', in A.H. Arthington, et al. (eds), *Environmental Flow Requirements of the Brisbane River Downstream from Wivenhoe Dam*, SEQ Water and Griffith University, Centre for Catchment and In-stream Research, Brisbane.

McEniery, M.B. (1980), 'Groundwater Resources, North Queensland', in R.A. Henderson and P.J. Stephenson (eds), *The Geology and Geophysics of Northeastern Australia*, Geological Society of Australia Incorporated, Queensland Division, pp. 435–45.

Moss, A.J., Rayment, G.E., Reilly, N and Best, E.K. (1992), *A Preliminary Assessment of Sediment and Nutrient Export from Queensland Coastal Catchments*, Report for Department of Primary Industries and Department of Environment and Heritage, Brisbane.

MWNRM (2005), *Mackay Whitsunday Natural Resource Management Plan*, Mackay Whitsunday Natural Resource Management Group (MWNRM) (http://www.mwnrm.org.au/).

Neill, D.T., Orpin, A.R., Ridd, P.V. and Yu, B (2002), 'Sediment Yield and Impacts from River Catchments to the Great Barrier Reef Lagoon', *Marine and Freshwater Research*, vol. 53, pp. 733–52.

NLWRA (2002), *Australian Catchment, River and Estuary Assessment 2002*, National Land and Water Resource Audit (NLWRA), Canberra.

NRMW (2006), *Whitsunday Draft Water Resource Plan Information Report*, Department of Natural Resources, Mines and Water (NRMW), Brisbane.

Paine, A.G.L. and Cameron, R.L. (1972), *Bowen, Queensland – 1:250 000 Geological Series Explanatory Notes*, Bureau of Mineral Resources, Australia, SF/55-4.

Perna, C. and Burrows, D. (2005), 'Improved dissolved oxygen status following removal of exotic weed mats in important fish habitat lagoons of the tropical Burdekin River floodplain, Australia', *Marine Pollution Bulletin*, vol. 51, pp. 138–48.

Proserpine Historical Society (1988), *Proserpine Then and Now, a Historical Record.*

Pusey, B., Kennard, M. and Arthington, A. (2004), *Freshwater Fishes of North-eastern Australia*, CSIRO Publishing, Collingwood.

QWRC (1981), *Progress Report on Groundwater Investigations Proserpine Area*, Groundwater Branch, Queensland Water Resources Commission (QWRC), Brisbane.

QDPI (1993), *Overview of Water Resources and Related Issues, the Mackay–Whitsunday Region*, Queensland Department of Primary Industry (QDPI), Brisbane.

Sattler, P. and Williams, R. (eds) (1999), *The Conservation Status of Queensland's Bioregional Ecosystems*, Environmental Protection Agency, Brisbane.

Stephens, A.W. (1993), *Evolution of the Proserpine Coastal Plains*, Geological Survey of Queensland Report 66/2.

SunWater (2001), *Proserpine River at Peter Faust Dam*, Revised Flood Study, SunWater Engineering Services.

Tait, J. (1994), *Lowland Habitat Mapping and Management Recommendations, Tully–Murray Catchment*, Report to Cardwell Shire Catchment Coordinating Committee, Cardwell.

Tait, J. and Perna, C. (2001), 'Fish Habitat Management Challenges on an Intensively Developed Tropical Floodplain', *RipRap*, vol. 19, pp. 14–21.

Thompson, W.P, Baker, D.E. and Cannon, M.G. (1981), *Soils of the Proserpine Lowland, North Queensland*, Technical Report No. 18, Agricultural Chemistry Branch, Department of Primary Industries, Brisbane.

Ullman and Nolan Pty Ltd (1975), *Proserpine River Flood Mitigation Project*, Proserpine Shire Council, Queensland.

Glossary

Term	Definition
Alluvial (alluvium)	weathered material transported and deposited by the movement of water
Anastomosing	a channel of water that divides into a number of smaller channels, which meet and then redivide and are separated by stable islands; water spreading across the river bed as numerous small channels
Aquifer	a water-bearing stratum of permeable rock, sand or gravel
Base flow	the portion of stream flow that comes from groundwater
Bioregion/s	relatively large land area characterised by broad, landscape-scale natural features and environmental processes that influence the functions of entire ecosystems. They are linked to fauna and flora assemblages and processes at the ecosystem scale, thus providing a useful means for simplifying and reporting on more complex patterns of biodiversity
Catadromous	biological state of some freshwater fish species that require salt water habitat in order to spawn
Carboniferous	period of geological time extending from about 360 to 290 million years ago
Coastal plain	any plain with its margins on the shore of the sea. Coastal Plains are generally a flat featureless area of low relief usually underlain by sediments
Colluvium	loose and incoherent materials accumulated at the foot of a slope, generally by movement of the material by gravity
Conglomerate	coarse sedimentary rock containing cemented rounded gravel or pebbles
Dendritic	having a form resembling a shrub or tree; a random branching drainage pattern for a river that is similar to a tree)
Denuded (denudation)	removal of matter. Commonly the removal of vegetation, but also the process of mass, or rapid, sediment removal
Duplex	light surface texture of sand or clay loam abruptly overlying clay
Ecology	study of the interrelationships of organisms with and within their environment
Ecosystem	a community and its (living and non-living) environment considered collectively; the fundamental unit in ecology
Environment	the total of all the external conditions that act upon an organism
Environmental quality	human (individual or social) concepts of desirable ecological situations
Erosion	process by which rocks are loosened, worn away and removed from parts of the Earth's surface. Seven processes of erosion discussed separately; in practice they overlap and it is often difficult to isolate the net effects of any one process: • *rainsplash erosion:* detachment and removal of soil and debris by raindrop impact • *overland flow or surface runoff:* water flowing over the surface before being concentrated into definite streams • *sheet erosion, sheet wash or slope wash:* combined effect of overland flow and rain splash • *gully erosion:* rapid development of gullies, usually in first- or second-order tributaries of streams, but also in situations unrelated to an integrated drainage system (e.g., highly dispersive soils) • *mass movement:* downhill movement of debris en masse rather than as individual particles; can occur slowly (creep) or rapidly (rock falls, slumps, landslides) • surface rock creep: movement of stones down sloping surfaces • *fluvial erosion:* detachment and removal by streams of material in solution, suspension or as bed load; includes removal of debris supplied to the streams by slope wash, mass movement and gullies.
Estuarine	mouth region of a river that is affected by tides

Term	Definition
Evaporation	process that changes a liquid or a solid into a gas. In the tropical hydrological cycle, involves the conversion to water vapour and return to the atmosphere of precipitation (rainfall) that has reached the Earth's surface
Evapotranspiration	combined effect of evaporation from the soil surface and transpiration from vegetation
Fauna	collective animals of a given region
Floodplain	the portion of a river valley that is covered during periods of high floodwater
Flora	collective plants growing in a geographic area
Fluvial	a river system
Geomorphological time periods	**Proterozoic (2500–545 million years ago)** During the Proterozoic two mountainous blocks, the Mt Isa Inlier and the Georgetown massif (current area of the Einasleigh Uplands) were formed. Formation was a result of faulting, folding, thrusting of deposited marine and terrestrial sediments, extrusive volcanics and igneous intrusions. Widespread metamorphism was associated with igneous intrusions and the deforming tectonic activities (Brennan 2004). **Palaeozoic (545–251 million years ago)** Extensive erosion and planation was the major process occurring during this period. Weathered sediments were stripped from the two Proterozoic blocks and deposited within the Tasman geosyncline between these two divisions. North-west of the Proterozoic Mt Isa Inlier a shallow sea transgressed from the south depositing carbonate-dominated marine sediments. These comprise the Barkly Tableland of the upper Nicholson and Settlement catchments today. In the Einasleigh Uplands some extrusive volcanics accompanied erosion processes and resulted in the formation of the Newcastle and Croydon ranges in the Norman and Gilbert catchments. In the west, erosion continued to form an extensive plain that grew eastwards and, by the early Mesozoic, the whole of the Gulf region was reduced to a flat plain (Brennan 2004). **Mesozoic (251–65 million years ago)** The Proterozoic to Mesozoic cycle of erosion was terminated by earth movements that warped the flat plains. The result was the transgression (higher sea levels) of the sea into the Carpentaria and Eromanga basins and the widespread deposition of Mesozoic sediments, namely sandstone, siltstone, mudstone, limestone, shale and conglomerate overlying the erosion surface of old, deformed Proterozoic rocks. By the end of the Mesozoic the only extruding Palaeozoic rocks remained in the east (Einasleigh Uplands) (Brennan 2004). **Early-Mid Tertiary (65–34 million years ago)** During this period the Mesozoic plain was uplifted ad warped, resulting in widespread erosion of the Mesozoic sediments. By the Mid-Tertiary most of the area was again reduced to a low relief plain that underwent laterisation (Brennan 2004). **Late Tertiary–Quaternary (34 million years ago to present)** Uplifting and warping increased slopes and initiated another period of erosion and planation. Streams adjusted to a new base level (increased sea levels) and the erosional surfaces extended inland, forming the dissected river valleys seen today. At the upland margins of the Gulf Plains, the late Cretaceous rocks (end of the Mesozoic period) were removed and within the steeper ranges rocks formed at end of the Palaeozoic period were eroded away. Accompanying widespread erosion was extensive deposition and the formation of new alluvial fans in the lower reaches of the Gulf catchments (Brennan 2004). Along the coastline, down-warping lowered the laterised older Tertiary plain to wave action level (hence increased sea levels). This formed low cliffs and a marine terrace. Due to a low offshore gradient and wave action and high loads of terrestrial sedimentation, constructional landforms were formed (e.g., barrier beaches and islands). A later drop in sea level and subsequent emergence of land led to the abandonment of barrier beaches that occur as parallel ridges around the Gulf of Carpentaria today, and the formation of a new lower, marine terrace (Brennan 2004). Some volcanic eruptions in the eastern block (Einasleigh Uplands) also occurred during this period, resulting in infilling of older valleys, particularly in the upper Flinders and Gilbert catchments (Brennan 2004).

Term	Definition
Geomorphology (geomorphological)	form or shape of the landscape and the processes that modify and change it
Gilgai	melon hole, mound depression surface
Global warming	warming of the Earth's atmosphere generally attributed to the burning of fossil fuels; also referred to as the 'greenhouse effect', capacity of the atmosphere to transmit short-wave energy (visible and ultraviolet light) to the Earth's surface and to absorb and retain heat radiating from the surface
Groundwater	water found underground in porous rock or soil strata
Holocene	period of geological time extending from about 10 000 years ago to present
Hydrodynamics	movements of water and other liquids
Hyporheic zone	area below the stream bed where water percolates through spaces between sediment particles
Inter-tidal	area between high and low tide
Littoral	shoreward region of a body of water in which light penetrates to the bottom
Macrophyte	macroscopic aquatic plant
Metamorphism	transformation of a pre-existing rock into a new rock by the action of heat (thermal metamorphism associated with igneous intrusions) or by severe compressional earth movements (regional metamorphism associated with folding, faulting, etc.). Changes occur to the texture, composition, physical or chemical structure of the original rock (Brennan 2004)
Natural environment	complex of atmospheric, geological and biological characteristics found in an area in the absence of artefacts or influences of a well-developed technological human culture.
Permeable rock	rock through which water can pass, either via either (a) a network of pores between the grains (b) interconnected joints, bedding planes and fissures (more correctly termed 'pervious rock')
Permian	period of geological time extending from about 285 to 250 million years ago
pH	power hydrogen. A negative logarithm of hydrogen-ion concentration or numerical expression of acidity or alkalinity
Piedmont	area of land formed or lying at the foot of a mountain or mountain range
PET	number of families of Plecoptera, Ephemeroptera and Trichoptera, or stoneflies, mayflies and caddisflies, which are generally regarded as pollution- and habitat- sensitive taxa
Planation	processes of erosion resulting in the formation of fundamentally, flat, even or level surfaces (Brennan 2004)
Pleistocene	first part of the Quaternary period of geological time lasting from about 2 million years to 10 000 years ago.
Potamodromous	fish species that complete life cycles and move wholly within fresh water
Precambrian	period of geological time extending from about 285 to 250 million years ago
Precipitation	collective term for the moisture, either liquid or solid, that falls on the earth from the atmosphere. In north Queensland, this is usually in the form of rain
Prograde (progradation)	accumulation of sediments and the subsequent migration of a bank or coastline outwards from the land
Riverine	pertaining to rivers
Salinity	concentration of any salt
Sediment	any usually finely divided organic and/or mineral matter deposited by air or water in non-turbulent areas
Sodic	dominance of sodium in the exchange complex of soil. High levels of sodium can cause moisture-infiltration problems and the accompanying generally high soil pH can cause nutrient disorders
Soil aggregation	lumping together of soil particles into a coherent mass
Soil profile	physical and chemical features of soil imagined or seen in vertical section from the surface to the point at which the characteristics of the parent rock are not modified by surface weathering or soil processes

Term	Definition
Stress	result or consequent state of a physical or chemical, or social, stimulus on an organism or system
TDS	total dissolved solids; a measure of the amount of material dissolved in a water sample
Terrain	tract of land and its physical features, with emphasis on bedrock geology
Terrestrial	pertaining to land, the continents and/or dry ground; contrasts with aquatic
Tertiary	period of geological time extending from about 65 to 2 million years ago
Topography	description or representation of natural or artificial features of the landscape; description of any surface, but usually the earth's
Transpiration	loss of water from plants, normally as vapour
Weathering	changes in the coherence, texture and composition of rocks and minerals by either physical (mechanical) or chemical processes as a result of exposure at the Earth's surface