A Summary Review of Groundwater Research and Knowledge for the Black River and Ross River Basins

August 2007

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Executive Summary

The purpose of this report is to review research and knowledge on groundwater in the Black River and Ross River Basins (Townsville and Thuringowa Local Government Areas). This information will support the Water Quality Improvement Plan, which is the key component of the Creek to Coral managed Coastal Catchment Initiative project for the Black and Ross River Basins.

Information gathered for this report came from both written and oral sources. Many reports and publications were reviewed, and data collected by consultation with people who have knowledge of groundwater in the study area. Information considered important was groundwater distribution and quantity, groundwater quality, groundwater extraction and regulation, groundwater interactions with surface water, and also with the environment.

Reviewing the literature produced a picture of groundwater research which is fragmented geographically. Many reports exist for the Bluewater Sub-Artesian Declared Area (North of Townsville) which is of significance to heavy industry. These reports are almost entirely related to determining sustainable yields to support allocations. Also a number of reports focus on aquifer yields in particular areas, to assess the viability of extracting groundwater for domestic use.

Some reports however had broader study areas and provided data, which is more relevant from a regional perspective. Two more recent studies looked at the processes of groundwater in this coastal dry tropical environment, and suggested potential issues relating to the environment.

Consultations resulted in the compilation of data primarily relating to groundwater use in the industrial, commercial, and private sectors. It is notable that outside the Bluewater Sub-Artesian Declared area production bores are not monitored and licenses are not required. Only in the last two years has it become necessary to use a registered driller to drill for groundwater, and for the driller to lodge the drill log with the Department of Natural Resources and Water.

The report indicates that a reasonable amount of historical groundwater data exists for the Black and Ross River Basins. If the data from the various sources were to be compiled and considered appropriately in relation to its age and accuracy, a broad view of groundwater in the study area would begin to emerge. Infill data may be required to complete the picture. This could be obtained by data collection from new or existing bores.

In conclusion there are many issues to consider in relation to groundwater in this region, and its relationship with surface water and the environment. Surface water in the dry tropics is often ephemeral and ecosystems have developed to depend on subsurface water in extended periods of dry weather. Understanding and protection of groundwater resources in the study area is paramount.

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Abbreviations

ANZECC Australian and New Zealand Environment and Conservation Council
ARI Annual recurrence interval
ARMCANZ Agriculture and Resource Management Council of Australia and New Zealand
AWQ Guidelines *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000*
AWR Australian Water Resources (Council) – River basins
COT City of Thuringowa
C2C Creek to Coral
DNRW Queensland Government Department of Natural Resources and Water
DPIF Queensland Government Department of Primary Industries and Fisheries
ESD Ecologically Sustainable Development
EPA Queensland Government Environmental Protection Agency
EPP Water *Environmental Protection (Water) Policy 1997*
EP Act *Environmental Protection Act 1994*
ERA Environmentally Relevant Activity
EVs Environmental Values
IDAS Integrated Development Assessment System
IP ACT *Integrated Planning Act 1997*
LGAQ Local Government Association of Queensland
NRM Natural resource management
QA Quality Assurance
TBL Triple Bottom Line
TCC Townsville City Council
WG Working Group
WQ Water Quality
WQOs Water Quality Objectives

1. Introduction

1.1 Background

Creek to Coral (a joint initiative of Townsville City Council and Thuringowa City Council) is an infrastructure-based initiative to maintain and enhance healthy waterways in the coastal dry tropics.

This groundwater research and review project has been undertaken by Creek to Coral to support its Coastal Catchment Initiative (CCI) project. CCI is a Commonwealth funded program aimed at achieving target reductions in pollution discharges into coastal waters of high conservation value. The Great Barrier Reef is considered to be an area of coastal water with a very significant conservation value.

The Coastal Catchment Initiative involves the development of a Water Quality Improvement Plan (WQIP) for the Townsville and Thuringowa sub-catchments. Fundamental to the Water Quality Improvement Plan is a holistic view of water cycle processes in the Townsville and Thuringowa area. As part of this broader picture a synopsis of groundwater research and knowledge in these local government areas has been undertaken. Information regarded as important in the study was groundwater distribution, groundwater quality, groundwater use and monitoring, interactions with surface water and ecosystems.

1.2 Project Objective

This project objective was to collate references and review available information, either written or oral, to provide an indication of the extent of existing groundwater information, to summarise relevant accessible information and to provide a preliminary indication of the knowledge of the linkages between groundwater and surface water and especially with relation to water quality and flow patterns.

The report does not attempt to provide all the groundwater information necessary for the development of a WQIP. Its purpose is to uncover the information that currently exists and to summarise the information that is readily available.

1.3 Study Area

The study is confined to the area encompassed by the CCI project. This area covers the Ross River and Black River Basins (as defined by the Australian Water Resources Council). The following surface water catchments are part of the study area: Ross River, Bohle River, Black River, Bluewater Creek, and Crystal Creek.

1.4 Methodolgy

The data collected for this report falls into two major categories, written information, and oral information. Appendix A is a list of publications and reports which were found to be relevant to this study, while appendix B is a list of people consulted in various organizations who provided knowledge on groundwater in the study area.

Written information in the form of publications and reports was collected by searching libraries and websites. Conversations with people also led to the discovery of some reports. Some of the more relevant data has been reviewed in this report.

Oral information was gathered by telephone interviews and face-to-face interviews. This data has been collated to form a broad picture of understanding and is included in the results of this report.

Appendix C is a sketch map of the study area showing researched areas and areas where observation bores are located. Appendix D shows catchment management units in the Black and Ross River Basins.

2. Results

2.1 Background

Groundwater is water held beneath the land surface within the interconnected openings of saturated rock. It plays a fundamental role in the natural water cycle; at any given time greater than 98% of all liquid fresh water on the planet is stored below the Earth's surface as groundwater.

Groundwater is held within the pore spaces (voids) of unconsolidated alluvium and colluvium and within pore spaces and fractures within bedrock. Recharge (topping up) of groundwater is via rainfall or from ponding or running water which then percolating into the groundwater system (aquifers). Generally recharge areas are in the upper catchment zone. Groundwater discharge often occurs into rivers and streams or directly into the marine environment either above or below the low-tide mark. Groundwater is dynamic and flows. At the most basic level it is gravity which makes groundwater migrate through rocks.

Groundwater and surface water are usually interconnected and interchangeable; with shallow aquifers often spending periods as surface flow.

Aquifers are bodies of saturated rock, which store and transmit important quantities of water. Groundwater is often stored in aquifers, which at depth are confined under pressure. These aquifers are referred to as artesian and do not require pumping as water rises to the surface due to the confining pressure. Shallow aquifer and sub-artesian aquifers require pumping. Shallow aquifers often vary in quantity and composition on a seasonal basis.

2.2 Literature Review

Appendix A is a list of publications and reports, which have been reviewed for this study; it also contains a short summary of their content.

Several studies which are reportedly in existence but were not easily available for review were considered beyond the scope of this project. They are listed below for reference.

- A groundwater study at Lavarack Barracks (Australian Groundwater Consultants information). The report is possibly available from the Defence Department.
- Reports on the Bluewater Sub-Artesian Declared Area (which contains the Black River Restricted License Area). Research and monitoring at Black River is related to heavy industry located in the vicinity. This industry – Queensland Nickel Refinery - is reliant on a constant groundwater supply. Reports have been done by both Queensland Nickel (QNI) and also by the Department of Natural Resources and Water (DNRW). These reports are available from DNRW although the QNI reports will require permission from QNI. A list of these reports is included in Appendix A.
- Seepage Investigation - Ross River Dam (1981). This report was not reviewed as it was considered to be too specific for this review. It is however very extensive and may have some relevance to further studies in the Ross River area.

Groundwater research in the Townsville region has generally been done in specific "Interest Areas". Usually the research has been done in response to a need for water resources.

A number of reports stand out however. The thesis *Hydrogeology of the Lower Ross and Bohle Rivers Area* (1975) aims to provide in depth baseline data (qualitative, quantitative and positional) for the project area. Also the groundwater section included in the "Townsville–Thuringowa Strategy Plan" (1996) is an important source of regional information and aims to outline issues of concern (in relation to groundwater) and also to recommend appropriate actions for managing the resource from an environmental protection perspective.

The Horseshoe Bay Drainage Management Plan is the most recent report reviewed. It is a thorough investigation and takes a whole of catchment approach. The data collected in this study puts the Horseshoe Bay area into the context of the coastal dry tropical environment and therefore gives valuable insight into catchment studies (in general) and groundwater (more specifically) throughout the coastal dry tropics.

2.2.1 Groundwater in the Bohle-Ross River Area, Townsville, Qld (1973)

This report concluded that the Bohle-Upper Ross River area contained a significant reservoir of underground water and proposed a well-field in the area of Kirwan and Condon – extending on the western side of Upper Ross River Road in the direction of the Dam. Estimates of a natural long-term yield of 7 million gallons/day were made at the time.

2.2.2 Hydrogeology of the Lower Ross and Bohle Catchments (1975)

This Honours thesis surveyed groundwater from 100 private bores in the vicinity of the Bohle-Ross aquifer system, North of Ross River. The research area is bordered by the Bohle River to the West and the Ross River to the East and South. It was intended as a reliable baseline study for further and more specific studies and would have covered most of the residential areas of Townsville at the time it was produced. Water levels were recorded and detailed chemical analysis carried out on the samples (Sodium, Chloride, Calcium, Magnesium and Potassium). Sampling methods are described and reliability of the results is considered in respect to minor effects on pH and conductivity due to pumping, and lifting of the groundwater samples.

The study concludes that the Ross and Bohle aquifer systems exist as a dual series of aquifers separated by a silica matrix sandstone aqiclude (a layer which separates aquifers but which is not always impermeable). The lower aquifer series is reportedly of good quality and abundant supply and maintained under sub-artesian pressure. The upper series of aquifers are reported as producing groundwater of various quality and quantity. Chemical analysis of the upper series of ground water shows a close relationship to superficial soil types and specific cases of seawater intrusion were reported.

A map of groundwater extent was also part of the thesis work however the map at this time has not been located. C & R Consulting may be able to produce this at a later date.

2.2.3 Gustav Creek Magnetic Island Groundwater Investigation (1981)

Groundwater at Gustav Creek was investigated from the perspective of two potential sources: surface sand which overlays a clay subsurface layer, and water within fractures in the underlying rocks. Materials encountered during drilling indicated that the soil profiles in the region of Gustav Creek were extremely variable and that the aquifer was limited in extent. The deeper rock aquifer was not explored due to the drill hole failing to intersect fractures in the selected area.

Extrapolated flow rates from pump tests indicated that unrestricted water usage on Magnetic Island was ten times the expected daily yield from this aquifer. It was concluded that the surface sands be insufficient to be considered as a viable alternative water supply for Magnetic Island. Recommendations were made however that the Gustav Creek Bore be connected to existing reticulation on Magnetic Island for use in the event of interruption to the existing supply.

2.2.4 Alligator Creek Development Water Supply Potential (1983)

The extent of development at Alligator creek was in 1983 dependent on the availability of suitable water supplies. This preliminary study aims to assess the potential of water resources at the Alligator Creek development site. All available hydrological data was reviewed.

The local bores in the area indicated low salinity levels with groundwater becoming more saline away from Alligator Creek. It was stated that during periods of low rainfall, salinity levels rise as the water table lowers. At this time more saline waters move from the margins of the catchment towards the pumping bores. During the period of the report, drought caused this phenomenon to be observed in domestic bores up to 1km West of Alligator Creek.

This reasonably thorough report concludes that the area of interest would potentially support sustainable exploitation of the groundwater resources in the area. It suggests that while Alligator Creek is flowing adequate recharge would occur for bores in the vicinity of the development site. The report proposes further investigation to confirm groundwater potential and determine the preferred location of production bores. It makes recommendations for geophysical survey, test drilling, and pump tests and data analysis.

2.2.5 Alligator Creek Development Domestic Water Supply(1983)

This report provides the results of a geophysical resistivity survey and drilling and pump test programs on land on the Eastern bank of Alligator Creek. The aim was to investigate the water supply potential of the site. Detailed water quality data is provided for 5 bores together with yields. A total of 24 Bores were drilled.

The investigation states that the water bearing zones of aquifers are the alluvial sand/gravels and the gravels of the colluvial sediments. It concludes that the random deposition of the colluvial and alluvial sediments has formed fan-shaped aquifers across the flood plain of Alligator Creek.

The report predicts a maximum recommended groundwater supply of 9L/s, which would meet the needs of the subdivision at that time.

2.2.6 Townsville-Thuringowa Strategy Plan - Natural Resources Management (1996)

This document aims to identify major goals for the renewable natural resources of the sub-region. It contains a regional but detailed assessment of the groundwater resources of the area and a short summary of relevant material is included here.

The sub-region of Townsville and Thuringowa is said to have significant groundwater resources, which are located in semi-unconsolidated sediments and in fractured rock. The best source of groundwater is the sediments and water quality is variable throughout the study area.

Three primary sources of groundwater are utilized in the Townsville-Thuringowa area: alluvial sediments, fractured rock and beach ridges.

Aquifer Host	Depth (m)	Flow Rates (L/s)
Young sediments	0-20	1-10
Old Sediments	20-30	0.5 – 1
Fractured Rock	25-40	0.5-2
Beach Ridges	3-10	0.25 – 0.5

A map of aquifers within the sub-region was produced by mapping geological features known to be aquifer – bearing. The report identifies a number of key issues in relation to groundwater:

- Recharge of groundwater aquifers is vital for their sustainability and dependent on the wet season. Loss of vegetation in recharge areas (often upper catchment) can reduce recharge due to increased run-off. Rates of recharge to young sediment aquifers could be affected by clearing, drainage of wetlands and large capacity urban drain infrastructure. This is particularly relevant in the Bohle and Deeragun areas.
- Young sediment aquifers are shallow and particularly vulnerable to contamination. Risks include the positioning of hazardous industry, waste dumps and also dense rural residential lots reliant on septic systems which are positioned on permeable soils in these areas.
- Pump supplies from shallow aquifers are dependent on the water table and accordingly some experience supply difficulties due to extraction exceeding recharge, particularly in times of drought.

A number of actions were proposed by the Townsville-Thuringowa Strategy plan in relation to groundwater including:

- Development of a strategic monitoring program to identify the quantity and quality of groundwater.
- Establishment of a research program to determine existing exploitation, yield, and reliability of groundwater.
- Development of a sustainable water supply strategy.
- Prevent the deterioration of groundwater quality and improve it where possible.
- Identify and map shallow sandy aquifers to guard against inappropriate land use.

2.2.7 Horseshoe Bay Drainage Management Plan (2006)

The Horseshoe Bay Drainage Management Plan (HBDMP) includes an intensive environmental study of the sensitive Horseshoe Bay area.

The study presents Horseshoe Bay as a unique environment in which the short and long term climate variability has shaped the landscape over the past 40 million years. This has created a complex geomorphology that controls the movement of water through the sub-catchment where ancient channels infilled by course sediment transport water slowly from the scarp through to the shoreline.

Horseshoe Bay is a compact system where all the land surfaces (and related systems) generally associated with a coastal plain area, is present within a very short distance. As such study of this area provides a great deal of information on the interactions of surface and groundwater. This data could be extrapolated to larger catchments in the region, which may not be so easily or economically studied.

The HBDMP notes that the threat of development to Horseshoe Bay lagoon and its associated wetlands is increased by the compact geomorphology peculiar to the bay and the normal stresses imposed on the system by the climate of the seasonally arid tropics.

The significance of groundwater at Horseshoe Bay can be summarized by the following points:

- Aquifers and drainage pathways across Horseshoe bay's narrow coastal plain are complex, acting as both storage units and seepage zones within the same system.
- Slow release of waters from the fractured rock in the upper catchment, together with the slowing process of the subsurface flow channels, prolongs the seepage of waters into the wetlands and lagoon systems. This provides moisture for wetlands and ecosystems through the dry periods.
- All ecological and geomorphologic features combine to create a unique environment that is dependant on the underlying hydrogeology.

- Recharge zones for the deeper aquifers are predominantly from fracture fill water and the zone immediately to the base of the scarp. Therefore for the protection of recharge at both shallow and deeper levels, are highly recommended.
- Shallow aquifers also include the fracture-fill and base of scarp sources. They are however supplemented by the more recent surface related alluvial/colluvial fans that emanate from the scarp, and porous and permeable zones occurring over the current land surface, including current stream channel pathways.
- Water quality of shallow aquifers varies from season to season, i.e. more saline in dry season. Deeper aquifers generally have excellent water quality which doesn't vary seasonally – although aquifer levels do.
- Hard engineering can interrupt shallow aquifers, i.e. where engineered drainage structures interrupt subsurface flows. Soft engineering options are preferable. Horseshoe Bay has some seasonally emergent subsurface flows.
- The deeper aquifers are vital for the maintenance of the hyporheic zone. These zones below existing riverbeds maintain groundwater dependent ecosystems through the dry season and are significant in surface and subsurface water exchange through nutrient recycling, organic decomposition, and the maintenance of the riparian zone in the dry season.
- High intensity, short term rainfall does not recharge aquifers efficiently. A period of "soaking rain" is required to allow water to penetrate dry and hardened soils.
- The subsurface flow, and its magnitude, is vital for the sustainability of the ecosystems and ephemeral wetlands at the surface and the viability of the Horseshoe Bay Environmental Park."

The HBDMP also comments on groundwater quality and geochemistry. The following points were noted:

- Often groundwater chemistry strongly reflects the composition of the geology or soils in which it is hosted.
- Groundwater chemistry can vary markedly through out the seasons in a dry tropical environment, due to the first rains providing a flushing effect through shallower aquifer systems. This effect can cause high levels of some analytes in groundwater, which, using surface water guidelines could be considered to be contaminants. It is therefore important that these processes be thoroughly understood, as remediation of groundwater with natural levels above accepted standards, might lead to destruction of microfauna present in the groundwater and groundwater dependent ecosystems that have adapted to these events.
- The recommendations of the HBDP are that more locally relevant guidelines for groundwater quality are necessary. And that guidelines relating to geomorphological zonation might be necessary.
- Groundwater quality will change spatially and temporally as flow, elevation and climate alter. These factors have to be considered when evaluating groundwater quality and compositional compliance.
- Acid Sulphate assessments for developments at Horseshoe Bay are recommended due to the nature of the shallow aquifer systems.

2.3 Consultation

Appendix 2 is a list of people consulted for this study.

Groundwater data in the Townsville and Thuringowa areas is fragmented and appears to be concentrated in areas of concern with little or no data to infill. Areas of concern have been investigated principally to monitor quantity in relation to use and water quality due to contamination (i.e. septic or recycled water use).

2.4 Groundwater Use

2.4.1 Industrial - Bluewater Sub-Artesian Area

Groundwater usage in the Townsville-Thuringowa area is only monitored in the Bluewater Sub-Artesian Area, which is a "Declared Area" under the Water Act 2000. Part of this Declared Area, the "Black River Restricted License area" is covered by the Queensland Nickel Agreement Act (1988) which protects Queensland Nickel's water allocation. This area South West of the Bruce Highway at Black River is approximately 1200km2. Bore licenses must be issued in the Bluewater Sub-Artesian Area. In the Black River Restricted Area however bore licenses are restricted and only issued under certain conditions. There are thought to be approximately 1600 private/residential bores within the area.

The sustainable yield for the Black River Well Field was originally put at 9000 megalitres; however it has now been reduced to approximately 6000 megalitres. This is due to a better understanding of the extent of the aquifer, which was originally interpreted as one continuous body and is now thought to be numerous ribbons. Changes in climate may also have had some impact.

2.4.2 Commercial

Other users of Groundwater are turf farms, aquaculture operations and some stock watering. These bores are not monitored or restricted.

There is some concern about groundwater use in rural/residential areas such as Oak Valley. More bores are being sunk there, and there have been reports that aquifer levels are dropping towards the end of the dry season. In an area where septic tanks are in use there may be some risk of contamination. The proximity of Oak Valley to the Ross River Dam is an added concern.

2.4.3 Private/Residential

Residential bores outside the Bluewater Sub-Artesian Area are not monitored or restricted in any way and therefore it is not known how many residential bores are in the Townsville-Thuringowa area. There is also no data on how many are in current use. In the last few years however, it has become a requirement to use a registered driller to put in a bore, and also for the driller to submit the drill log to DNRW. Previous to this arrangement, drill logs were only provided to DNRW on a voluntary basis. DNRW is attempting to put all drill log information into a digital database. Some of the Drill logs go back 20-30 years.

Drilling Logs are organized by suburb and contain information on location (lat/long of Northing/Easting), depth, strata description and conductivity (as a measure of salinity). There are still a lot of bores being sunk in some areas up to 66 in Kelso in 2006.

Surface water extraction (by residents with riparian rights) is not monitored.

2.5 Monitoring

Monitoring bores are generally used to check water levels and to guard against contamination of groundwater. The following monitoring bores are in current use.

- DNRW have some monitoring Bores around the Bluewater and Black River areas.
- NQ Water monitors some shallow aquifers (locations not known).
- Citiworks have groundwater monitoring holes at Dean Park, South Townsville.

- Citiwater has observation bores at Horseshoe Bay (20-30) and Picnic Bay (4). At Horseshoe Bay monitoring is for quality (nitrogen, phosphorous, ph, conductivity) and quantity. These bores are either in the vicinity of water treatment plants or near areas where recycled water is in use for irrigation. Citiwater also have observation bores on Helene Downs (near Cluden) at the Waste Water Treatment Plant and at Rowes Bay Golf Course (where recycled water is in use).
- Origin Energy plant at Stuart
- Fuel Station around the Townsville-Thuringowa area (the EPA may monitor these).
- The Main Roads Department may also have some.

The idea of using private bores for monitoring is appealing due to their number and extent. There is however a number of factors that would need to be considered if observation bores are monitored.

Firstly not all bores are known i.e. some are not listed with DNRW. Secondly access can be difficult to private bores, agreement is needed from the property owners and often pets are a complicating factor. Lastly monitoring from producing bore can cause a “draw down effect” which will bias results and needs to be accounted for.

3. Discussion and Conclusion

3.1 Discussion

The sparse and task-specific nature of the data reviewed for this report show in general that little is understood about the importance of groundwater in the Coastal dry tropical environment of Townsville-Thuringowa study area. Data has been gathered on the basis of need for water resources or risk assessment (in relation to contamination), with little focus on understanding the extent or nature of the resource in a broad sense. Certainly only a few reports describe the relationship between groundwater and the surface environment.

In researching groundwater for this report the link between groundwater and the ecosystems and waterways of Townsville-Thuringowa coastal dry tropics is difficult to ignore. Characteristically the dry tropics are an area where climatic extremes are often encountered and periods of high rainfall are generally followed by annual periods of dry weather. Often these periods last for several years due to the failing of the wet season. Surface water in this environment is often ephemeral due to high evaporation rate. In this extreme environment ecosystems become stressed and fragile and depend heavily on groundwater. Some flora and fauna have developed to cope with unusual water chemistry, which is often associated with low water levels in aquifer.

Some of the important points which link groundwater and surface environments are listed here:

- Groundwater has the potential to maintain wetlands through a drip-feed system long after surface water has evaporated.
- Groundwater contributes to the base flow of many creeks and river systems. This base flow is fundamental to the maintenance of riparian vegetation and groundwater dependant ecosystems.
- Reduced flow rates of groundwater into the coastal marine environment result in saline waters encroaching landward. This has the potential to harm environments which are not tolerant to increased salinity. Groundwater resources may also be impacted.
- The Hyporheic beneath river channels is maintained by deeper aquifers, and has numerous roles in maintaining healthy ecosystems in and around the river bed.
- Groundwater often spends time on the surface in it's migration through the catchment. Changes in groundwater flow and chemistry will therefore directly impact surface flow and chemistry and there ability to sustain the environment.
- Recharge zones commonly associated with scarp/base of scarp environments, will fail to provide their service to groundwater resources where tree clearing, or urban drainage infrastructure are allowed to occur without due consideration.
- Contamination of groundwater has implication for contamination of surface water.
- Potential Acid Sulphate Soils are vulnerable to changes in groundwater condition.

3.2 Conclusion

Currently, groundwater in the Townsville-Thuringowa area can only be accurately mapped in a number of discreet areas. For a better understanding of the location and nature of groundwater in the Townsville-Thuringowa area, a more comprehensive dataset would be required. In the first instance collation of existing data from the numerous sources referred to in this document might facilitate a more detailed regional view. This composite dataset might then serve to highlight areas where additional data collection is necessary. This would result in a more complete dataset which might be used for monitoring of groundwater in the future.

Historical data would need to be assessed to determine its current relevance; it could for example be given a rating in it value to the dataset. Water quality data is often useful to map aquifers in a comparative way – even when groundwater chemistry may have changed. Using a Geographical Information System to coordinate the data would greatly enhance its usefulness.

From the research done in compiling this report a number of key issues are recognized:

- Groundwater is an unseen and generally little understood resource, which may benefit from better educating the community, in its important role in the environment.
- Sustainable extraction of groundwater resources will only be achieved by improved understanding and monitoring of existing groundwater resources.
- Groundwater consideration at the engineering design phase of development projects is essential to assist in the protection of fragile ecosystems in the coastal dry tropics and should be included in any Environmental Impact Assessments in this region.
- Protection of Recharge areas in the upper catchment is fundamental to the continued maintenance of water quantity in aquifers and water quality and quantity at discharge which is often directly into marine environments. Due to low rates of water movement through aquifers often the damage is done long before the effects are noticed lower in the catchment.
- The significance role of groundwater in the maintenance of wetlands in the coastal dry tropical environment of the Townsville-Thuringowa area needs to be carefully studied to ensure their protection.
- Extraction of groundwater resources proximal to the coastline requires monitoring to prevent increasing salinity in these aquifers, and causing stress to near-shore vegetation.

Unsustainable extraction of groundwater could impact on the function of the Hyporheic zone and consequently groundwater dependent ecosystems including riparian vegetation. For this reason groundwater extraction needs careful monitoring.

Appendix A

Bibliography

Name	Author	Date	Source
General			
Australian Water Resource Assesment 2000	National Land and Water Rources Unit (DEH)	2000	Corporate Library
Hydrogeology Principles and Practice (text)	Kevin M Hiscock	2005	Corporate Library
Groundwater in the Environment (text)	Paul L Younger	2007	Corporate Library
Townsville-Thuringowa Area			
Groundwater in the Bohle-Ross River Area	Australian Groundwater Consultants	1973	CorporateLibrary
Hydrogeology of the Lower Ross and Bohle River Aquifer Systems	Peter Reid (Honours Thesis)	1975	JCU Library
Gustav Creek - Magnetic Island Ground water Investigation	Gutteridge, Haskins and Davey for TCC	1981	Corporate Library
Report on Seepage Investigation Ross River Dam	Qld Water Resources Commission	1981	CSIRO Library
Alligator Creek Development - Water Supply Pottential	Australian Groundwater Consultants	1983	Corporate Library
Preliminary Report on Alligator Creek Development - Domestic water supply	AGC (Australian Groundwater Consultants)	1983	Corporate Library
Townsville-Thuringowa Strategic Plan 1996 Draft policy Paper	Natural Resources Working Group	1996	Corporate Library
Horseshoe Bay Drainage Management Plan	C & R Consulting	2006	P&D TCC
Bluewater Sub-Artesian			
Review of Groundwater Investigations made by AGC in Townsville Region	Metal Exploration N.L.	1971	DNRW
Report on the estimated yeild of the Black River	McIntyre and Associates	1971	DNRW
Yabulu Wellfield Management Report 1975-1976	Australian Groundwater Consultants(AGC)	1977	DNRW
Yabulu Wellfield Management Report 1974-1975	Australian Groundwater Consultants	1976	DNRW
Yabulu Wellfield Management Studies 1974-1977 !st Triennial report	AGC	1978	DNRW
Bluewater Proclaimed Area Licencing Assesment	Qld Water Resources Commission	1984	DNRW
Yabulu Wellfield Assessment 1980-1984	AGC	1985	DNRW
Yabulu Wellfield Assessment 1987-1990	AGC	1991	DNRW
Townsville Plant Water Supply Wellfield Extensiln Completeion Report		1975	DNRW
Report on Black River Groundwater Review	DNRW	1992	DNRW
Black River Bore field Assessment	C & R Consulting for BHP Billiton	2005/6	DNRW
Regional Groundwater Model - Yabulu Wellfield	AGC	2004	DNRW

Appendix B

Consultation Notes

Appendix B Consultation notes

Organisation	Contact	Position/Area of Involvement	Comments
DNRW	Ian Boyce	Involved with sand extraction	Main area of interest Bluewater; non-routine collection of GW data at other points
DNRW	Gary Jensen	Senior Hydrologist NQ	Residential bores not useful for monitoring due to draw down effect. DNRW have no monitoring bores - some service stations do.
DNRW	Linda Whiteley	Riverine Protection	Recommended Sandy Frances to get access to GW DataBase
DNRW	Peter Verwey	Senior Project Officer Water Quality	Mostly looking at sediment on GBR
DNRW	Sandy Frances	Administration Officer	Provided details of bore information held by DNRW
NQ Water	Rob Hunt	Manager - Environmental Services	Interested in Study of GW at Oak Valley - due to septic use in the area. Referred back to Ian Boyce.
TCC Citiworks	Adam Sadler	Environmental Engineer	Groundwater monitoring wells at Dean Street Contact Nicola P&D TCC and Chris Cuff
Thuringowa City Council	Alan Walker	Strategic Stormwater Engineer	Not available
TCC Citiwater	Peter Driscoll	Environmental Engineer	Monitoring bores at Horseshoe, Picnic,Helene Downes, Rowes Bay Golf Course. Where there is recycled water in use or proximity to water treatment plants
Burdekin Dry Tropics NRM	David Reid	Wetlands Coastal and Marine	Rocky Springs - Gary Jensen(DNRW); some monitoring Black River. GW not raised as a community issue for BDT Awareness of GW in Community low
AGE consultants	Rob Lait	Groundwater Consultant	Not much known about groundwater in the Townsville- Thuringowa area - mostly because exploration has shown there to be very little groundwater Some work done at Lavarack ask Defence Environment Officer, also at Yabulu/Bluewater area and RR dam. Residential Bores in TCC and CoT not monitored or allocated
DPIF	Adam West	Ecologist	Not Available
JCU - ACTFR	John Faithful	Water Quality Scientist	Checking - doesn't think he has anything
CSIRO	Christie Matthes	Librarian - Davis Laboratory	Found report on Ross River Dam leakage
JCU - Library			BSc (Hons) thesis on GW 1975 (Peter Reid)
TCC P & D	Nicola Doss	Coordinator - Technical support	E-mailed draft report on Horseshoe Bay Drianage MP
TCC P & D	Amanda Badger	Technical Support	Attended P&D Meeting on Horseshoe Bay and Rocky Springs
	Reece Fraser	Student	Obtained bore hole data for Townsville /Thuringowa area from DNRW in Digital form. TCC Land Information Unit are currently putting the data into a GIS

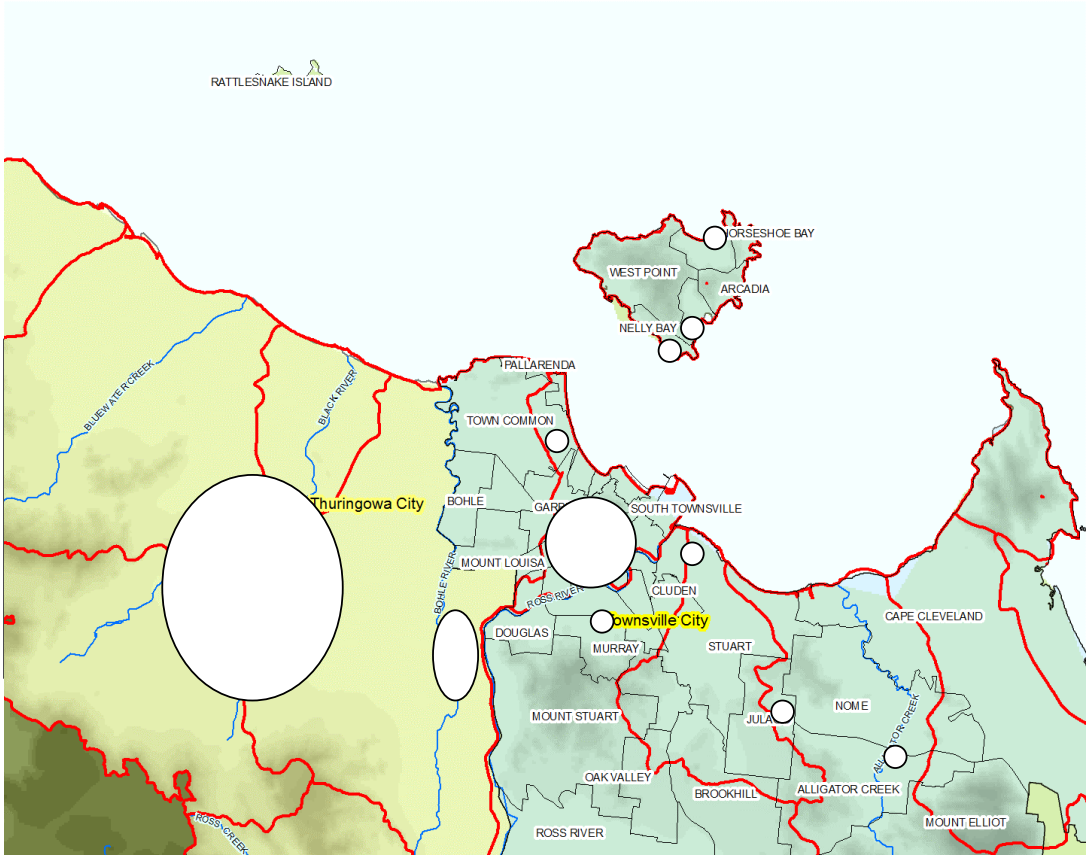
C & R	Chris Cuff	Director/Geochemist	1973 map of GW extent - Chris has this
C & R	Cecily Rasmussen	Director/Geomorphologist	Information on Black River bore field; Outlined relevance of HBDMP to regional GW

Department of Natural Resources and Water DNRW
Townsville City Council TCC
Department of Primary Industries and Fisheries DPIF
James Cook University – Australian Centre for Tropical Freshwater Research JCU - ACTFR
Planning and Development P & D
C & R Consulting C & R

Appendix C

Groundwater Information Location

Appendix C Groundwater Information Location



Sketch Map showing areas which have been researched or where observation bores are being monitored.

Appendix D

Study Area

Appendix D Black and Ross River Basins Study Area