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Late dry season stream flows and groundwater levels, upper Roper River, October 2013

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Cover photo: Roper River upstream of Elsey Creek (Steven Tickell)

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Summary

A set of stream gaugings and water quality measurements were made along the upper reaches of the Roper River in late October 2013. At that time of year all of the stream flow is baseflow derived from the Tindall aquifer of the Daly Basin. The river progressively gained in flow as it passed over the aquifer and reached a maximum flow of 5.4 cumecs at the margin of the basin. The rates of groundwater inflow along the various sections of the river have been identified as well as one downstream section that loses a small amount of water to the aquifer. Baseflows are currently near record high levels, reflecting a trend of higher than average rainfall since the mid-1970's.

Groundwater levels are slightly lower than those measured in early November of 2012 but on the scale of the last ten years they remain relatively high.

Field water quality variations reflect several sources of groundwater with differing salinities. Biological as well as physical processes in the river also affect its chemistry.

Aim

To carry out a set of end of dry season stream gaugings and water quality measurements along the upper reaches of the Roper River and its main tributaries. This work has several purposes; the first is to provide a baseline dataset that future flows and water qualities at equivalent times of year can be compared to. The second is to provide actual data to assist with the calibration of the hydrological model used to make annual water allocations. The final purpose is to better define zones along the river where groundwater discharge (or recharge) occurs and at what rates. The information gained will also be used to rationalise the number of monitoring sites required under the Water Allocation Plan for the Tindall aquifer.

Introduction

The Roper River rises in the Mataranka area in the Top End of the Northern Territory and flows eastwards for some 250 kilometres where it discharges into the Gulf of Carpentaria. This study looks at the headwaters of the river where it passes over carbonate rocks of the Palaeozoic aged Daly Basin. The basal formation of the basin, the Tindall Limestone forms a regional scale fractured and karstic aquifer. The Roper River is one of several main discharge sites for the aquifer. Groundwater discharges into the river as it cuts through the unconfined aquifer and maintains stream flow throughout the dry season.

This monitoring pre-empts the Water Allocation Plan (WAP) for the Tindall Limestone Aquifer (Mataranka). The final plan will ensure that water allocation and its management is done in a sustainable manner. A monitoring program was developed for the WAP to ensure that all the aspirations of the plan are met. The monitoring requirements, monitoring objectives and factors affecting the accuracy of the measurements are detailed in Appendix A. Details of the sites visited during the current survey, including water levels and the date/ time of measurements (Table 3 & Table 4). site descriptions and flow measurements are listed in Table 5. Field water quality results are listed in Table 6. Water samples were collected for the analysis of major ions and nutrients but these will be reported on at a later date.

Several late dry season gauging snapshots have been done in the past, notably in November 2003, October 2004 (Karp, 2008), May 2009 and October 2009. This survey builds on the previous results by including more sites to answer questions about details of groundwater inflows (and outflows) to the river.

Observations

Stream Flows

The location of monitoring sites is shown on Figure 1.The discharge data (Figure 2) illustrates an overall downstream increase in flows. The last substantial rains occurred in March, some seven month earlier. In the first week of October rainfall of less than 2mm was recorded at G9030001 and G9030176. That event was too small to result in any significant runoff that might have impacted on the measurements.

Bitter Springs is the largest individual inflow point and consists of a 400m tributary of the Roper Creek flanked by a Livistona palm and pandanus swamp with a central channel from 2 to 3 metres deep (Plate 1). Areas of 'boiling'' sand were observed on sections of the channel floor but no karstic openings (caves) were seen. The high discharge of the spring suggests that a major cavern(s) supplies the spring. Downstream of the spring the stream gains a further 1.2 cumecs before the creek joins the Waterhouse River to become the Roper River. The major proportion of that increase (0.9 cumecs) occurs upstream of the road to Mataranka Homestead Resort.

Plate 1 Bitter Springs looking upstream, (photo S. Tickell)

The flow of the Waterhouse River at the National Park boundary was only 0.012 cumecs. Rainbow Spring contributes 0.4 cumecs. The spring emerges from a limestone cavity in the base of a circular pool about 5 metres in diameter. At the time of the visit, deep sand had buried the cavity but water could be seen welling up through several open holes in the sand. A narrow outlet channel extends from the spring to a public swimming pool and then to the river. The spring is situated on a narrow floodplain that is covered in a tall Livistona palm forest with a closed canopy.

On the Roper River flow gradually increases downstream of the Waterhouse River / Roper Creek junction from 2.3 cumecs to a maximum of 5.4 cumecs some 40km downstream where the river passes out of the Tindall Limestone. Inputs between successive gauging sites range from 0.03 to 0.54 cumecs / kilometre. Zones with higher input rates suggest the presence of karstic springs in the river bed. To date only one such feature has been observed in the bed of the Roper River near the Elsey Creek junction where there is an upwelling of water (D. Karp, pers. comm.).

Tufa deposits form cliffs up to 9 metres high along the right bank of the Roper River downstream as far as Elsey Station homestead. Tufa is a type of limestone formed when calcium carbonate is precipitated from discharging groundwaters, often in the form of natural dams. Small tufa dams are currently active (Mataranka and Roper Falls) but the tufa in the cliffs are fossil deposits formed thousands or tens of thousands of years ago when groundwater discharge was apparently higher. The tufa itself forms a thin fractured and karstic aquifer which is in direct hydraulic connection with the Tindall aquifer below. Groundwater discharging out of the tufa such as at Fig Tree Spring is considered to originate largely from the Tindall aquifer. Fig Tree Spring (Plate 2) has a discharge of about 0.025 cumecs and emerges from small cavities in the base of a tufa cliff. In that area an inlier of Proterozoic sandstone is exposed on the left bank so all discharge to the river likely occurs through the tufa on the right bank.

Plate 2 Fig Tree Spring, (photo S. Tickell)

Salt and Elsey Creeks are right bank tributaries of the Roper River and both contribute some dry season flow. Salt Creek was dry at the Roper Highway at the time of the current survey and had an estimated flow of only 0.1 cumecs just above its confluence with the Roper River. Elsey Creek was flowing at 0.43 cumecs at its confluence with the Roper River (Plate 3) and 0.42 cumecs at the Roper Highway (Plate 4), indicating that most of the water originates upstream of the highway. A long waterhole extends from just below Warlock Ponds to just above the Roper Highway. Groundwater inflows must occur into that waterhole. It was interesting to note that the Elsey Creek was observed to flow underground for a short section just downstream of a gauging done 800 meters above its confluence with the Roper River.

A second inlier of Proterozoic sandstone occurs in the vicinity of the gauging site 14. Downstream the river flows gradually decreased by 0.31 cumecs between the next three gauging sites. The reason for the decrease could be due to either lack of groundwater inflows combined with evapotranspiration losses or to loss of river water to the aquifer. The evapotranspiration loss over that stretch of river is of the order of 0.03 cumecs, considerably less than the actual decrease in flow. The most likely explanation is that the river is losing water to the aquifer.

Site 17 is situated on the downstream most patch of Tindall Limestone and a major increase in flow, 1.3 cumecs (0.54 cumecs/kilometres) was recorded between there and the next site downstream. The river then decreases in flow downstream of site 18. At Red Rock some 130 kilometers downstream, the flow had reduced to 2.5 cumecs.

Plate 3 Elsey Creek at its junction with the Roper River (foreground),(photo S. Tickell)

Plate 4 Elsey Creek at the Roper Highway, looking downstream,(photo S. Tickell)

Groundwater levels

There is a network of twenty eight bores in the Mataranka Water Control District that monitor water levels in the Tindall aquifer (Figure 3). Two bores RN20509 and RN35863 monitor a Cretaceous sand aquifer. The levels were measured in the week beginning the 21st of October 2013, the same time as the stream gauging was carried out. The water levels are listed in Table 4 both as depths below the measuring point and relative to sea level (Australian Height Datum).

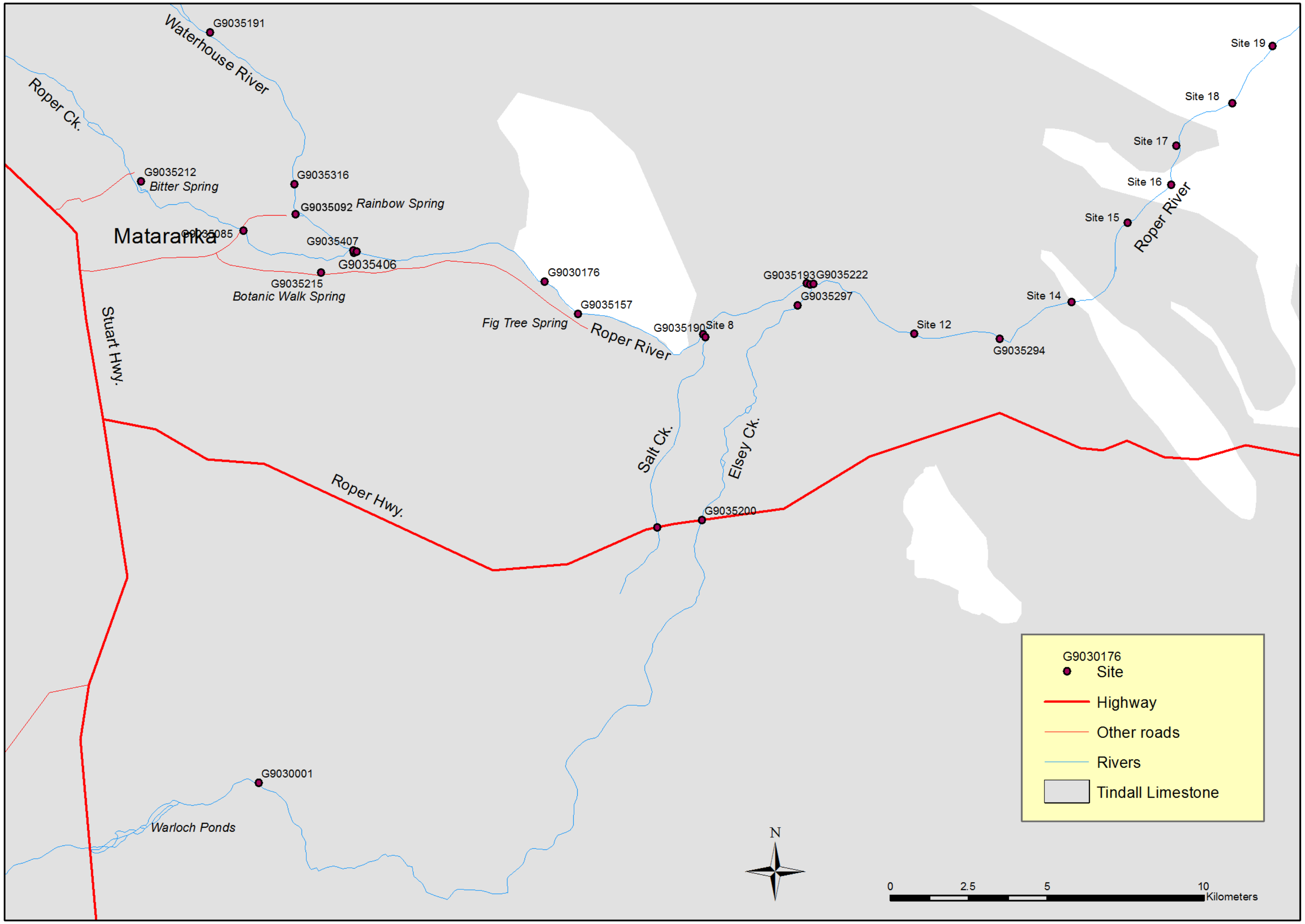

Figure 1 Monitoring Sites, October 2013

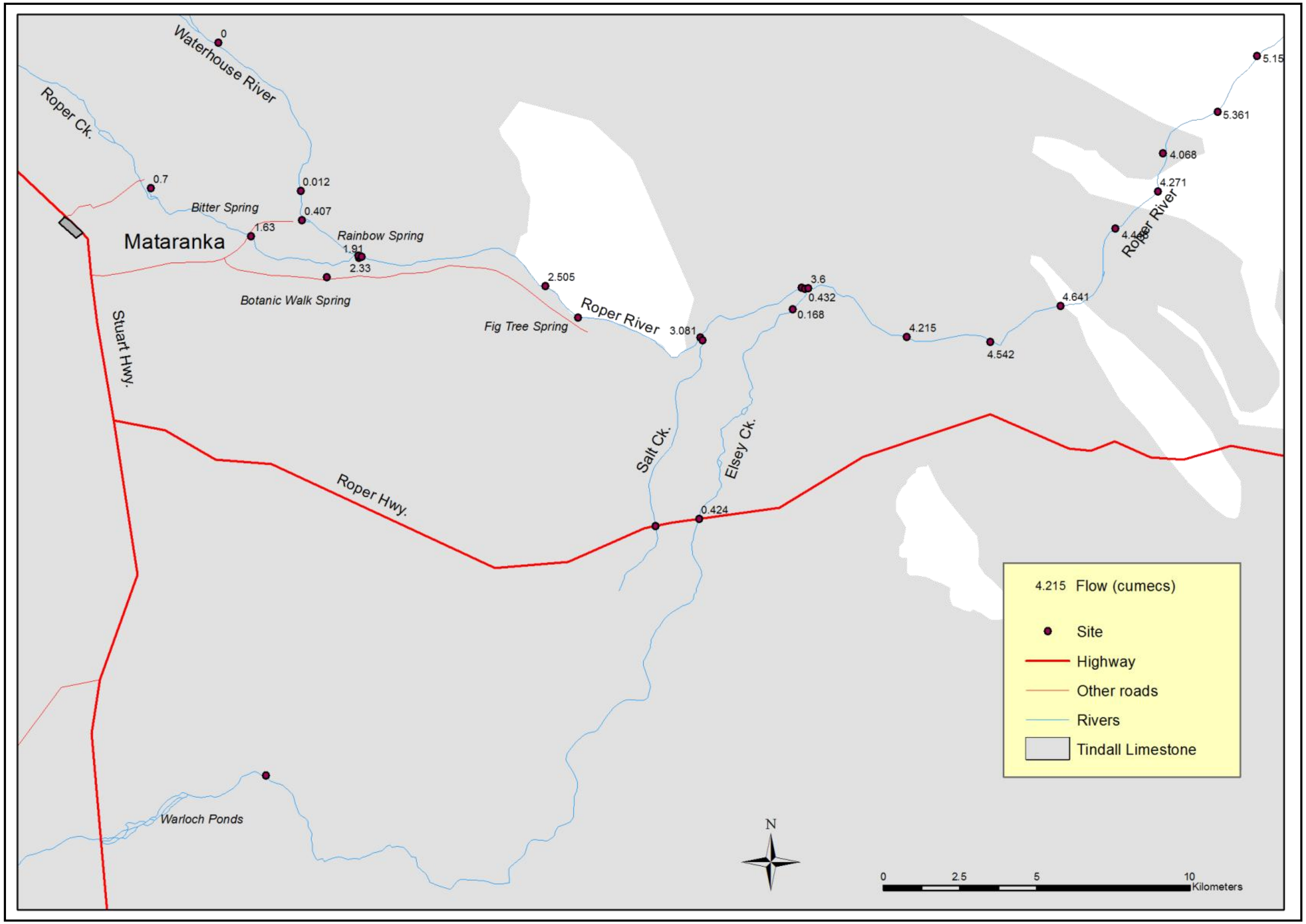

Figure 2 Stream Flows, October 2013

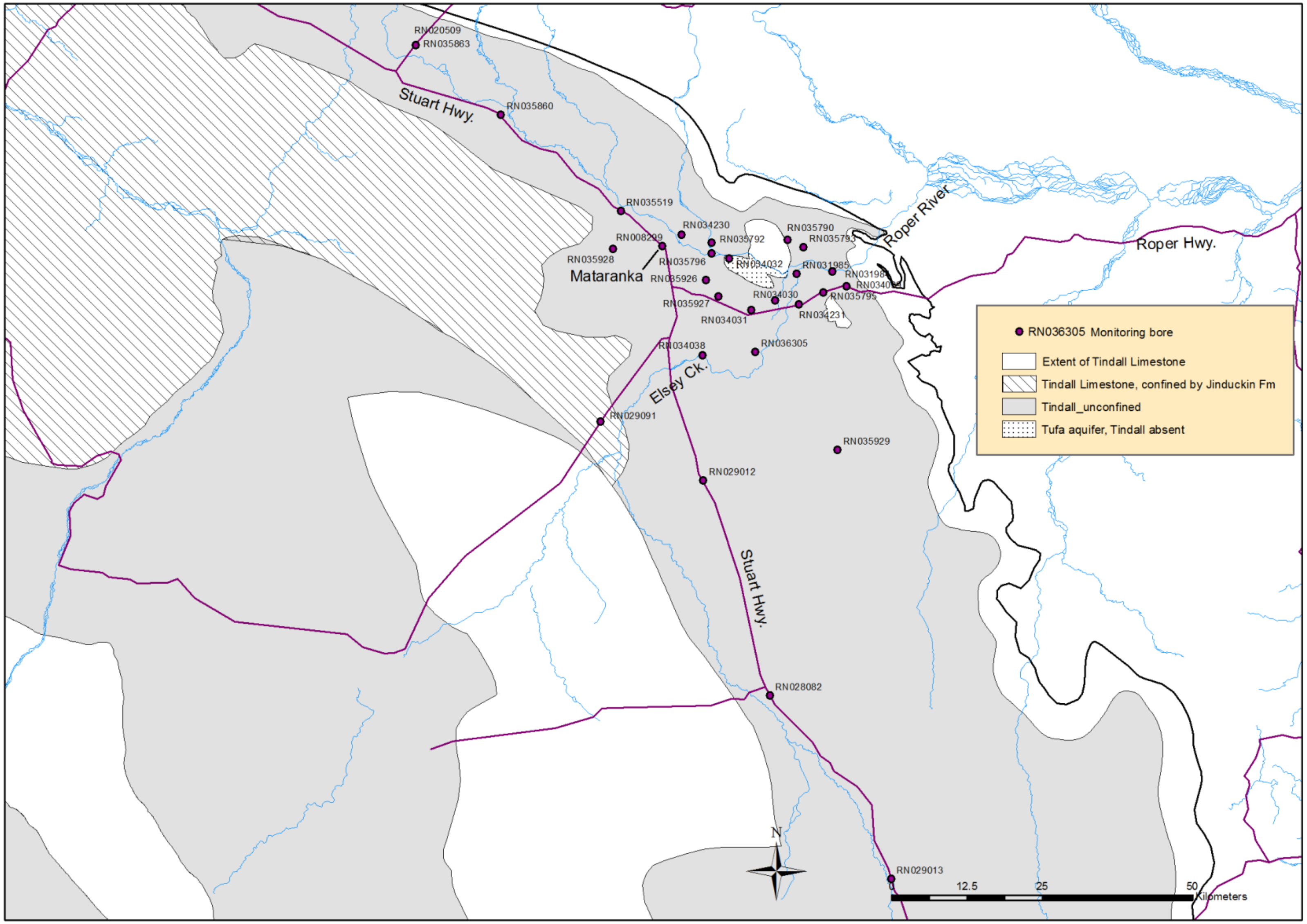

Figure 3 Monitoring bores

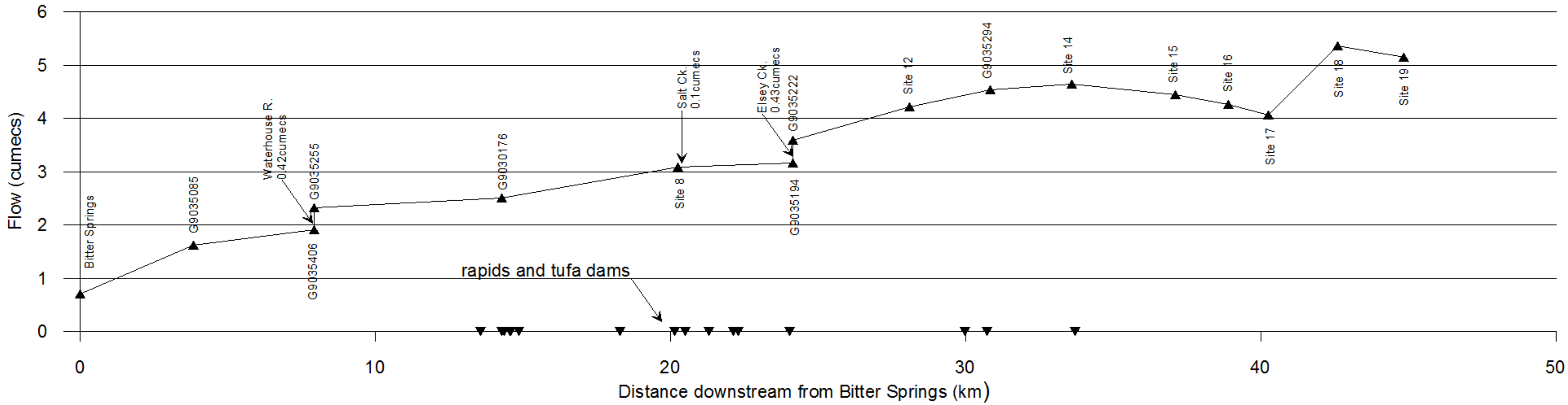

Figure 4 Profile of flows along the Roper River

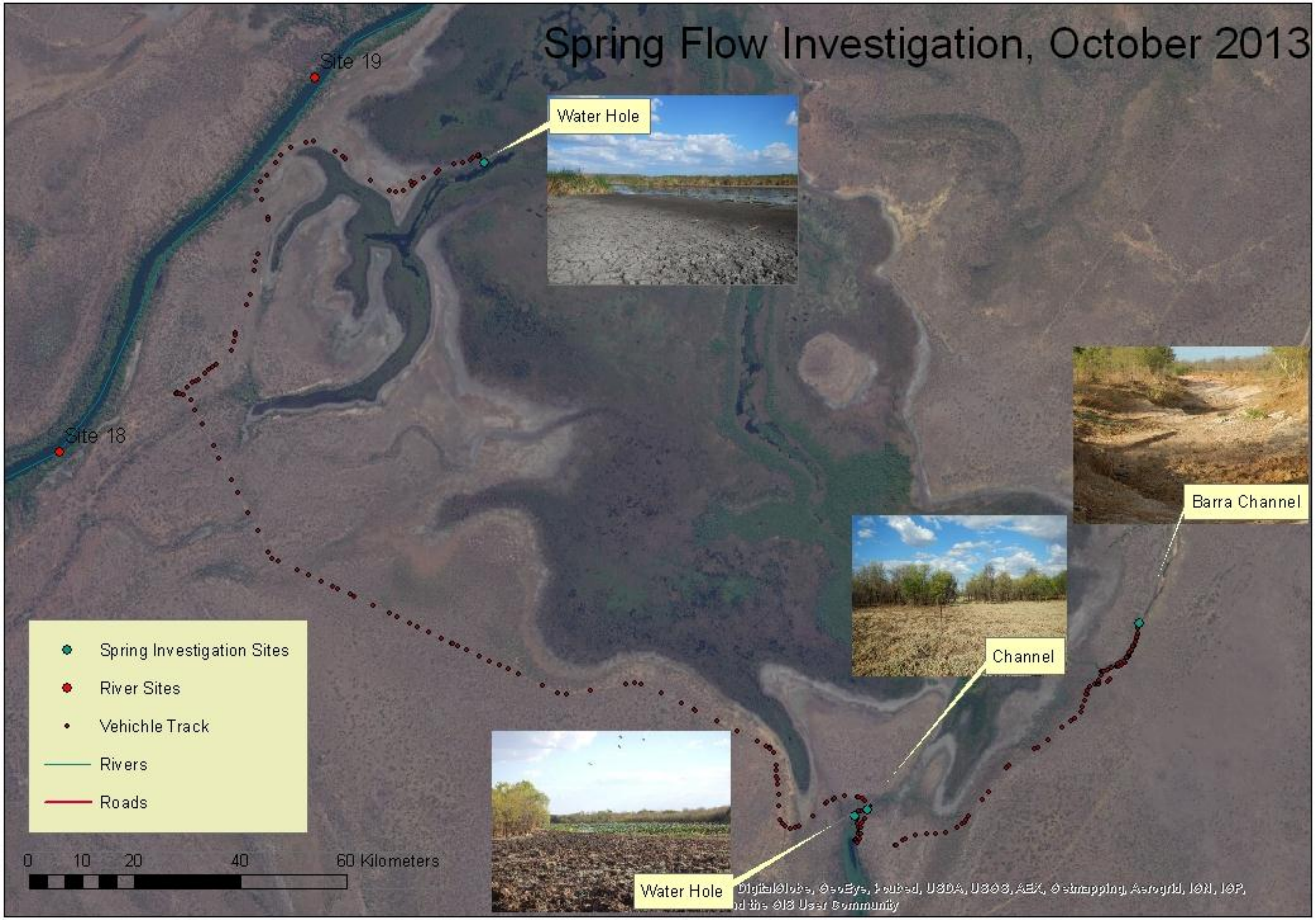

Figure 5 The area searched for springs

Water Quality

Field measurements were made of basic water quality parameters at all gauging sites as well as a few additional sites. Electrical conductivity (EC), pH, dissolved oxygen, temperature and turbidity were measured (Table 3) (Plate 5). The data has been plotted in the form of a profile along the Roper Creek and Roper River to show any downstream trends (Figure 4).

Plate 5 Water quality sampling at Rainbow Spring, (photo S. Tickell)

Rapids

It was intended to map the rapids and geology on the Roper River but due to insufficient time only a few kilometres of river upstream of Elsey Creek were investigated. As an alternative to a field survey, satellite imagery was used to identify the location of rapids (Figure 4 & Figure 9). A few sites have been visited on previous occasions but the remainder remain to be confirmed on the ground. Two tufa dams known as Mataranka and Roper Falls (Plate 6) are located immediately upstream of Salt Creek and two kilometres upstream of Elsey Creek respectively. The rapids in the vicinity of the gauging station G9030176 are made up of Proterozoic sandstone. The ones at the mouth of Elsey Creek and at the Elsey Homestead ford are Tindall Limestone (Plate 7).

Spring investigation

The area immediately east of sites 18 and 19 was visited to determine if any spring flows were present in the wetland area downstream of Red Lilly Lagoon. The wetland is confined by an escarpment on the east with only possible outflows occurring on the north eastern side towards the main channel of the Roper River and at the south eastern side towards "Barra" channel. Two main water holes and a drainage channel on the south eastern part of the wetland were inspected (Figure 5).

The entire wetland area was extremely dry with very little vegetation present. Both waterholes had water present although it was minimal and there were no indications that they are spring fed. The drainage "barra" channel was completely dry and the condition of the channel indicating that it had been dry for quite some time.

Plate 6 Roper Falls, a tufa dam on the Roper River, (photo R. Metcalfe)

Plate 7 A rock bar across the Roper River at the Elsey Creek junction, (photo R. Metcalfe)

Discussion

Stream flows

Groundwater discharges into the upper reaches of the Roper River and several of its tributaries. The river cuts across the south western margin of the Daly Basin, a layered sequence of carbonate rocks that dip gently towards the centre of the basin. The oldest formation in the basin, the Tindall Limestone underlies much of the Mataranka area and forms a substantial fractured and cavernous rock aquifer.

The Roper River and tributaries are incised into the unconfined aquifer and act as natural discharge zones. In the late dry season all stream flow is derived from groundwater. The stream gaugings mostly show a progressive increase downstream (Figure 2), reaching a maximum of 5.4 cumecs at the margin of the Daly Basin. This amount represents the total discharge from the Tindall aquifer in late October of 2013.

A general estimate of the total evapotranspiration loss can be made by applying an average figure of 0.004 cumecs / kilometre of river (Tickell and others, 2002 and Zaar, 2009). The reaches of the Roper and Waterhouse Rivers and Elsey and Roper Creeks that contained water amounted to 90km. The evaporation loss was therefore about 0.4 cumecs, making the total groundwater discharge 5.8 cumecs.

The amount of discharge between successive gauging sites, expressed as cumecs / kilometre of river is shown on Figure 6. Flows are also depicted as a profile starting at Bitter Springs on the Roper Creek and extending downstream along the Roper to site 19 (Figure 4). Discharge is not evenly distributed among the river. There are major point sources of discharge, notably Bitter and Rainbow Springs with flows of 0.7 and 0.4 cumecs respectively. Other springs occur but all have discharges less than 0.03 cumecs. The upstream limit of stream flow was Bitter Springs on the Roper Creek and a point on the Waterhouse River approximately 3 kilometres upstream of Rainbow Springs. The Roper Creek was flowing at a few litres per second at the road crossing immediately upstream of Bitter Springs but flow probably did not extend much further upstream.

Late dry season flows have been monitored in the Roper River since 1961 at the gauging station G9030176 (Figure 7). The flow of 2.5cumecs measured during the current survey indicates that baseflows since 2003 remain close to the highest on record. This closely reflects the pattern of increasing rainfall since the mid-1970's.

The measurements performed in May 2009 and October 2013 shows similar trends in both the reduction of flows between sites 14 to 17 and the increasing of flows from site 17 to 19 (Figure 8).

Water quality

Electrical conductivity

Electrical conductivity increases gradually downstream from 1300 to1600 µS/cm (Figure 9). Variations in the pattern of increase are most likely due to a combination of variations in the rate of inflow and in the EC of the local groundwaters. There are two main regional groundwater sources that discharge to the river, low EC waters (average 800 µS/cm) flowing from the north-west and higher EC waters (average 1600 µS/cm) flowing from the south. A third but more localised groundwater source is associated with spring waters emerging from the swampy area along John Hauser Dve. They tend to have EC's in the 2000 to 3000 µS/cm range as do groundwaters at Djilkminggan. Both these areas have shallow watertables and the groundwater salinity has probably been increased by evaporative concentration. Fig Tree and Botanic Walk Springs emerge from this swampy area and have EC's of 2470 and 2010 µS/cm respectively.

The water from Bitter Springs and Rainbow Springs is influenced by both regional sources and so have relatively low EC's of 1295 and 986 µS/cm respectively. Downstream of the springs the higher EC groundwaters progressively become the main source of baseflow. From site 12 onward EC's remain constant at around 1580 µS/cm., a similar value to the regional groundwater.

pH

Bitter Springs and Rainbow Springs have pHs of 6.8 the lowest of all the waters tested. Downstream from Bitter Springs it rises sharply to 7.8 at the Waterhouse River junction (Figure 9). Such downstream increases in pH were attributed to outgassing of CO_2 in the Gregory River of north-west Queensland (Drysdale and others, 2002). From that point to Elsey Creek, pHs remain between 7.6 and 7.8. This zone corresponds with the spring waters described above that are associated with swampy areas. Fig Tree and Botanic Walk Springs emerge from this swampy area and have pHs of 7.8 and 7.3 respectively. The pH then drops abruptly to 7.1 between Elsey Creek and site 12 and then follows a steady rise to the end of the profile. This final stretch represents input of lower pH regional groundwater and progressive degassing of CO_2 that causes the pH to increase.

Dissolved Oxygen

The levels of dissolved oxygen appear to follow a weakly increasing trend downstream (Figure 9). Bitter Spring has the lowest value of 1.6 mg/l and the highest value recorded of 7.4 mg/l is at the opposite end of the profile. No account has been taken of the time of day that the measurements were made or of the specifics of each site. These and other factors can influence the amount of dissolved oxygen present.

Turbidity

All of the waters have relatively low turbidity's with the springs having the lowest values. There are no obvious trends across the profile (Figure 9). The variations recorded probably relate to the situation of each site, such as if it is in a slow moving pool or in fast flowing water.

Temperature

Temperatures ranged from 29 to 33^0C. Measurements were made at various times of the day.

Salt Load

Streamflow and EC were combined to calculate the weight of dissolved salts carried past each site. EC's were converted to mg/l by multiplying by a factor of 0.61. That figure was obtained by plotting EC against Total Dissolved Solids from many analyses of groundwaters in the region. The salt load increases downstream as more groundwater discharges to the river (Figure 9). There is an abrupt increase downstream at Elsey Creek resulting from the influx of higher EC waters (1600 to 1700µS/cm). The maximum salt load is 450 tonnes/day at site 18, where the flow is also greatest. The groundwaters are calcium/magnesium bicarbonate type waters so the bulk of the dissolved solids being exported by the river are calcium and magnesium carbonate.

Groundwater levels

Water levels measured during the current survey (late October 2013) were compared with those taken in early November 2012 (the week beginning the 5th of November 2012) (Table 4). In all cases levels were slightly lower in 2013, ranging between 0.04 and 1.14 meters lower. Part of the drop can be explained by the fact that readings were made up to two weeks later in 2013 than in 2012. The other cause is that the rainfall in the 2011/12 wet season totalled 689mm but was only 632mm in 2012/13.

The groundwater levels were converted to metres (Australian Height Datum) and contoured (Figure 10). They show progressive falls in watertable elevation from the south-south-east and the north-west towards the Roper River. The watertable has a very low gradient in most of the area but within ten kilometres from the river it steepens as the groundwater discharges to the river.

The longest groundwater level records at Mataranka only date back to 2004. The current readings remain higher than most end of dry season levels from 2005 to 2009 (Figure 11).

Conclusion

Overall the Roper River was found to be progressively gaining water downstream from Bitter Springs to site 18. All of the water is sourced from the Tindall aquifer. A maximum flow of 5.4 cumecs was recorded immediately downstream of the north-eastern limit of the aquifer. The flow then gradually decreases downstream due to evapotranspiration losses. At Red Rock some 130 kilometres downstream the flow had reduced to 2.5 cumecs.

Bitter Springs and Rainbow Springs are two major point sources that contribute to the stream flow. No other point source springs with significant discharges were observed but it is possible that some exist undetected on the river bed.

A stretch of the river between sites 14 and 17 loses water at a greater rate than would be expected from evapotranspiration alone. It is suspected that the water is lost to the aquifer but further investigations are required in this regard.

End of Dry season flows are comparable to those experienced since 2003 and are amongst the highest on record. Higher average rainfall during that period is likely the main cause.

Field water quality measurements show various trends along the river profile. Trends in EC and pH appear to reflect three main groundwater sources that discharge to the river. Each source has distinctive water qualities. The three sources are low EC waters from the north-west, local high EC waters from the swampy areas immediately south of the river and medium EC waters from the south.

An inspection of the area east of Red Lilly Lagoon showed no indication of any groundwater discharge.

Groundwater levels are slightly lower than those measured in early November of 2012 but on the scale of the last ten years they remain relatively high.

Recommendations

Future monitoring sites

The current set of gaugings was a one off snapshot of late dry season river flows. Its main aim was to determine which sections of the rivers gained or lost water and by how much. This was achieved but in future years the late dry season flows need to be monitored bi-annually in order to assist with the calibration of the hydrological model that is used for water allocations. This can be achieved with fewer than the current nineteen sites. Five sites are recommended based on their locations in relation to the main sources of groundwater inflows and ease of access. These include:

G9035294 (Roper River 400m D/S Elsey Station Homestead). This site captures 85% of baseflow from the Tindall aquifer. It would be suitable for the placement of a permanent gauging station. Downstream the sites are difficult to access and the river is too deep and slow flowing for a gauging station. It is recommended that gaugings continue for several years on sites 17 and 18 in order to establish a relationship between flows at G9035294 and site18. Once this has been done the total baseflow from the Tindall aquifer should be able to be estimated from the readings at G9035294.

G9030176 (Roper River at downstream Mataranka Homestead). This monitors just under half of the rivers baseflow. It is a permanent station with a record of stream heights and spot gaugings dating back to 1961 and so should be continued.

G9035085 (Little Roper @ Mataranka Homestead Xing). Bitter Springs and the stretch of Roper Creek between the spring and this site are the largest single contributor of baseflow to the Roper River. Bitter Springs is an important tourist attraction and its flow should be monitored. Gauging at the spring itself can sometimes be difficult because of swimmers in the water. G9035085 captures the spring flow and has the advantage of easy access. It is also the closest site to farms and orchards along the Roper Highway which are major water users. Spot gaugings and stream height measurements have been done at the site since 2007 and the two parameters show a reasonable correlation. A more accurate assessment of the flow recession could be obtained by installing a water level logger at the site.

G9030175 (Mataranka Homestead at Hot Springs). Rainbow Spring attracts large numbers of visitors and although its flows are relatively small compared to the total baseflow, it should be monitored to provide warning of reductions in flow. The majority of baseflow in the Waterhouse River originates from Rainbow Spring.

G9035200 (Elsey Creek @ Roper Hwy.) The Elsey Creek supplies around 7% of the total baseflow and most of that originates upstream of the Roper Highway. The irrigation farms on the Roper Highway also have potential to impact on Elsey Creek flows. The site is easily accessible and would capture the majority of flows from the Elsey Creek.

Groundwater investigations

The increase in flow recorded between sites 17 and 18 warrants further groundwater investigation to determine the source of the water. Two drill holes are recommended, one close to the river adjacent to site 17 and another situated around 4 kilometres to the north-west. The decrease in flow recorded between sites 14 and 17 also requires some explanation. A single hole drilled just upstream of site 15 should resolve that problem.

Spring Flows

A hydrological model is used to simulate the effects of varying recharge and pumping regimes on groundwater levels and on groundwater discharge to the rivers (including the discharges of major springs. The model can generate groundwater levels at any point in the aquifer. In the case of Bitter and Rainbow Springs these levels could be used to estimate discharge if a relationship can be established between measured discharge and measured groundwater levels in a nearby bore. Flows from Bitter Springs as measured at G9035085 correlate well with groundwater levels in the monitoring bore RN34230, despite the two sites being some 800 metres apart. The nearest monitoring bore to Rainbow Spring is RN35796 which is just over one kilometre away. There is poor correlation between the spring discharge and the groundwater levels in that case. RN34230 should be adequate as an indicator of discharge from Bitter Springs but a new monitoring bore located closer to Rainbow Spring would be required for estimation of the spring discharge.

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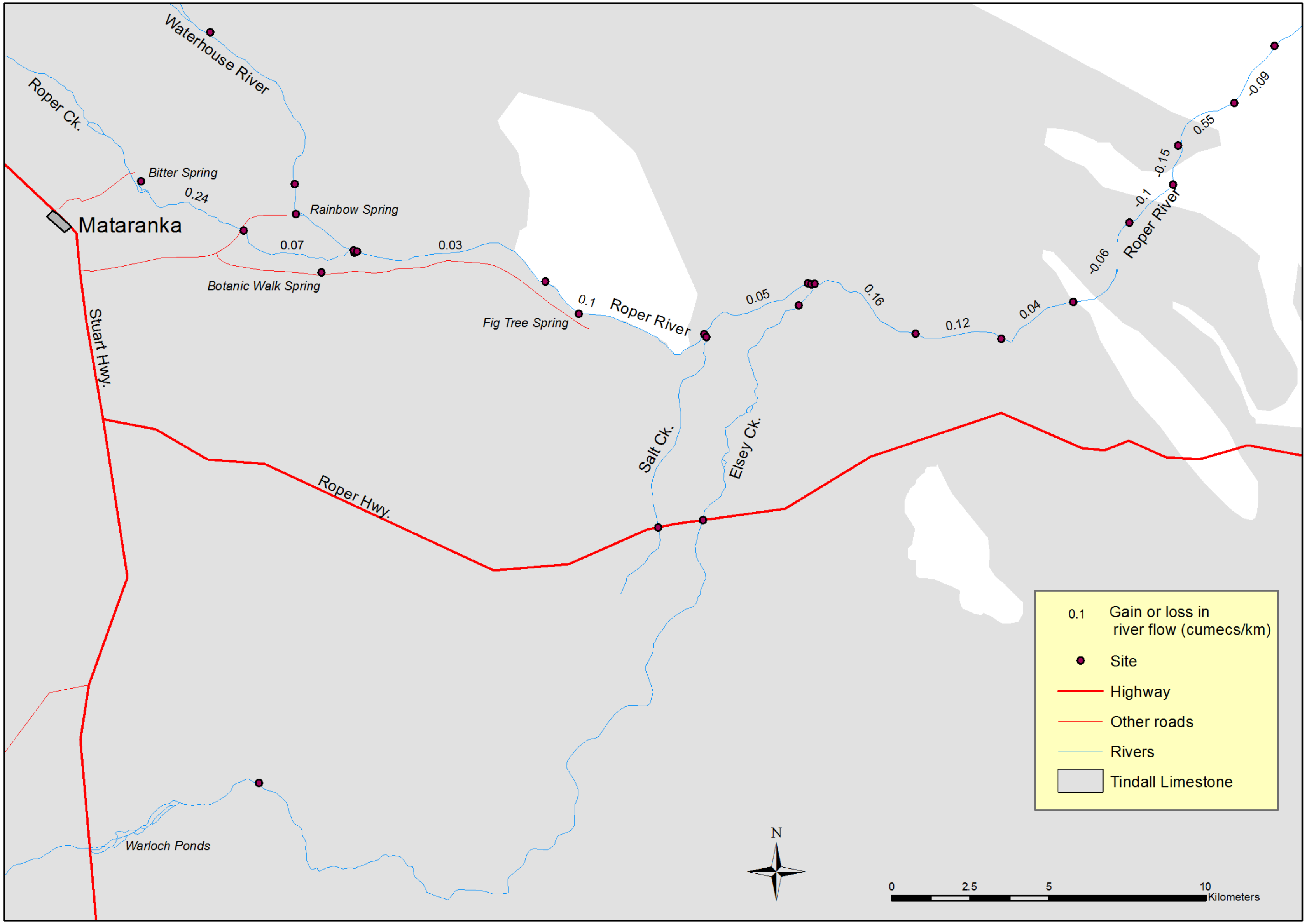

Figure 6 Gains or losses in stream flow between gauging sites, expressed as cumecs/kilometre of river.

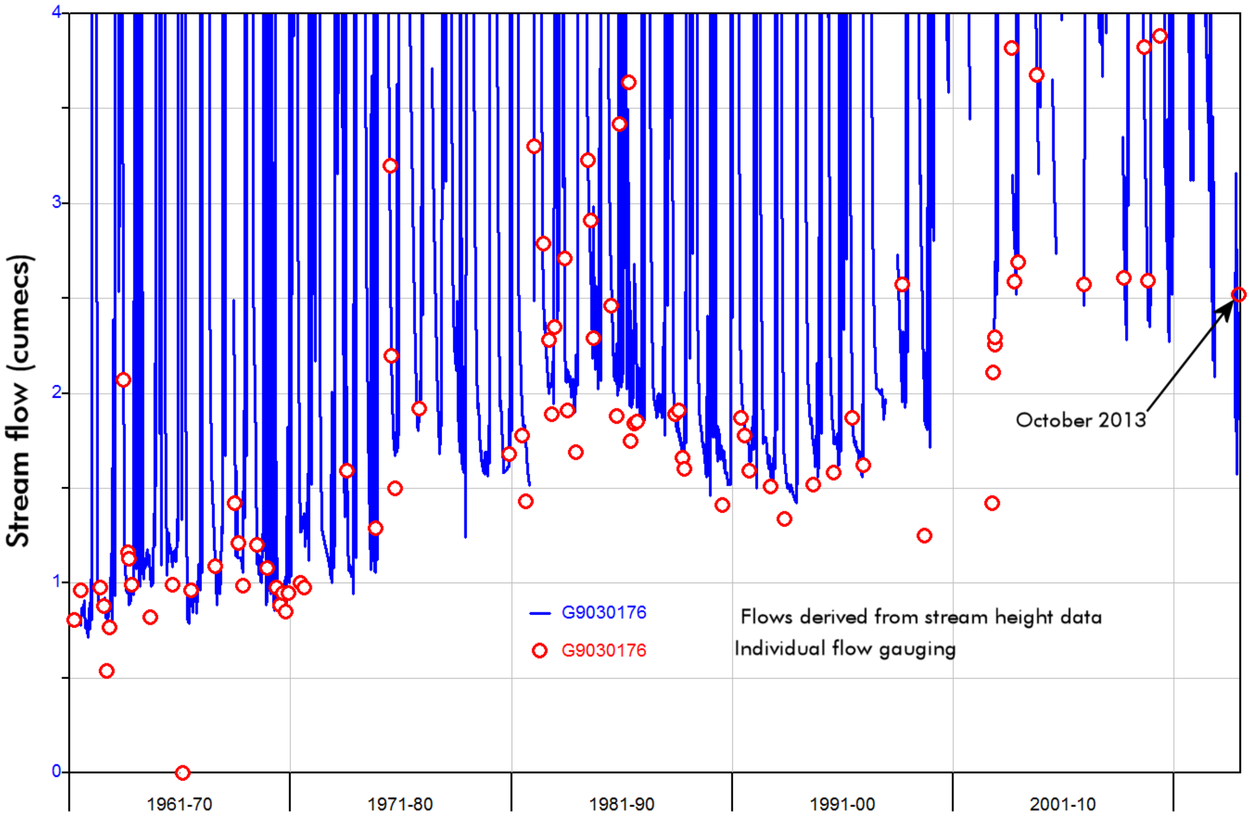

Figure 7 Low flows at Roper River gauging station G9030176

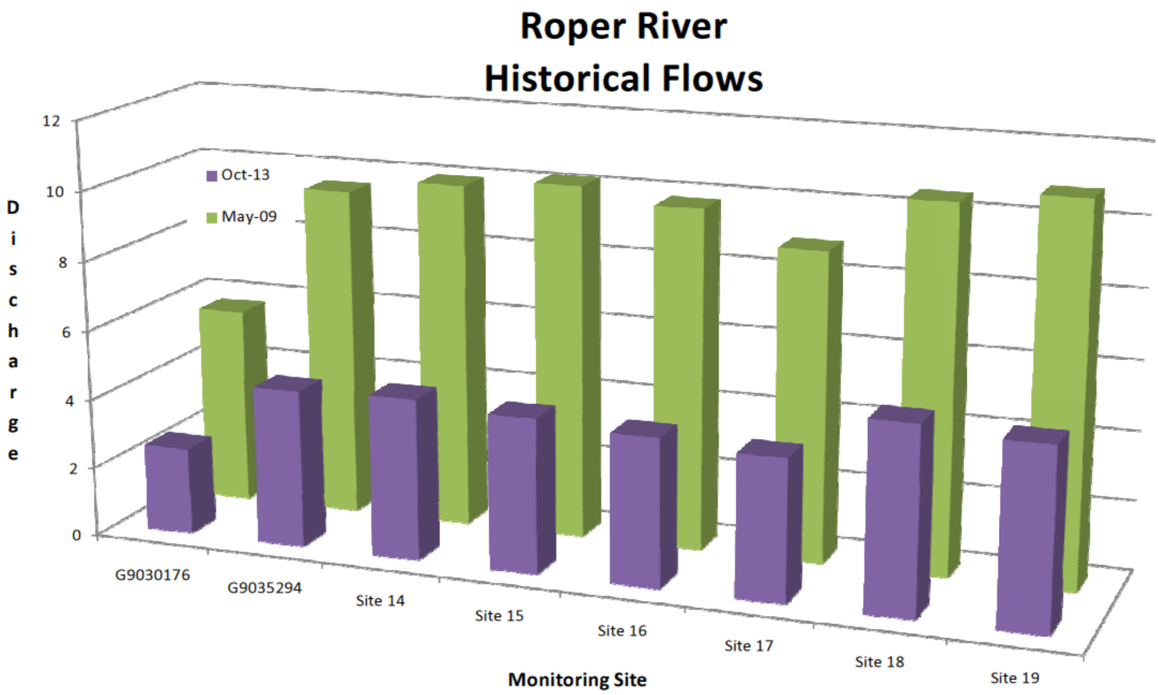

Figure 8 Comparison between May 2009 and October 2013 flow

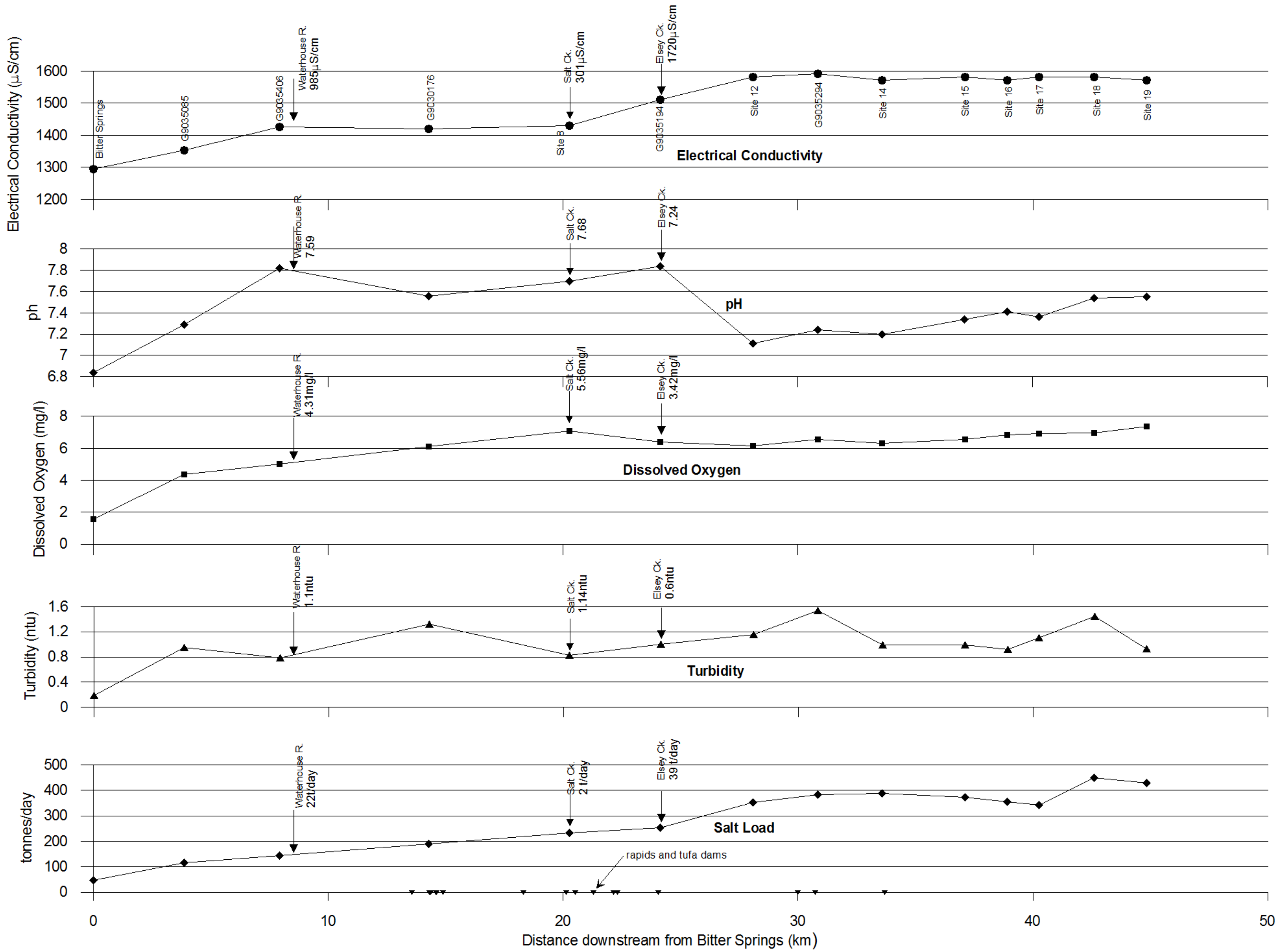

Figure 9 Water quality profile

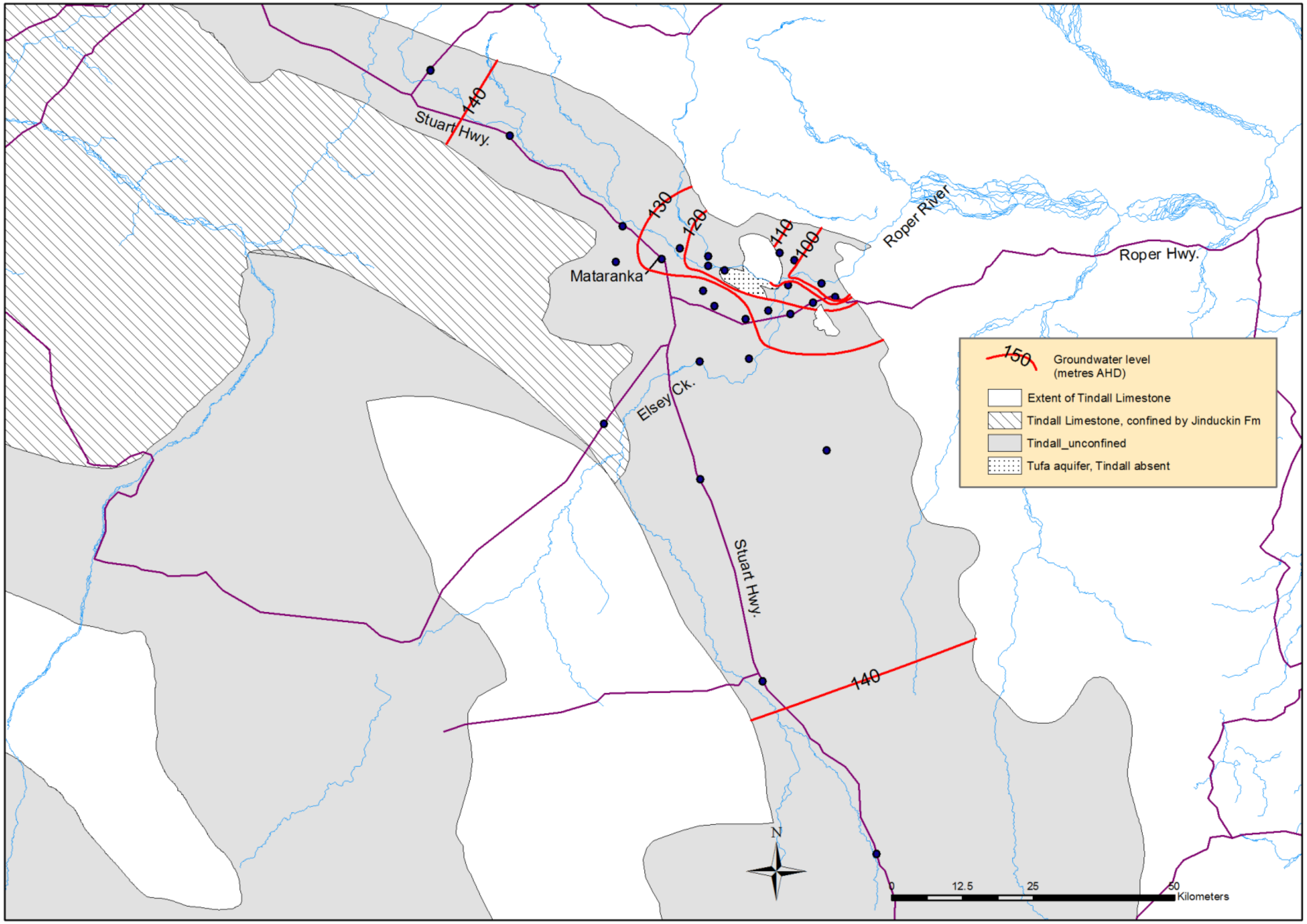

Figure 10 Watertable elevation (metres AHD) October 2013

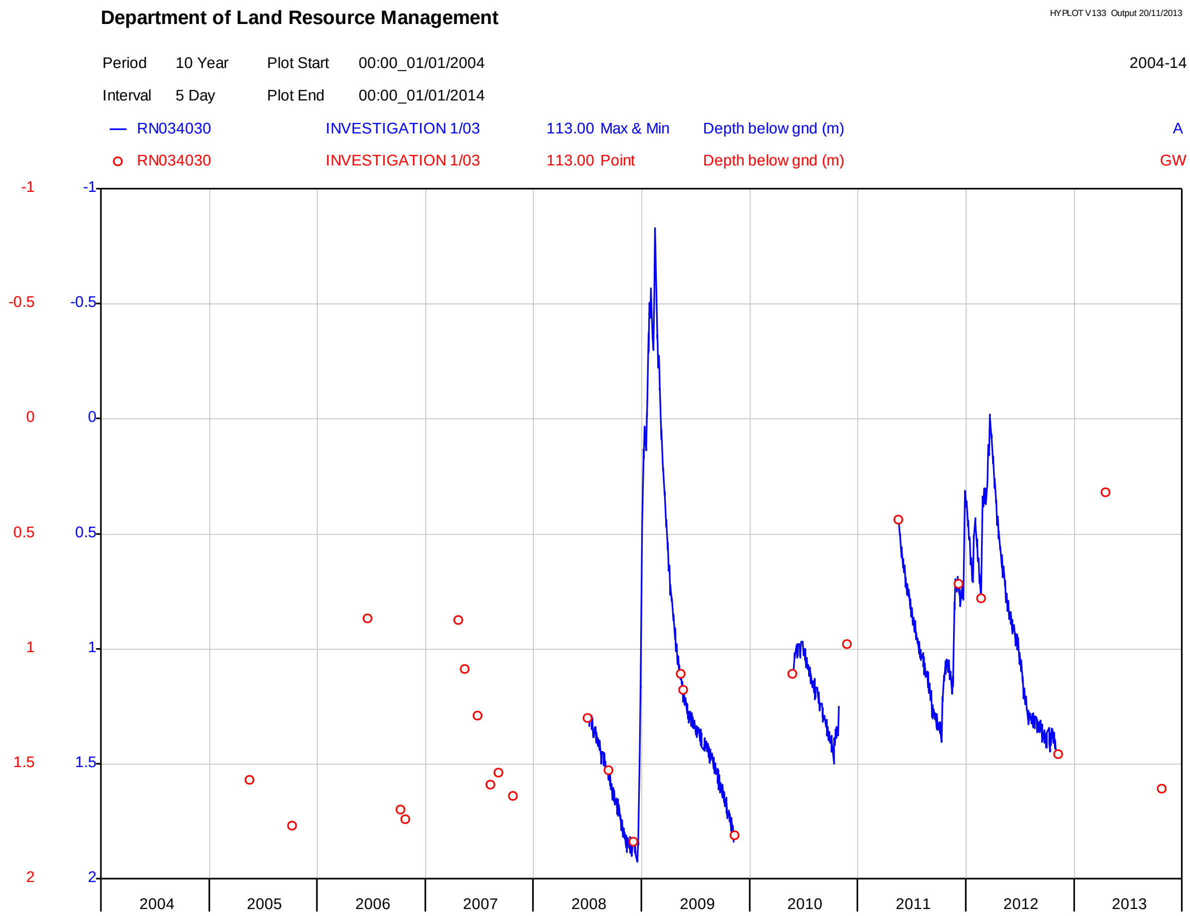

Figure 11 Bore hydrograph of RN034030, the red dots are manual readings and the blue lines are continuous logger data

Appendix A

Water Allocation Plan Monitoring Program

The monitoring program is based on detailed monitoring objectives, frameworks and data requirements for each of the monitoring sites within the respective area. The monitoring framework primarily consists of the following two categories.

- continuous monitoring of stage and discharge for the development of stage discharge relationships. This information is used to perform flow calculations and statistical analysis of catchment characteristics.
- snap shot of water levels and discharge in the catchment at the end of the wet and dry seasons. This information is used to assist with the calibration of the hydrological model.

The Mataranka Tindall Limestone Aquifer WAP Measurements report summarises the measurements performed during the “snap shot” measurement exercise. The information collected during the measurement exercise is mainly used to assist with the calibration of the hydrological model used for the prediction of water levels and flows in the Tindall Limestone Aquifer (Mataranka) area.

The snap shot measurements are performed after the wet season or last flood event and at the end of the dry or before the first rainfall event, which are normally during the months of June and October respectively. The time frame of snap shot measurements are not fixed and can vary annually based on the weather conditions. The indicators that the user must take into account to determine the time for snap shot measurements can be categorised under the following points.

- measurement of water levels and flow at the end of the wet when the hydrograph recession leg approaches base flow and there are no further indication of rainfall in the catchment.
- measurement of water levels and flow at the end of dry before the first rains to ensure that measurements encompasses only base flow.

The hydrological information collected during the “snap shot” measurements is also used to compare current flow conditions against previous year runoff, which gives an approximation of what the flows would be by the end of the season.

In the case of project work to better understand the interaction between surface water and groundwater it is acceptable for temporary monitoring locations not to have any water level reference datum. Monitoring sites assigned for the WAP monitoring program must comply with the minimum standards of at least a BM.

Monitoring Objectives

The monitoring objectives are documented in the monitoring programs under *Monitoring Objectives* as shown in the Surface Water and Groundwater monitoring frameworks in *Diagram 1.0* and *Diagram 1.1* respectively. The monitoring objectives for the snap shot measurements are based on surface water and groundwater monitoring requirements (Table 1).

Table 1 Monitoring requirements

Measurement	Surface Water	Groundwater
Water Level	Gauge Board \ Survey	Dip Tape
Discharge	Flow Measurement	Flow Measurement at Springs
Water Quality	Field parameters (EC, temp, pH and DO), Major Ions, Nutrients and Metals.	Field parameters (EC, temp, pH and DO), Major Ions, Nutrients and Metals.

The monitoring requirements for the "snap shot" measurements at each monitoring site are detailed in the *Monitoring Requirements* of Tindall Limestone Aquifer (Mataranka) WAP monitoring program.

Details of factors that can influence the accuracy water level, stream flow and water quality measurements made are discussed below. Details of sites including date/time of measurement and water level are listed in Table 3 and site descriptions and flow measurements are listed in Table 4. Field water quality results are listed in Table 5.

Field Measurements

Water Levels

Factors influencing accuracy

The main factors that have an influence on the accuracy of water level measurements at surface water and groundwater monitoring sites summarised in Table 2.

Measurement Results

The water level measurements results obtained during the “snap shot” measurement exercise are summarised in Table 4 and Table 5for both surface water and groundwater monitoring sites.

Measurement Accuracy

The water level measurements taken during the “snap shot” measurement exercise are within the required standards for monitoring sites equipped with gauge boards except where otherwise stated in Table 2. The majority of surface water monitoring sites that was visited during the “snap shot” measurement exercise are not equipped with gauge boards \ BM. The lack of referencing water levels against a fixed datum makes it difficult to determine measurement accuracy of flow measurements and identifying trends in water levels.

Table 2 Site influence indicators

Type	Conditions	Influences	Description
Surface Water	Hydraulic	Wave action	Waves created during high flows, wind and or turbulence at gauge plates
		Instrument Location	Point of measurement is a significant distance from gauge plates, especially during high flows.
		River Bend (outside)	Water level higher at the outside of the bend.
		River Bend (inside)	Water level lower at the inside of the bend.
		Velocity	High velocities creates turbulence, etc.
		Turbulence	Eddies \ turbulence created at gauge boards. Create difficulty in reading due to fluctuations in water level.
		Back Flow	Back flow creates difficulties in reading gauge plates
	Site	Sediment	Sediment deposition at gauge plates. Gauge plates can be buried under sediment.
		Debris	Debris that is collected at gauge plates. Difficult to take readings without maintenance work
	Gauge Plates	Unstable gauge posts	Gauge posts that are unstable create inaccuracies in the gauge plate heights.
		Unreadable gauge plates	Gauge plates that are in a bad condition is difficult to read and create inaccuracies in the readings
		Gauge Plate Numbers	Missing numbers create confusion and can create mistakes of up to 1m in gauge plate readings.
		Surveys	In correct surveys and adjustments on gauge plates causes error in gauge plate readings.
Ground water	Production Boreholes	Size of Well	Insufficient space to perform water level measurements with existing equipment
		Pumping	Pumping operations influences the water level measurements
	Casing Collar	Unstable casing	Unstable casing causes errors in the water level measurement
	Level Indicators	Equipment condition	Instruments with faded increments can cause errors in measurements.
		Increments	Course increments on tape measure will lead to different interpolation of values

Discharge

Factors influencing accuracy

The factors influencing the accuracy of the discharge measurements can be categorised under environmental and system influences. System influences are created by the type of instrumentation used and can be minimised if standards are followed. Environmental influences have a much greater impact as this is result of site conditions and actions by operator and for this reason will be discussed in further detail. Environmental factors that have an influence on the accuracy are the following:

- **W**: Wind: The wind causes the water level to oscillate which has a large effect on the flow if the wind direction is parallel with the flow direction.
- **LP**: Large pools: Reduce velocity drastically
- **WG**: Water grass: Influences the flow measurements, very high inaccuracies with depth and velocity measurements.
- **A**: Algae growth: Algae that floats in the water influence the signal strength of the ADCP.

The Hydraulic (**H**) requirements of a monitoring section are essential for accurate discharge measurements. The monitoring site needs to comply with the following hydraulic requirements during the gauging section selection process:

- Uniform cross section
- Flow in the stream should be confined to a single well-defined channel with stable banks.
- Bends upstream of site must be avoided if possible
- Steep slopes upstream should be avoided if possible.
- Avoid deep pools that can influence the flow
- Avoid prominent obstructions in a pool or excessive plant growth that can affect the flow pattern.
- Turbulence \ eddies must be avoided if possible.
- Negative \ back flow must be avoided at all times.

The abbreviations for the various factors as indicated in the above information (highlighted in bold) is shown in the gauging result tables indicating the various influences encountered at each site.

Measurement Results

The discharge measurement results obtained during the "snap shot" measurement exercise are summarised in Table 5. Monitoring sites are listed from the most upstream monitoring site in the catchment to the lowest monitoring site in the catchment with increasing in flow.

Measurement Accuracy

The majority of the measurement locations stipulated for the "snap shot" measurement exercise do not comply with hydraulic and site requirements for discharge measurements as summarised in Appendix B. The measurement locations were selected based on further understanding of surface water and groundwater interactions and therefore it is accepted that the quality of measurements will be affected.

The main factors that influenced the accuracy of measurements were the presence of algae on the river bed and measurement locations in deep pools drastically reducing the water velocity. The discharge measurements performed apart from the factors as mentioned comply with most of the requirements as stipulated in the Department standards. A quality matrix is completed for each measurement for the purposes of assigning a quality code to the measurements.

Water Quality

Factors influencing accuracy

- Instrument \ Sensor calibration.
- Compliance of water sampling procedure.
- The measurement location should be as close as practical to the mid-point of the stream.
- The sensors should be as close to the surface as possible.
- Turbulence (waves, eddies) at the surface should be avoided; the measurement point should be moved away from these areas as physical-chemical parameters will be affected.
- Standing water at the edges of streams should be avoided, as these are not representative of the stream.
- Deep pools with very low flow should be sampled as close as possible to the center of the main pool.

Measurement Results

The water quality measurement results obtained during the "snap shot" measurement exercise for surface water monitoring sites are summarised in Table 6. Water Quality parameters were not measured at groundwater monitoring sites.

Measurement Accuracy

The water quality measurements performed during the "snap shot" exercise comply with all the requirements as stipulated in the Department standards. Hydrolab instruments were calibrated before and after the "snap shot" measurement exercise to ensure that instrumentation complied with the required accuracy during measurements. The water quality data collected during the measurements were adjusted based on the pre and post calibration results for sensor drift.

Table 3 Surface water site details

Site Number	Site Name	Date	Time	Level	Site Influences
G9030001	Elsey Creek at Warlock Ponds	22/10/2013	1230		The condition of the gauge boards had an influence on the accuracy of reading
G9035092	Mataranka Homestead At Hot Springs	22/10/2013	1000		
G9030176	Roper River at downstream Mataranka Homestead	22/10/2013	0910		
G9030250	Roper River at Red Rock	25/10/2013	1005		
G9035085	Little Roper @ Mataranka Homestead Xing	22/10/2013	1320	1.380	
G9035157	Fig Tree Spring @ Roper River Elsey Park	23/10/2013	1215		
G9035190	Salt Creek U/s Roper River Confluence	23/10/2013	1736	None	No BM \ Gauge Boards
G9035191	Waterhouse River @ Cave Creek Station Xing	22/10/2013			
G9035193	Elsey Creek Upstream Roper River confluence	24/10/2013	1010		
G9035194	Roper River Upstream Elsey Creek Inflow	24/10/2013	1225	None	
G9035200	Elsey Creek @ Roper Hwy.	23/10/2013	1415		
G9035212	Bitter Springs @ swim. access	22/10/2013	1132	0.490	
G9035222	Roper River downstream Elsey Creek Inflow	24/10/2013	1130		
G9035294	Roper River 400m D/S Elsey Station Homestead	23/10/2013	1730	None	No BM \ Gauge Boards
G9035297	Elsey Creek 400m U/S Roper River confluence	23/10/2013	1600		
G9035316	Waterhouse River 1.2km U/S of Rainbow Springs headwater	22/10/2013	0930	4.370	
G9035406	Roper Creek near Waterhouse R confluence U/S	23/10/2013	0820		
G9035407	Waterhouse River U/S confluence with Roper Creek	23/10/2013	1000		
Site 8	Roper River @ near Salt Creek	22/10/2013	1736	None	No BM \ Gauge Boards
Site 12	Roper River @ Near Djilkminggan	23/10/2013	1200	None	No BM \ Gauge Boards
Site 14	Roper River @ Site 14 (Site 1, May 2009)	23/10/2013	1710	None	No BM \ Gauge Boards
Site 15	Roper River @ Site 15 (Site 1, May 2009)	24/10/2013	1210	None	No BM \ Gauge Boards
Site 16	Roper River @ Site 16 (Site 2, May 2009)	24/10/2013	1200	None	No BM \ Gauge Boards
Site 17	Roper River @ Site 17 (Site 3, May 2009)	24/10/2013	1130	None	No BM \ Gauge Boards
Site 18	Roper River @ Site 18 (Site 4, May 2009)	24/10/2013	1513	None	No BM \ Gauge Boards
Site 19	Roper River @ Site 19 (Site 5, May 2009)	24/10/2013	1445	None	No BM \ Gauge Boards

Table 4 Groundwater levels

Site Number	Date	Time	Level (metres below measuring point.)	Level (metres AHD)	2013 level minus 2012 level
RN008299	21/10/2013	1550	6.53	128.699	0.28
RN020509	25/10/2013	0952	27.07	157.343	0.08
RN028082	23/10/2013	0850	41.15		0.05
RN029012	23/10/2013	0820	36.39	135.545	0.24
RN029013	23/10/2013	920	39.62	145.865	0.04
RN029091	22/10/2013	1512	9.69	133.811	0.36
RN031984	24/10/2013	0851	8.49		
RN031985	24/10/2013	1040	11.15	110.811	0.44
RN034030	24/10/2013	1138	2.83	122.724	0.15
RN034031	24/10/2013	1215	5.72	130.887	0.21
RN034032	22/10/2013	1347	7.8	115.651	0.33
RN034038	22/10/2013	1600	2.15	132.382	0.26
RN034039	24/10/2013	0947	17.29	97.817	0.51
RN034230	24/10/2013	1551	3.63	127.302	0.29
RN034231	24/10/2013	1020	2.93	125.667	0.24
RN035519	21/10/2013	1530	7.96	131.409	0.37
RN035790	22/10/2013	0952	10.68		1.14
RN035792	22/10/2013	0857	17		0.24
RN035793	22/10/2013	1024	8.92	101.637	0.74
RN035795	24/10/2013	1012	7.85	115.228	0.28
RN035796	22/10/2013	1515	4.72	116.86	0.17
RN035860	21/10/2013	1500	20.73	135.869	0.5
RN035863	25/10/2013	949	27.38	157.154	0.16
RN035926	24/10/2013	1355	2.66	130.894	0.25
RN035927	24/10/2013	1325	14.18	131.062	0.21
RN035928	25/10/2013	0845	45.72	133.696	0.41
RN035929	23/10/2013	1110	26.72	135.355	0.3
RN036305	23/10/2013	1426	2.62		0.16

Table 5 Site descriptions and flow measurements

Site Number	Site Name	River System	Flow m^3/s	Date	Gauging Instrument	Site Influences	Comment
G9030001	Elsey Creek at Warlock Ponds	Tributary	---	22/10/2013			Flow measurement not done due to limitations of measuring equipment
G9035092	Mataranka Homestead At Hot Springs	Spring	0.407	22/10/2013	Pygmy		
G9030176	Roper River at downstream Mataranka Homestead	Main Reach	2.505	22/10/2013	StreamPro		
G9030250	Roper River at Red Rock	Main Reach	2.506	25/10/2013	StreamPro		
G9035085	Little Roper @ Mataranka Homestead Xing	Tributary	1.630	22/10/2013	StreamPro		
G9035157	Fig Tree Spring @ Roper River Elsey Park	Spring	0.025	23/10/2013	Pygmy		
G9035190	Salt Creek U/s Roper River Confluence	Tributary	---	23/10/2013	StreamPro \ Workhorse	water grass / algal growth	Site conditions not conducive for flow measurements with ADCP instruments due to algae growth.
G9035191	Waterhouse River @ Cave Creek Station Xing	Tributary	0.000	22/10/2013			No Flow
G9035193	Elsey Creek Upstream Roper River confluence	Tributary	0.432	24/10/2013	StreamPro		
G9035194	Roper River Upstream Elsey Creek Inflow	Main Reach	---	24/10/2013			Not measured
G9035200	Elsey Creek @ Roper Hwy.	Tributary	0.424	23/10/2013	StreamPro		
G9035212	Bitter Springs @ swim. access	Spring	0.700	22/10/2013	StreamPro		
G9035222	Roper River downstream Elsey Creek Inflow	Main Reach	3.600	24/10/2013	StreamPro		
G9035294	Roper River 400m D/S Elsey Station Homestead	Main Reach	4.542	23/10/2013	StreamPro		
G9035297	Elsey Creek 400m U/S Roper River confluence	Tributary	0.168	23/10/2013	Pygmy		
G9035316	Waterhouse River 1.2km U/S of Rainbow Springs headwater	Tributary	0.012	22/10/2013	Approximate		
G9035406	Roper Creek near Waterhouse R confluence U/S	Tributary	1.910	23/10/2013	StreamPro		
G9035407	Waterhouse River U/S confluence with Roper Creek	Tributary	0.420	23/10/2013	StreamPro		
Site 8	Roper River @ near Salt Creek	Main Reach	3.081	22/10/2013	Workhorse	large pools	
Site 12	Roper River @ Near Djilkminggan	Main Reach	4.215	23/10/2013	StreamPro		
Site 14	Roper River @ Site 14	Main Reach	4.641	23/10/2013	Workhorse	large pools	

Site Number	Site Name	River System	Flow m^3/s	Date	Gauging Instrument	Site Influences	Comment
Site 15	Roper River @ Site 15	Main Reach	4.446	24/10/2013	Workhorse	large pools	
Site 16	Roper River @ Site 16	Main Reach	4.271	24/10/2013	Workhorse	large pools	
Site 17	Roper River @ Site 17	Main Reach	4.068	24/10/2013	Workhorse	large pools	
Site 18	Roper River @ Site 18	Main Reach	5.361	24/10/2013	Workhorse	large pools	
Site 19	Roper River @ Site 19	Main Reach	5.156	24/10/2013	Workhorse	large pools	

Table 5 continued

Table 6 Water quality results

Site Number	Site Name	Date	Time	Temp (˚C)	pH	D.O. (mg/L)	DO % sat	E.C. (µS/cm)	Turb 1 (NTU)	Turb 2 (NTU)	General Chemistry Sample (500mL)	Nutrient Sample (250mL)	Nutrient Filtered Sample (125mL)
G9030001	Elsey Creek at Warlock Ponds	22/10/2013	1230	31.02	7.42	4.26	57	245	2.58	2.64	✓	✓	✓
G9035092	Mataranka Homestead At Hot Springs	22/10/2013	1000	32.96	6.86	0.57	8	986	0.65				
G9030176	Roper River at downstream Mataranka Homestead	22/10/2013	0910	30.14	7.56	6.10	81	1420	1.32	1.39	✓	✓	✓
G9030250	Roper River at Red Rock	25/10/2013	1005	31.16	8.04	7.32	99	1454	1.32	1.26	✓	✓	✓
G9035085	Little Roper @ Mataranka Homestead Xing	22/10/2013	1320	31.80	7.29	4.35	59	1353	0.95		✓	✓	✓
G9035157	Fig Tree Spring @ Roper River Elsey Park	23/10/2013	1215	26.38	7.78	4.73	59	2470	0.12		✓	✓	✓
G9035190	Salt Creek U/s Roper River Confluence	23/10/2013	1736	30.19	7.68	5.56	74	301	1.14	0.96	✓	✓	✓
G9035191	Waterhouse River @ Cave Creek Station Xing	22/10/2013	0900	27.71	7.78	3.15	40	423	1.50				
G9035193	Elsey Creek Upstream Roper River confluence	24/10/2013	1010	28.96	7.24	3.42	44	1720	0.60		✓	✓	✓
G9035194	Roper River Upstream Elsey Creek Inflow	24/10/2013	1225	31.05	7.84	6.39	86	1510	1.00				
G9035200	Elsey Creek @ Roper Hwy.	23/10/2013	1415	29.68	8.25	8.18	108	1760	1.63		✓	✓	✓
G9035212	Bitter Springs @ swim. access	22/10/2013	1132	33.27	6.84	1.57	22	1295	0.19		✓	✓	✓
G9035294	Roper River 400m D/S Elsey Station Homestead	23/10/2013	1730	30.9	7.24	6.57	89	1592	1.54	1.53	✓	✓	✓
G9035297	Elsey Creek 400m U/S Roper River confluence	23/10/2013	1600	29.94	8.30	5.84	77	1750	0.96		✓	✓	✓
G9035316	Waterhouse River 1.2km U/S of Rainbow Springs headwater	22/10/2013	0930	28.20	7.57	2.95	38	1171	5.80				
G9035406	Roper Creek near Waterhouse R confluence U/S	23/10/2013	0820	29.35	7.82	5.02	66	1427	0.78		✓	✓	✓
G9035407	Waterhouse River U/S confluence with Roper Creek	23/10/2013	1000	31.04	7.59	4.31	58	985	1.10		✓	✓	✓
Site 8	Roper River @ near Salt Creek	22/10/2013	1736	31.22	7.7	7.08	96	1431	0.83	0.94	✓	✓	✓
Site 12	Roper River @ Near Djilkminggan	23/10/2013	1200	30.68	7.11	6.15	83	1582	1.16	1.38	✓	✓	✓
Site 14	Roper River @ Site 14	23/10/2013	1710	30.51	7.2	6.3	84	1572	0.99	1.16	✓	✓	✓
Site 15	Roper River @ Site 15	24/10/2013	1210	31.23	7.34	6.55	89	1582	0.99	0.73	✓	✓	✓
Site 16	Roper River @ Site 16	24/10/2013	1200	31.16	7.41	6.84	93	1572	0.92	1.01	✓	✓	✓
Site 17	Roper River @ Site 17	24/10/2013	1130	30.88	7.36	6.93	94	1582	1.1	0.93	✓	✓	✓
Site 18	Roper River @ Site 18	24/10/2013	1513	31.75	7.54	6.96	95	1582	1.45	1.31	✓	✓	✓
Site 19	Roper River @ Site 19	24/10/2013	1445	31.24	7.55	7.35	100	1572	0.93	1.14	✓	✓	✓
G9035215	Botanic Walk Spring	24/10/2013	1700	30.44	7.29	3.95		2010					