HYDROILEX

Groundwater Geosciences

REPORT FINAL

BOREHOLE IMPACT MANAGEMENT PLAN (BIMP)

WARRUMBUNGLE SHIRE COUNCIL
TIMOR ROAD BOREFIELD - COONABARABRAN

PREPARED FOR: **WARRUMBUNGLE SHIRE COUNCIL**

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1.0 INTRODUCTION

1.1 BACKGROUND

Hydroilex was commissioned by Warrumbungle Shire Council in March 2018 to assist in the provision of hydrogeological services in the development of the Timor Road Borefield, located on the western outskirts of Coonabarabran. A number of drilling targets had been selected jointly by *NSW Office of Water (NOW),* Council and *Hydroilex*. This Borehole Impact Management Plan (BIMP) has been prepared for the Timor Road borefield designed to augment the Warrumbungle Shire Council (WSC) Town Water Supply (TWS). Eight (8) bores have been constructed and tested in the new borefield (*herein referred to as the site*). An additional (3) pre-existing bores have been integrated into the scheme.

The strategy for the borefield design and its necessity is summarised by the following factors:

- Current drought conditions had reduced the storage capacity of the Timor Dam necessitating its exclusion as the primary water supply for the town;
- Investigation along the existing pipeline route from the Timor Dam to the town via the water treatment plant;
- Bore locations within the Council lands including roadside verges at convenient locations to power supply;
- Exploration targets within the Jurassic-aged Pilliga Sandstone, recognised as a significant aquifer in the region;
- Bore locations with minimal impact on existing users;
- Exclusion of shallow aquifers by grouting of upper 30 metres of the bore hole;
- Investigation drilling to 150 metres depth;
- Borehole design assisted by borehole geophysics and detailed cuttings logs;
- Determination of aquifer indicative yields and lithologies in air-drilled test holes;
- Determination of likely sustainable yields based on 72-hour aquifer tests;
- Water quality analyses;
- Incorporation of bores within the existing groundwater supply network;

This BIMP documents the hydrogeological setting and borefield operations. Potential impacts are identified, and in particular, any potential interference on existing users and Groundwater Dependant Ecosystems (GDEs). A monitoring regime is provided with expected effects, sample parameters, sample frequency, assessment criteria, trigger levels, mitigation measures and general protocols for the management of monitoring data and technical reporting. This document has been prepared in accordance with the requirements of the *WaterNSW/ NRAR* and consistent with the spirit and principles of the *NSW State Groundwater Policy Framework Document* (NSW Government 1997), the *NSW State Groundwater Quality Protection Policy* (NSW Government 1998) and the *NSW State Groundwater Dependent Ecosystems Policy* (NSW Government 2002).

This report summarises the results of extensive operations incurred in the development of the resource, and references individual assessments conducted at each production bore site.

The determination of bore capacities and associated sustainable yields are provided to support applications for groundwater entitlements on each bore.

1.2 OBJECTIVES

The reporting objectives were to prepare a site specific Borehole Impact Management Plan (BIMP) to identify the potential impacts of the proposed borefield and document management systems and mitigation measures in support of license applications to *WaterNSW/NRAR*.

1.3 SCOPE OF WORK

The management plan was prepared for the borefield by undertaking the following scope of work:

- Meetings with WSC and discussions with *WaterNSW* (Dubbo);
- Review of available site data including; previous reports; spatial data; registered bore records, and pump test results;
- Review of the proposed borefield operations;
- Distance drawdown analysis;
- Detailed review of existing bores within a predicted impact radius;
- Assessment of potential groundwater impacts;
- Development of monitoring regime and mitigation measures; and
- Documentation of BIMP including recommendations for borefield operations management;

1.4 PREVIOUS REPORTS

The study area has previously been the subject of hydrogeological assessments by *Hydroilex.* This *BIMP* should be read in conjunction with the following reports:

Table 1. Inventory of *Hydroilex* Timor Road bore completion reports (refer to Appendix 1):

Bore Name	Report Number	Report Date	Content
Namoi Street	Hg18.5.2DU	May, 2018	Hydrogeology Enviro/User Impacts Aquifer tests Chemistry Borehole geophysics Form A
Nandi Park	HG18.5.5DU	May, 2018	As above
Water Treatment Plant	HG18.5.1DU	May, 2018	As above
Nandi Creek	HG18.5.4DU	May, 2018	As above
Homeleigh Drive	HG18.6.4DU	June, 2018	As above

Bart Bok	HG18.5.3DU	March, 2018	As above
Timor Dam	HG18.11.3DU	November,2018	As above
Morrisey Corner	No formal report		As above

2.0 SITE DESCRIPTION

2.1 LOCATION

The borefield is located to the west of Coonabarabran, principally on Timor Road, the main access route to the Warrumbungle National Park. The route follows the upper drainage catchment of Castlereagh River which is dammed (Timor Dam) in the more elevated terrain on the eastern margin of the Warrumbungle Range. The Siding Spring Observatory is located approximately 8km to the west of the dam. The borefield location, incorporating pre-existing bores is provided in **Figure 1**.

2.2 TOPOGRAPHY

A review of the site topography and hydrology was conducted with reference to the current series Coonabarabran (8735S) 1:25,000 topographic map sheet and Six Maps. Topography can provide a valuable indication of groundwater controls and flow regimes. Groundwater flow systems typically imitate surface topography and catchment structures driven by the location of recharge and discharge zones.

The site topography in relation to the subject bores is shown in **Figure 1**. It is dominated by the east-north easterly drainage trend of the Castlereagh River, having its headwaters in the Warrumbungle National Park. The topography is gently rising to the west, where approximately 110m elevation difference is recorded between the western and most easterly bores. As observed in the aerial image in **Figure 2**, more elevated vegetated areas lie adjacent to the north and south of the valley corridor.

3.0 HYDROGEOLOGICAL SETTING

The regional geological setting is provided in **Figures 3 &4,** where the mapped geological units are identified. The stratigraphy is defined from published geological maps, where the youngest formation comprises Tertiary-aged basalt, located principally in the western and southern part of the region. The underlying Pilliga Sandstone comprised of medium to coarse-grained sandstone, conglomerate and shale sequences have been the main target objective in the area. The sandstone sequence dips gently to the northwest, and is the main aquifer recharge sequence to the Great Artesian Basin.

The most significant geological feature in the region is the Warrumbungle Volcanic Complex, which has intruded the Jurassic Pilliga Sandstone. **Figure 4** shows the extensive regional distribution of the basaltic lavas and associated pyroclastics and intrusives. The aeromagnetic map shows the northerly-trending primary centres, identified by the magnetic 'highs' related to the 'Warrumbungle Volcano'. The volcanic centre is deeply eroded, where a radial drainage system is evident on topographic maps.

3.1 RECHARGE AND DISCHARGE

The Pilliga Sandstone has an extensive outcrop distribution to the south and east of the site. This sequence of porous sandstone is the most important recharge unit for the Great Artesian Basin. Aquifer recharge in the region is considered to be dominantly from within this geological sequence. Secondary recharge is also from within the elevated Warrumbungle region. The generalised predicted groundwater flow and recharge *areas* are shown in **Figure 4**.

It is expected that groundwater systems in the area are recharged by infiltration over an extensive catchment area. During the scope of work no signs of groundwater discharge (seeps or springs) were identified at the site. It is noted that the aquifer testing was conducted during a period of extended drought. In addition, it must be considered that during times of reduced rainfall**,** the aquifer supply is limited by that held in aquifer storage.

Plate 1 provides a stratigraphic display of the distribution of aquifers in relation to the sedimentology of the Pilliga Sandstone, as intersected in the respective bores. The correlation, based on gamma-ray records and cuttings logs clearly identify an upper sequence dominated by sandstone (sandy facies), and a lower sequence dominated by shales (shaly facies). Significant aquifers are identified within both sequences.

4.0 BOREFIELD DESCRIPTION

4.1 BORE LOCATIONS

Borehole locations were recorded with handheld GPS. Coordinates are provided in the construction summary table (**Table 2**) with locations mapped in **Figure 1**.

The criteria for test bore locations were principally:

1. Land ownership by Council;
2. Access to pipeline and power;
3. Bore separation distances of up to 3km, where possible to avoid interference;
4. Setbacks from watercourses;
5. Minimal impacts on existing licensed users;
6. Safety distances from road and verge width;

4.2 BORE CONSTRUCTION

Hydroilex understand the bores were generally constructed in accordance with the guidelines set out by the *National Uniform Drillers Licensing Committee* (*NUDLC*) in the *Minimum Construction Requirements for Water Bores in Australia – 3rd Edition* (2012). Detailed bore construction records are documented in the 'Form A' reports contained in the documents, as listed in **Table 1**. A summary of the construction data and aquifer intercepts is provided in **Table 2**. Composite summary logs are included in **Appendix 1**.

Drilling operations were conducted by *Watermin Drillers* using a combination of air and rotary mud drilling techniques. The following procedures were adopted:

- Test drilling to 150m nominal depth using a downhole hammer drilling method;
- Geophysical and cuttings logging;
- Bore design jointly by *Watermin* and *Hydroilex*;
- Reaming of test bore to the required depth in 250/300mm bore, and installation of 200mm NB steel casing, grouts and gravelpacks;
- Test pumping in the constructed bore;

5.0 GROUNDWATER CHEMISTRY

Groundwater chemistry and associated detailed comments are provided in **Table 3**. Overall, the water quality is excellent, where TDS range is 20-185 mg/L. Low-level exceedance in iron and manganese are however noted several bores.

The inclusion of potassium and bicarbonate alkalinity is required in future analyses, in order that an improved understanding of aquifer chemistry can be determined.

6.0 AQUIFER PARAMETERS

The bores were subjected to 4-stage step tests and three (3) day drawdown and recovery pumping test conducted between March and November 2018. Pumping test design and methodology was developed and conducted in accordance with the Australian Standard for Test Pumping of Water Wells (AS 2368-1990). The pumping rate, duration and depth setting was selected following detailed review of the hydrogeological conditions including depth of target aquifers, aquifer type, available drawdown, bore construction and borehole geophysical records. Testing was conducted by *Watermin Drillers* using a submersible *Grundfos* pump. Water level data was collected both manually and automatically with a submersible water level data logger programmed to record water levels at 10 minute intervals.

A summary of the drawdown and recovery test results is provided in **Table 2**. Drawdown and recovery data was tabulated and plotted to produce aquifer response curves. This data is provided in the specific bore reports as referenced in **Table 1**, and **Appendix 1**.

6.1 CAPABLE YIELD

For the purposes of this groundwater management plan, capable or 'safe' yield is defined as the volume of groundwater that can be extracted from an aquifer on a sustained basis over a specified timeframe without impacting on the quality of the groundwater, dewatering the lower aquifers or adversely impacting on the environment.

In estimating a long-term 'capable yield', the most critical factor is considered to be *maximum available drawdown level* (*MADDL*) which is directly related to the position, relative yields of the aquifer/s intersected, and the depth of the main aquifer. This level is the level at which the yield of the bore is not significantly compromised, and is also the level below which the rate of fall of the water table as pumping continues, significantly increases. The water table during pumping should not fall below the *MADDL*. Other factors of importance relate to the minimisation of cascading water and associated preservation of water quality by reduced water oxygenation.

The *MADDL* levels for each of the respective bores are provided in **Table 2**. The maximum available drawdown *ADD* for each bore has been determined, being the difference between the *MADDL* and the SWL. In most cases, the *MADDL* has been taken at the top or middle part of the main aquifer.

For each of the bores, the pumping duty has been determined from the drawdown character, where maximum pumping duties have been calculated from the drawdown data and associated plots, as presented in the respective reports for each bore, as provided in **Table 1**.

7.0 POTENTIAL GROUNDWATER IMPACTS

7.1 PREDICTED DRAWDOWN

For each of the bores, the distribution of aquifers and test results have enabled the determination of maximum available drawdown levels, designed to preserve aquifer integrity and reduce impacts. From this data, trigger levels have been established, as detailed in **Section 9**.

Impacts on existing users have however been minimized by the sealing of shallow aquifers (to a depth of 30m) from which most local users exploit. Production bores at the site have all been drilled to 150m depth to explore the deeper aquifer potential, and only draw groundwater from those zones.

The potential drawdown influences from other pumping bores and environmental factors such as recharge from rainfall are difficult to predict. A numerical groundwater model may be considered for further assessment pending additional data from installation of monitoring bores and actual bore performance. *WaterNSW* may impose cessation of pumping based on certain drawdown or decline in drawdown after a period of time. It is recommended that site specific thresholds and trigger values be reviewed after 12 months monitoring and pumping. Landowners may be consulted to enable Council to install data loggers in nearby bores, and to establish baseline data.

7.2 REGISTERED BORES

A review of *WaterNSW* registered bore records was conducted to develop a conceptual understanding of regional groundwater conditions, including aquifer depths, yields, and water quality. The distribution of registered bores is identified in **Figure 5**. At a site-specific scale, the recognition of existing bores was carefully considered in the planning of production bore locations. The main strategy was to develop bores much deeper than domestic bores, and to seal the upper 30m to exclude any groundwater from the shallow interval.

Hydroilex recognise additional unlicensed bores may have been drilled in the area or are yet to be entered into the *WaterNSW* database. This assessment has considered all available data as provided by *WaterNSW*.

It is notable (to the best of our knowledge) that Council has not received any complaints from private groundwater users since the new town bores have been commissioned.

7.3 GROUNDWATER DEPENDENT ECOSYSTEMS

A review of the borefield land and surrounding lands indicate that the site does not contain or form part of any critical habitats. Site inspections did not identify any significant areas of groundwater discharge or Groundwater Dependent Ecosystems (*GDE's*) in vicinity of the site, nor identified in the Water Management Plan for the GAB. *GDE's* were considered to comprise hanging swamps or vegetation communities' dependent on groundwater discharge. In summary the aquifer testing and hydrogeological assessment demonstrates that under the recommended extraction regime the subject bores are unlikely to result in any significant measurable impact on environmental conditions.

7.4 ENVIRONMENTAL FLOWS

The Timor Road borefield is located within the valley of the Castlereagh River, where the bores are generally 100-300m distance approximately from the river. The bore construction, especially in relation to sealing the upper 30m depth, indicates that the bores are not in significant hydraulic connection with potential shallow aquifers and surface water. Hence the bores are assessed to present no significant risk of impacting on environmental flows in the borefield area.

8.0 PRODUCTION PUMPING AND SCHEDULES

The main operational facts advised by Council are that all loggers are now installed in the bores, including the town bores. In view of the facts, as noted below, it not considered possible to conduct formal test on those bores.

- 'Old' bores contribute approximately one-third of the production volume, and the new bores, approximately two-thirds;
- All bores pump simultaneously on-demand, supplying water directly to the WTP;
- None of the bores cease pumping due to reduced head;
- All bores, including monitoring bores have loggers installed;
- Usually, bores pump for 4-6 hrs per day, and recharge overnight;
- Data loggers are all recording at 5-minute frequencies;

- Pump controls and real-time data is recorded and managed at the plant, where a high level of detailed recording is maintained;
- Drawdown levels and recovery levels seem to be stable;
- There would seem to be no local user objections to the scheme, where Council have not received any complaints;
- The scheme would seem to be functioning extremely well, where fine-tuning of bore performance has been established;
- Water chemistry has remained unchanged. Quality control is conducted each day, and formal analyses are being undertaken on a six-monthly basis;
- The implementation of aquifer testing for 72hrs for each of 4 'old' bores (Bores 1,2,4 & 6) was difficult in view of the reliance of that supply for current usage, where it was considered necessary to have each of the bores off-line. An alternative practical test program was devised; it is noted too, that there is not a clear understanding of the aquifer distribution, construction and equipping of these bores; it is also noted that these bores are 'shallow', extracting groundwater from the upper aquifer system that have been excluded in all other bores; they are likely to be in partial hydraulic connection to the adjacent river.

8.1 OPERATIONAL COMMENTS

1. Pumping vs recovery durations are providing a low-level stress on the system, where all bores are operating at approximately 15% duty (~4 -6 hrs/day);
2. It is not forecast that production changes will be varied significantly over the ensuing periods;
3. Bore impacts are considered 'low', both a function of short pumping durations and bore construction, where shallow aquifers have been excluded by sealing/grouting (in all new bores) to minimize 'stock/domestic' private bore interferences;
4. The field is providing significant groundwater productivity, meeting demands, even though river water is not being utilised; Level 4 water restrictions are however still in place;
5. Field groundwater abstraction management is excellent, and operational controls would seem to be well established without any major alerts on bore drawdown trigger levels (at pumps) being met;
6. Since commissioning, operational fine-tuning would seem to have been established, with sufficient operational time to assess the overall performance against hydrogeological and environmental constraints;
7. Some bores would seem to have additional pumping capacity, providing an upside resource potential; similarly, proven aquifer continuity in the western part of the field will enable the construction of new bores, if required to meet new demands;
8. The need for dedicated 72-hr tests on each of the 'town' Bores 1,2,3 & 4 is not warranted in view that these bores are operating harmoniously within their capabilities. An alternative qualitative assessment approach was considered more appropriate;

8.2 ASSESSEMENT RECOMMENDATIONS

The following was considered to be a practical means of assessing the field performance, to meet the criteria of a borefield management plan based on the current levels of historic production and current forecast. The data was provided by Council.

1. Assemble a comprehensive summary of average field statistics for each bore per calendar month for each production bore – refer to **Table 2**;
2. In lieu of conducting formal 72-hr tests on the 'old' bores (and one new bore- Bore 3) in the east of the field, determine operational yields based on both available bore construction data and field results; this will eliminate the need to effectively shut down production from those bores to reach required performance data, realising too, that construction data from the older bores is poor;
3. Utilise only the detailed data from September 2019 records to achieve '2' above;
4. Change logging time readings from 5 minutes to 10 minutes;
5. Provide all formal historic chemical analytical data for review of any significant variations;

9.0 MONITORING PLAN

9.1 MONITORING BORE LOCATIONS

Given the proposed groundwater use to supplement the WSC Town Water Supply it is recommended that monitoring bores be managed to facilitate necessary groundwater monitoring for the Borefield. However, given the distribution of the bores, and their construction, most bores are considered 'safe' due to good management protocols and associated production rates and monitoring at the production bore sites. The exception does however exist in the WTP locality, where existing test holes have been utilised. The 'Morrissey Corner' bore has been utilised for monitoring in that locality. Additional monitoring bores may be necessary where impacts are recognised.

9.2 SAMPLE FREQUENCY

Water level monitoring will provide important baseline water level data and facilitate the long-term sustainable management of the groundwater resource. Monitoring at the site should include the following:

- Measure and record water levels in the bores using an automated water level data logger and recorder;
- Program the water level data loggers to record measurements at a sample interval of one (1) measurement every four (4) hours; and
- The water level logger should be maintained and downloaded regularly by a qualified groundwater consultant, or the site manager should be fully trained in the operation of the water level data logger. *Hydroilex* understand that WSC has set up the monitoring of water levels through telemetry back to a control centre and alarmed to the recommended trigger levels, similar to existing creek and rainfall gauging.

Sample frequency may be revised in monitoring bores following review of preliminary water level data, and smaller sample intervals may be required in production bores to accurately record the maximum drawdown and recovery rates.

10.0 TRIGGER LEVELS

Trigger levels in production bores and monitoring bores should be updated and finalised after 12 months monitoring. Final levels can only be determined after monitoring bores have been assessed during pumping.

The practical purpose for creating trigger levels for groundwater abstraction thresholds is in consequence of the following:

- The need to manage the resource in a sustainable manner;
- To provide protection for other users in the region, where increased drawdown due to pumping may cause other users to be disadvantaged;
- To minimise the dewatering and cascading of aquifers, where oxidation and associated dewatering can affect both the aquifer and groundwater chemistry;
- To reduce any impact of severe drawdown on the environment – e.g. baseflow declines, depletion of groundwater storage, impacts on distal GDE's; and
- To provide a level of confidence and protection to the designated authority (*WaterNSW*)) for the issue of the appropriate license.

Groundwater management requirements on the site may be outlined in the licence provided by *WaterNSW*. The importance of limiting drawdown by excessive pumping will be important to maintain water quality consistency, pumping efficiency, and preservation of the resource-based business. To enable accurate water level management, data-loggers have been installed in the production and monitoring bores. In addition, recorded data will provide a historic record for the operator, which will assist with identifying any potential impact on water levels by the project. A number of factors that have been considered important in the development of trigger levels are:

- Consideration of the aquifer boundaries, aquifer heterogeneity, and shape of the drawdown cone. A high level of confidence has however been gained by the regional knowledge, stratigraphic control, test data, and particularly the drawdown levels recorded during testing operations;
- Climatic changes which may impact on groundwater levels and recharge rates;
- Impacts from any abstraction from future new bores on adjoining properties, especially if not controlled by an allocation or metered discharge rates (e.g. excessive abstraction from 'stock & domestic' licensed bores);
- The need to record accurate data by automated data recording, in addition to the manual records, with the need to record levels with greater awareness if abstraction volumes are increased;

- The need to establish levels which certify the preservation of the environment, which are acceptable to the community. Recognition of groundwater abstraction attitudes, and perceptions of abstraction abuse which may or may not be tangible;
- The likely need to review trigger levels upon license renewal, or as required, in the event that conditions change;
- The setting of sensible trigger levels which are equitable for both the viability of the operation, other users and the environment;
- The need to review trigger levels in the event that new bores are constructed in the immediate area;
- Recognition that the aquifers are (predominantly) relatively 'deep' and in fractured/porous sandstone;
- The absence of any known users (based on the current database) in the immediate area who depend on groundwater;
- Awareness of any new bore construction in the region, especially irrigation bores, and compliancy with respect to setbacks; there are no bores in the region of the borefield that are licensed for any 'irrigation' purposes;

10.1 PRODUCTION BORE TRIGGER LEVELS

It is proposed that three (3) trigger levels, or 'alarms' be created, having different levels of reporting requirements, as detailed in **Table 4**. The development of Trigger Levels is primarily based on the position of the aquifers, screens and available drawdown levels within the production bores. Level 1 and 2 are designed to identify unexpected drawdown levels and trigger reviews of bore operations. Level 3 provides a cease to pump action at a level above the available drawdown to avoid potential dewatering and structural damage to the primary aquifer and borehole construction.

Table 4 Groundwater Mitigation Measures

Trigger Level	All bores	Recommended Action
1	Monitored water level in the production bore during *any* production pumping period falls to a level of **10m** above the logger (at pump)	**Record** date of impact in water level database.
2	Monitored water level in the production bore during *any* production pumping period falls to a level of **5 m** below ground level	**Record** date of impact in water level database. **Consider** adjusting the pumping period where the trigger water level is not exceeded, **OR** **Consider** adjusting both the extraction rate and the pumping period where the trigger water level is not exceeded.
3	Monitored water level in the production bore during *any* production pumping period falls to a level of **2 m** above the logger (at pump)	**STOP PUMPING** **Record** date of impact in water level database. **Notify** the *Senior Hydrogeologist, WaterNSW* and the hydrogeological consultant by email or letter within 5 days. **Assess** all monitoring and production data. **Make** conclusions and provide recommendations. **Meet** with the *Senior Hydrogeologist, WaterNSW* to discuss results, cause/s of the declining water level and a contingency plan to go forward.

It is noted in **Table 2** that several bores, particularly the 'old' bores have pumping levels which exceed the trigger levels which are elaborated in **Table 4**. In those bores, construction details are either non-existent or scanty, and aquifer depths are not known. It is noted that pumping should not be reduced below the main aquifer, and it is apparent that those depths are not known. It is recommended that for the 'old bores', where data is unknown, consideration be given to evaluating their construction by geophysical techniques, and reconstructing, where appropriate. Where reductions in discharge rates are recommended, it is likely that a slight change in the rate will effect a significant improvement. Under those conditions, the pumps may be run for a longer period to realise a similar production.

Several points to note are:

1. Bore 1 – the bore is very shallow (22m), where water levels above the pump during pumping and recovery are 3.0 and 3.8m respectively. In view that the bore is shallow, those levels are likely to be sustainable, subject to more information about the aquifer distribution.
2. Bore 4 – the bore is shallow (26m) where drawdown to 1.5m above the logger is critical; it is recommended that the discharge rate should be reduced;
3. Bore 6 – it is recommended that the pump rate be reduced; the bore recovers with significant pump submergence.

10.2 MONITORING BORE WATER LEVELS

Trigger Value

A 'significant' decrease in water level over time that may or may not be observed in other monitoring bores particularly in proximity to production bores. A significant decrease is herein defined as:

1. a relatively 'sudden' decrease where the rate of fall exceeds the established 'normal' rate of water level decrease (recession) observed in all background water level data; and
2. An absolute water level lower than the minimum water level recorded for that monitoring bore in the background water level data.

It is proposed that initial trigger levels be applied to a ***3m drawdown below the standing water level***.

Immediate Action

Continue to monitor and assess water level data, establish trends and correlate with groundwater extraction regimes and climatic data (rainfall). Apply statistical analysis to assess trends if required. Determine whether any decrease in water level may be due to impacts from the TWS.

Follow-up Action

If some or all of the water level declines in the monitoring bore network are assessed by the hydrogeological consultant to be due to impacts from the TWS, determine amount and rate of inflow of any groundwater into the catchment and determine aerial extent of any distance interference. Continue to monitor and assess significance of any impacts.

10.3 WATER QUALITY MONITORING

Trigger Value

The Australian Drinking Water Guidelines (2011) (Chapter 9) identifies a number of key indicators for raw water monitoring as summarised in **Table 5**. It is considered that a set of trigger levels can only be satisfactorily developed after sufficient data is collected in the medium term and a natural range of variations established and assessed. A preliminary round of water quality sampling has been completed. Data is available to assist with establishing baseline levels. It is proposed that initial levels be developed after a second round of testing.
A preliminary approach, pending acquisition of long-term data, is a 'significant' decrease in water quality in particular decreasing pH, increasing EC and increasing TDS over time in monitoring bores. A significant decrease is herein defined as:

1. a pH less than 6.0;
2. a gradually increasing trend in EC & TDS values compared with any trends observed in the background control bores.

Frequency

Monitoring frequency should be selected based on the sample variability and the aesthetic and health significance. Sampling frequency should be increased during flooding, drought, emergency operations and following repair works or interruptions to supply. A summary of monitoring frequency is provided in **Table 8**. It is recommended that raw water monitoring be conducted at least quarterly for the first 12 months, with frequency refined based on the results of the annual data review.

Immediate Action

Continue to monitor and assess bore water quality data, establish trends and correlate with TWS activities and climatic data (rainfall) to determine a causal link (if any) with the TWS operations. Apply statistical analysis to assess trends if required.

Follow-up Action

If evolving geochemical anomalies are detected in groundwater sampled from monitoring bores and an impact from the TWS activities on the aquifer system is demonstrated, continue to monitor and contact a suitably qualified groundwater professional to assess the results and advise suitable action.

Table 5 Initial Groundwater Monitoring Frequency

Analyte	Freq.	Comment
Aluminium; Fluoride;	Weekly	Concentrations can change relatively quickly within a distribution system, and may have important public health or aesthetic significance. Particular disinfectants (and byproducts) will only require monitoring if they are used. Fluoride and aluminium may not require frequent monitoring if fluoridation is not carried out, or if alum-based coagulants are not used for clarification.
Iron; Manganese; pH; Total Dissolved Solids; Turbidity; E.coli (or thermotolerant coliforms)	Fortnightly	Iron and manganese can cause taste and staining problems. Concentrations in a distribution system can change as a result of microbial growths in pipes and chemical changes in distribution systems. Changes in the water quality of deep storages can also occur due to temperature stratification.
Arsenic; Pesticides; Sodium; Selenium; Sulphate; Hardness;	Quarterly	While some change is possible within a distribution system, this is likely to be very slow. Concentrations are generally stable and are determined by conditions in the water storage or catchment (for example, elevated concentrations of boron may result from irrigation return water).
Cyanide;	Annual	It would be unusual to detect these constituents in most Australian drinking water supplies. If rarely or never detected, monitoring is probably unnecessary. Local information may indicate that more frequent monitoring is required.

Source: Adapted from Table 10.3 (ADWG; 2004)

11.0 EXTRACTION SCHEDULE

11.1 NORMAL & PEAK CONDITIONS

The capable yield represents the maximum recommended production, however the hours of operation and pumping rates may be refined based on operational limitations and TWS requirements. Details of the 'standard' operating conditions should be updated after six months of operation. **Table 2** summarises the production data based on the pump test results, capable yield calculations together with actual production levels.

Based on the existing data, the borefield is producing approximately 400 ML per annum, derived from the ten bores in the field.

In order to satisfy peak demands, there is considerable upside potential to increase pumping durations from each of the new bores, where their pumping duty is much less than that determined from aquifer testing.

12.0 WATER SHARING PLAN

12.1 PLAN DETAILS

Coonabarabran is managed by *WaterNSW* consistent with the *Water Sharing Plan for the NSW Great Artesian Basin Groundwater Sources,* and is located within the *Southern Recharge Groundwater Source.* The water source relates to 'intake beds' where recharge to the basin is associated with intake within the Pilliga Sandstone aquifers. The water source extends from Warren and Dubbo in the south, Coonabarabran in the east and Narrabri in the north along an ~80 km x 300 km belt of the outcrop and sub-crop of the sandstone.

A draft revised (2020) Water Sharing Plan has been released since the original 2008 plan.

The annual net recharge for the zone is reported in the 2008 plan was being 42,400 ML/yr, but increased in the 2020 Draft Plan (no details are provided).

Currently, the water source has a share component of 3,066 ML/yr for local water utilities, 13,500 ML for 'domestic and stock' rights, and 24,462 ML for aquifer access licenses.

The long term annual extraction limit for the water source has been increased from 29,400 ML to 38,700 ML (2008 vs 2020 revised plan).

12.2 ACCESS TO WATER ACCESS LICENSES

The groundwater management plan specifies that applications for access licenses can be accepted for a local water utility, at the minimum required to meet the purposes for which the water is to be used. Consistent with the findings of the groundwater investigation, it is evident that the bores will induce minimal harm to the environment, groundwater dependent ecosystems, and the water source. It is assumed that, in satisfaction of the groundwater issues, an access license will be issued by *WaterNSW*.

We note that Baradine (same water source) has a significant entitlement of 221ML, which may be reassigned, if required.

Table 6 Water Sharing Plan Provisional Rules (2020 Draft Plan)

Plan Provision	Proposed Rules
Rules for water supply works approvals Rules to minimise interference between bores	Water supply works (bores) are not to be granted or amended within the following distances of existing bores and infrastructure: • 200 m from a bore that is nominated on an aquifer access licence on another landholding. • 200 m from a bore that is used to extract basic landholder rights on another landholding. • 1000 m from a bore nominating a local or major water utility access licence. • 400 m from a bore that is used by the Office for monitoring purposes (unless agreed to in writing by the Office). • 200 m from a property boundary (unless negotiated in writing with neighbour). • 500m from a contamination source, or 250m from the edge of a plume. • 40m from the high bank of a creek. These specified distances may be varied by the Minister after year four of the plan. These distances restrictions do not apply if the Minister is satisfied that: • the bore is used solely for basic landholder rights, • the bore is a replacement bore, • the bore is used for monitoring, environmental management or remedial works, • the location of the bore would result in no more than minimal impact on existing extractions within the water source, or • a hydrogeological study submitted by the applicant, shows that the location of the bore at a lesser distance will have no more than minimal impact on existing extraction from the water source, subject to any actions

12.3 DROUGHT RESTRICTIONS

In the event of extended drought conditions all monitoring data shall be reviewed to assess borefield performance and aquifer conditions. A groundwater professional should be consulted to advise appropriate actions including:

- Adjusting pumping rates and hours of operation. In general it is recommended to reduce pump rates under increased duty to minimise drawdown in the pumping bore;
- Liaise with groundwater license holders within a 1 km radius of the production bores to ensure existing users are aware of their allocation limits. Consider voluntary restrictions on pumping by existing users; and
- Increase frequency of monitoring data review including water quality and level data.

13.0 DATA MANAGEMENT PROTOCOL

The recommended protocol for data management is summarised as follows:

- The water level data downloaded from the loggers in the bores should be imported into an electronic database or spreadsheet and viewed following each round of monitoring. This process will ensure that a progressive record of the data is stored and maintained, and the integrity/quality of the data can be checked on a regular basis. If a problem with the data is discovered, for example the logger has failed or the corrected water level in the data logger does not reasonably correspond with the manual measurement taken at the time of downloading, remedial measures can be implemented immediately. If there is a problem, the worst case scenario is that water level data may be lost for that period or part of the monitoring period since the last downloading was carried out. In this way, any problem should not be carried through in the medium to long term.
- Email a copy of the water level data to the hydrogeological consultant for assessment and keep a backup copy of the water level database or spreadsheet in a secure **off-site** location;
- Develop and maintain an electronic water quality database or spreadsheet. This database can also be part of the electronic water level monitoring database. A suitable database and progressive charting can be developed;
- Develop and maintain an electronic rainfall database or spreadsheet; and
- Provide copies to *WaterNSW*, if requested.

14.0 REPORTING PROTOCOLS

The recommended protocol for reporting, separate from special reporting associated with any specific impacts, is summarised as follows:

- All water level data and any groundwater quality monitoring results should be recorded, collated and duly reported in-house on at least a six-monthly basis for the first 12 months then on an annual basis. The data should be reviewed by the consulting hydrogeologist. The aim is to assess any changes in water levels or groundwater chemistry and identify reasons for the changes if they occur. The monitoring schedule should be reviewed annually and changed if deemed appropriate by the consultant.
- A complete set of results of the monitoring program should be formally reported to the *WaterNSW* on an annual basis. The report should include but not necessarily be limited to:
    - A progressive record of the water level measurements in the monitoring bores
    - A figure showing the locations of the monitoring bore network
    - A set of hydrographs
    - Rainfall data correlations
- Progressive assessment of any trends in water level fluctuations:
    - Analytical results and progressive assessment of any trends in geochemistry
    - Conclusions and recommendations

- The report should be submitted in hard copy and electronic format to *WaterNSW* . The raw water level and water quality data will be appended to the report in electronic form.

15.0 SUMMARY AND RECOMMENDATIONS

The following summarises the main results of the groundwater investigation:

1. The Coonabarabran groundwater supply abstracts water of high quality from the Pillaga Sandstone from within the Southern Recharge Groundwater Source located along the eastern margin of the Great Artesian Basin.
2. The Timor Road groundwater investigation conducted in 2018 realised the construction of 8 new production bores, 7 of which were put into production. Bores were located along an existing pipeline route from the Timor Dam at convenient locations for power supply and access within Council lands. Bores were drilled to a depth of approximately 150m. The bores supplement 4 existing bores located at the eastern end of the field.
3. Each of the bores were sealed and grouted to a depth of 30m to eliminate the drainage from shallow aquifers and impacting on local domestic bores, which principally sourced from shallow aquifers.
4. Historic production to date has not resulted any significant reported impacts from landholders.
5. Aquifer testing was conducted over 72hr periods, from which equipping and pumping recommendations were determined.
6. A review of production data has realised that the new bores are all performing close to their design predictions, providing adequate supply.
7. The 'old' bores are relatively shallow, with poor construction and hydrogeological details. They have not been formally tested. Their drawdown levels are close to pump suction levels, requiring a greater level of management.
8. Site management of the borefield by Council is considered excellent, where all bores are carefully monitored by telemetric logging, associated with pumping durations which are generally much less than recommended duties.
9. The borefield has been producing approximately 400ML to meet town water requirements.
10. Formal licensing of all bores has been undertaken, and we understand that a process has been initiated to acquire water access licenses consistent with guideline rules of the associated water source.

16.0 REFERENCES

Agriculture and Resource Management Council of Australia and New Zealand, 2013. Minimum Construction Requirements for Water Bores in Australia. Edition 3, Sept. 2013.

Australian Government, 2011. Australian Drinking Water Guidelines 6. National Water Quality Management Strategy. Natural Resource Management Ministerial Council. National Health and Medical Research Council. Version 35 updated August 2018.

Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Volume 3, Primary Industries - Rationale and Background Information (Chapter 9).

Cooper H.H. and Jacob C.E. 1946. A Generalised Graphical Method for Evaluating Constants and Summarising Field History. Trans. Amer. Geophys. Union. Vol. 27, pp.526

Domenico P.A. and Schwartz F.W. 1997. Physical and Chemical Hydrogeology. Second Ed. John Wiley & Sons, Inc. pp. 145

Freeze R.A. and Cherry J.A. 1997. Groundwater. Prentice-Hall, Inc.

Hydroilex Reports, as referenced in Table 1 herein.

WaterNSW. 2008 Water Sharing Plan for the NSW Great Artesian Basin Groundwater Sources – Background Document.

WaterNSW. 2008 Water Sharing Plan for the NSW Great Artesian Basin Groundwater Sources – Guide.

WaterNSW. 2020 Water Sharing Plan for the NSW Great Artesian Basin Groundwater Sources, draft water sharing plan.

FIGURES

PLATES

Appendix 1

Form A Bore Construction Reports

Appendix 2

Pumping Test Results

Appendix 3

Registered Bore Reports

Table 2. Summary of Coonabarabran Timor Road Bore Data and Management Recommendations

		ROBERT'N ST	NAMOI Sth	NAMOI ST new	NAMOI NTH	NANDI PARK	WTP OLD	WTP NEW	NANDI CREEK	HOMELEIGH DRIVE	BART BOK	TIMOR DAM	MORRISEY CORNER
BORE NUMBER		1	2	3	4	5	6	7	8	10	11	12	
GENERAL	**DETAIL**												
TB LICENSE/GW	80BL	242128	GW00361	620500	242132	620495	GW806052	620494	620501	620499	620497	620503	620498
LAND TITLE	LOT/DP			23/1099367	23/1099367	7041/1027284		4/839637	adj.7012/103045	adj.300/255639	adj.3/576865	8/222722	adj.9/1128151
LOCATION	E	716540	716310	716200	716165	715680		715307	714863	713480	708095	705096	713480
	N	6537900	6537995	6538368	6538450	6538035		6537894	6537730	6538567	6537935	6537725	6538567
ELEVATION (approx)		510	510	510	510	515	515	515	515	538	545	615	520
DISTANCE TO COONA.	KM	0.5	0.5	0.8	0.5	1	1.5	1.5	2	5	9	12	3.5
CONSTRUCTION							no data						
DEPTH TEST BORE	m			150		104		151	150	150	150	200	150
DEPTH COMPLETED	m	22	24	90	26	50		88	150	150	136	144	142
SCREEN	m		open hole	15-20,56-58,60-88 open		30-45			30-42,72-80,130 148	48-51,54-57,62-73,92-98,104-106,124-128,140-146	42-54,68-80,98 130	75-144	74-102,112-142
CASING OD	mm		150	125		219		219	219	219	219	160	219
TYPE	pvc/steel		Steel	PVC		STEEL		steel	steel	steel	steel	PVC	steel
GROUT	m			14		29		30	25	30	30	30	50
SWL	m		5.05	4.7		3.09		7.25	3.45	15.4	21.9	81.5	13.2
AQUIFER INTERVAL	m		15.8-23.4	77-81		30-46		40-50,78-82	35-42,73-87,130-142	48-146	45-130	92-144	13-45,79-140
MAX. AVAIL. D'DN LEVEL_MADDL	m		20	55		30		40	40	72	72	120	
AVAIL. DRAWDOWN_ADD	m			50		27		33	36	57	50	38.5	
TESTS													
TESTED 72 HRS	Y/N		N	N		Y		Y	Y	Y	Y	Y	N
TEST RATE	L/s					4		4	4-6	3.6	6.0	2.0	
DDL at 72 hrs	m					20.6		43.5	23	64.23	36.7	102.5	
Transmissivity	m3/day/m					53		80	10	4.7	118.0	55?	
CHEMISTRY													
TDS	mg/L			86				111	93	176	62	87	
EC	uS/cm					166			151	318	75	174	
HARDNESS	mg/L			9		56		80	55	108	18	68.4	
RECOMMENDATIONS													
PUMP SETTING	m			55		40		60	50	88	85	140	
PUMP RATE	L/s			0.25		4.5		3.5	5	3.8	8-10	3	
MAX PUMP DUTY	% time			100		100		75	*75*	100	100	100	
REVIEW NEEDED	Y/N			Y		Y		Y	Y	Y	Y	Y	

REVIEW RECOMMENDED	mths			6		6		6	6	6	6	6	
LIKELY PROD. / ANNUM	ML			**10-15**		**140**		**80**	**115**	**120**	**240**	**100**	nil
MANAGEMENT													
LOGGER SAMPLING	Hrs			1		1		1	1	1	1	1	12
FLOW METER	Total			Y		Y		Y	Y	Y	Y	Y	N
IMPACT RISK ON OTHERS	H-M-L			M		M		M	M	M	L	L	M
1ST TRIGGER LEVEL	m DDL			47		25		35	35	67	67	115	
CRITICAL TRIGGER LEVEL	m DDL			52		30		40	40	72	72	120	
ACTION PLAN													
a. Contact h'geo at 1st TL				Y		Y		Y	Y	Y	Y	Y	
b. Stop pumping review				Y		Y		Y	Y	Y	Y	Y	
ACTUAL PERFORMANCE													
AVERAGE DISCHARGE	L/s	2	2.6	1.2	1	4.8	2.2	4.3	5	2	7	3	
PUMPING LEVEL above logger		3	11	41.2	1.5	5	2	25	10	10	30	18	No prod'n
RECOVERY LEVEL above logger		3.8	14.7	50.5	6.3	58	26	56	45	51	57	30	
AVERAGE PUMP T 6mths	hrs/day	6.12	6.12	6.12	6.12	6.21	6.12	6.12	6.89	7.29	9.38	12.6	
PRODUCTION SEPT'19 KL	KL	1934.6	2651.5	873.6	980.6	5288	1888.6	3314	3105	5006	8256	3141	
Indicative annual prod'n	ML	**23**	**32**	**10**	**12**	**63**	**23**	**40**	**37**	**19**	**99**	**38**	
TRIGGER STATUS		poor	fair	excellent	poor	fair	poor	good	good	good	excellent	good	Mon. bore

Table 3.Summary of Major Ion Chemistry -Coonabarabran Bores (Jan'19 data)

Note: concentrations in mg/L

BORE	Ca	Mg	Na	K	HCO3	Cl	SO4	TDS	Fe	Mn	Hardness	pH
1	19	15	48	nd	nd	37	9	185	0.01	0.005	108	7.4
2	8	5	9	nd	nd	8	1	59	0.05	0.005	40	6.7
3	1	1	5	nd	nd	5	1	24	0.01	0.029	4	5.5
4	2	1	1	nd	nd	9	1	20	0.01	0.029	2	5.2
5	21	7	7	nd	nd	6	1	74	0.18	0.011	55	6.8
6	3	2	2	nd	nd	11	1	34	0.01	0.005	16	5.8
7	12	9	9	nd	nd	6	1	78	0.39	0.006	66	6.8
8	9	8	8	nd	nd	6	1	64	0.7	0.008	57	6.8
9	nd			nd								
10	5	3	2	nd	45	4	1	36	0.33	0.041	24	6.8
11	6	2	2	nd	40	4	1	36	0.41	0.009	23	6.7
12	20	4	4	nd	52	12	26	87	0.11	0.122	68	7.5

COMMENTS (above data):

1. TDS data confirm that all samples are relatively 'low salinity' / fresh (<1,000 mg/L)
2. Bicarbonate (alkalinity) data not available for all bores. This species likely contributes the main analyte in all bores.
3. Potassium data required in future analyses.
4. Source analyses dated 14.2.18 and 9.1.19 generally demonstrate that water quality has improved with longer term pumping.
5. Iron concentrations exceed asthetic concentration limits (0.3 mg/L) several bores.
6. Manganese concentrations generally 'low' (<0.1 asthetic).
7. Chloride concentration are 'low', and unlikely to affect plant growth.
8. pH variable, close to neutral in most samples;
9. There are inadequate complete analyses to identify aquifer chemical variation fields (piper diagram).
10. Bore 10 water is classifiedas a *bicarbonate* water; bores 11 &12 are *bicarbonate-calcium* waters.

Comments - other water chemistry data:

1. Trace metals (antimony,arsenic,barium,cadmium,chromium, copper, lead,mercury, nickel, selenium,silver) are 'low', and meet all ADWG guidelines.
2. Nitrate concentrations are variable ('low'), within guidelnes.
3. Microbiological results pass on e.coli, but elevated coliforms in bores 1 &2.
4. Radiolgical results are all below guideline concentrations.
5. Pesticide data is incomplete.
6. Bromide concentrations are 'low' and not expected to be an issue in the chlorination process.
7. High Exceedance levels in water quality have been eliminated by subsequent analyses.

REFERENCE

BORE	ID	BORE	ID	BORE	ID
Timor Dam	TD	Nandi Ck	NC	NAMOI NTH	NN
Bart Bok	BB	Water Tr. Pl.	WTP	NAMOI STH	NS
Homeleigh Dr.	HD	Nandi Park	NP	ROBERT'N	R
Morrrisey Cnr.	MC	Namoi St	N		

N

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UTM: -
Dec-19
Drawn: RJL
Approved: RJL

Warrumbungle Shire Council - Timor Road Borefield

Timor Road Borehole Location Map

Figure: 1

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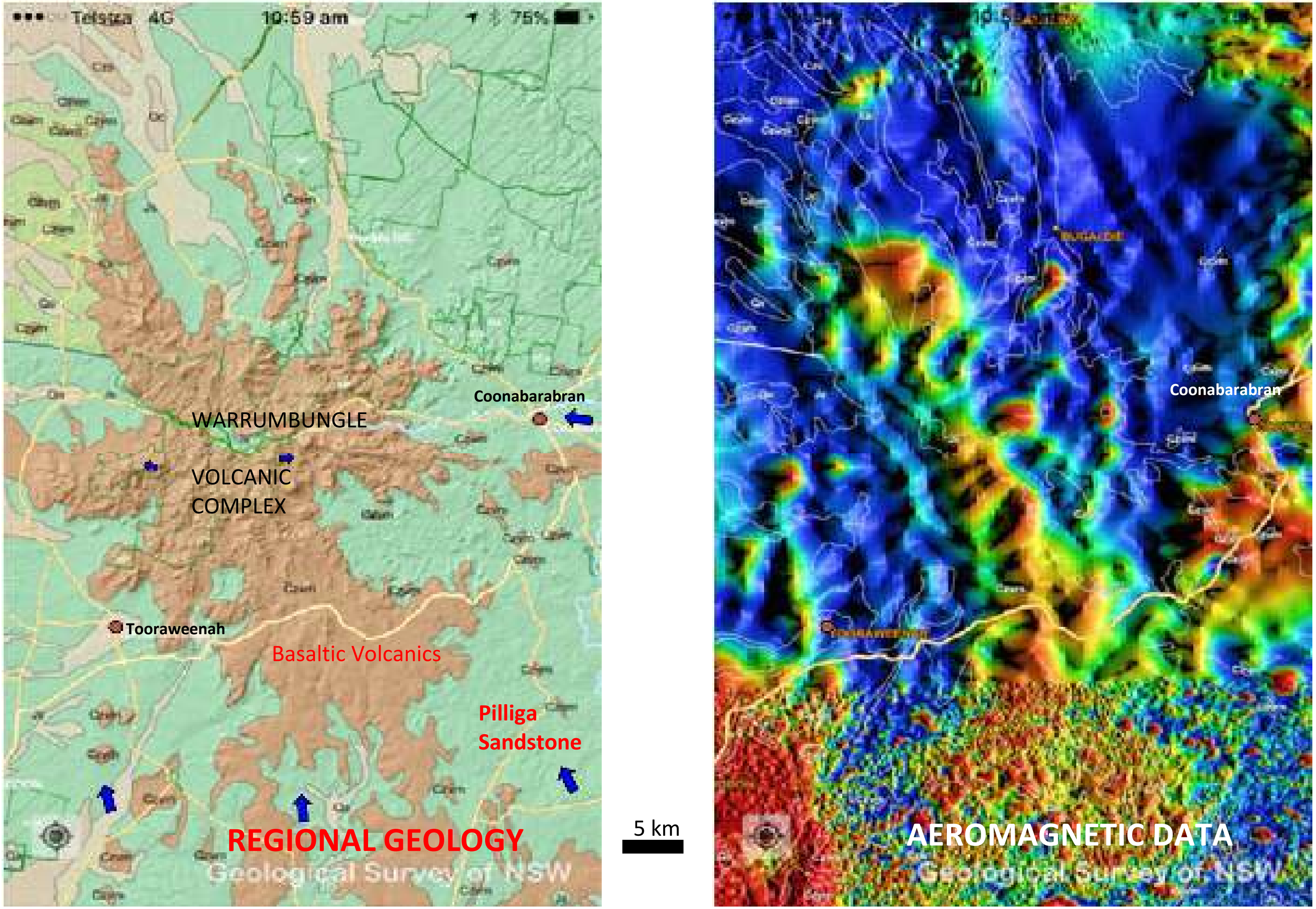
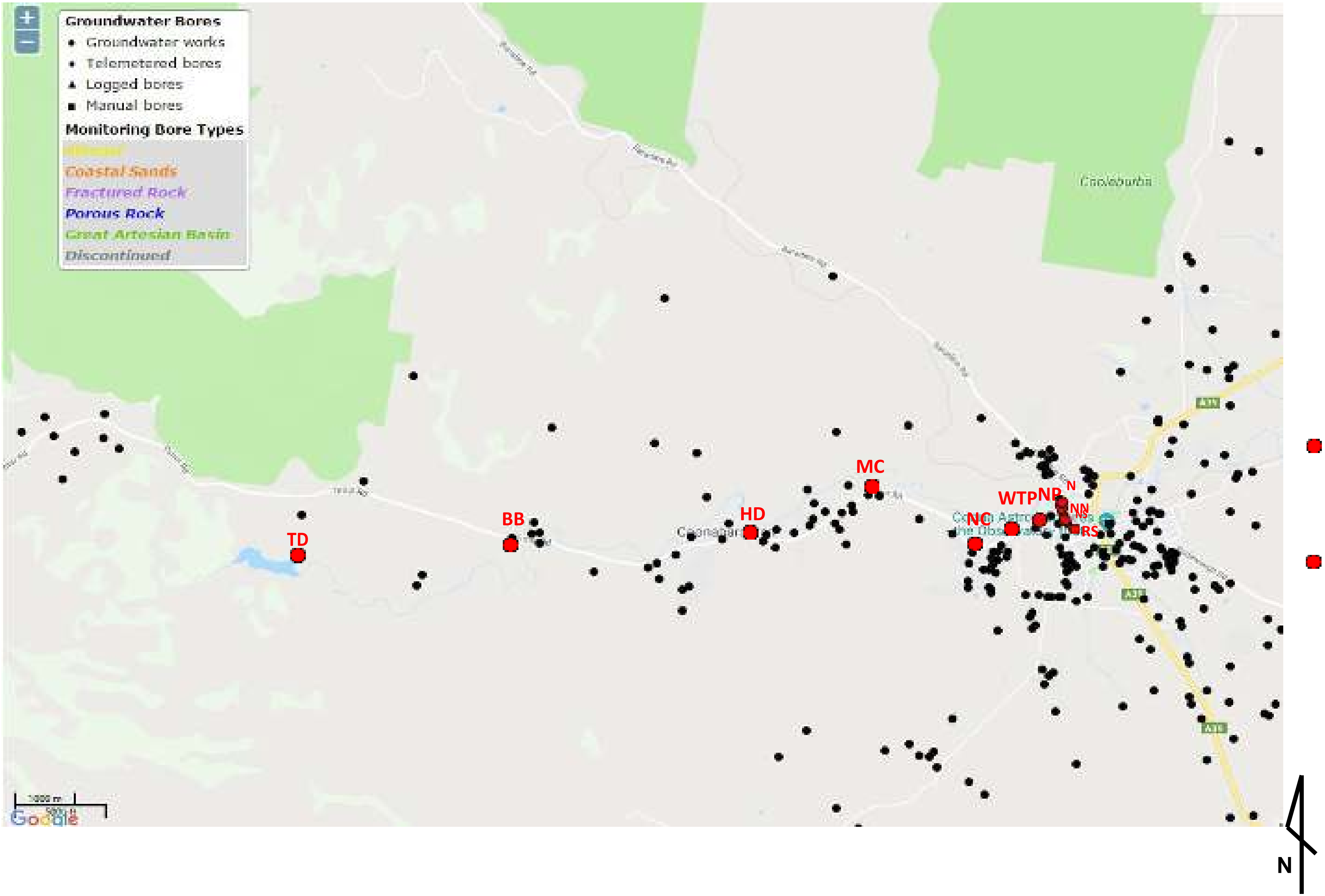
UTM: -	Warrumbungle Shire Council - Timor Road Borefield	Figure: 2
Dec-19		
Drawn: RJL	**Borefield Aerial Plan**	
Approved: RJL		

Hydroilex Pty Ltd www.hydroilex.com.au	UTM: - Dec-19	Warrumbungle Shire Council - Timor Road Borefield	Figure: 3
	Drawn: RJL Approved: RJL	Site Geological Setting	



Predicted groundwater recharge

Hydroilex Pty Ltd www.hydroilex.com.au	UTM: -	Warrumbungle Shire Council - Timor Road Borefield	Figure: 4
	Dec-19		
	Drawn: RJL	Regional Geological Setting & Aeromagnetic Data	
	Approved: RJL		



Hydroilex Pty Ltd www.hydroilex.com.au	UTM: -	**Warrumbungle Shire Council - Timor Road Borefield**	**Figure: 5**
	Dec-19		
	Drawn: RJL	**Location of Production Bores in relation to Registered Bores**	
	Approved: RJL		

PLATE 1. STRATIGRAPHIC CORRELATION - TIMOR RD BORES