Town Water Supply Bores

Review of casing condition

Warrumbungle Shire Council

22 May 2023

→ **The Power of Commitment**

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The Power of Commitment

Executive Summary

GHD was engaged by the Warrumbungle Shire Council to undertake a review of the casing condition of five (5 No) production bores operated by the council. The review has been based on the bore construction information, and downhole camera inspections commissioned by the council.

A summary of the findings has been provided in the table below.

Town	Bore local id	Findings and recommendation
Baradine	Baradine Main GW273121	Steel cased bore approaching 15 years in age. The DN200 casing has been pressure cemented. Bore undergoes cleaning (mechanical scrubbing / treatment) and development. Monitoring program implemented.
	Baradine back-up GW025187	Steel cased bore over 50 years in age, with pump house casing cemented. This bore is beyond its serviceable life and should be decommissioned and replaced with an inert cased bore. Subject to Council risk appetite, Council could continue to operate in the short term, whilst bore funding and planning is secured. A monitoring program would need to be implemented.
Bulgardie	Bulgardie GW001969	Bore is approaching 100 years in age and is beyond its serviceable life. This bore should be decommissioned and replaced with an inert cased bore as a high priority.
Kenebri	Kenebri GW007716	Bore is approaching 70 years in age and is beyond its serviceable life. This bore should be decommissioned and replaced with an inert cased bore as a high priority.
Dunedoo	Dunedoo Old GW059164	Short term – Redevelop bore, expose screens and sump, specific capacity test. Long term – Replace with inert casing bore. Attention required on selection of screen aperture sizing.

Additional recommendations have been made regarding monitoring of bore performance, and considerations for future casing condition assessment programs.

This report is subject to, and must be read in conjunction with, the limitations set out in section 1 and the assumptions and qualifications contained throughout the Report.

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Glossary of Terms

Acronym	Description
ATV	Acoustic Televiewer
CCTV	Close circuit television
CCL	Casing Collar Locator
DN	Diameter nominal
GAB	Great Artesian Basin
ID	Inside diameter
OD	Outside diameter
OTV	Optical televiewer
NB	Nominal bore
WSC	Warrumbungle Shire Council

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1. Introduction

GHD Pty Ltd (GHD) was engaged by the Warrumbungle Shire Council (WSC) to undertake a casing condition assessment of five (5 No) town water supply bores servicing various towns within the Council's operational area.

1.1 Purpose of this report

The objective of this report is to interpret the downhole condition of five production bores based upon CCTV inspection survey information provided by WSC.

1.2 Limitations

This report: has been prepared by GHD for Warrumbungle Shire Council and may only be used and relied on by Warrumbungle Shire Council for the purpose agreed between GHD and Warrumbungle Shire Council as set out in section 1.3 of this report.

GHD otherwise disclaims responsibility to any person other than Warrumbungle Shire Council arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

Accessibility of documents

If this report is required to be accessible in any other format, this can be provided by GHD upon request and at an additional cost if necessary.

GHD has prepared this report on the basis of information provided by Warrumbungle Shire Council and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

1.3 Scope

GHD's scope of works was documented in correspondence to WSC (dated 17th May 2023). The scope included the review of five bore CCTV surveys and providing a hydrogeological assessment of the bore's casing condition. GHD were also to make recommendations regarding appropriate actions to be undertaken with each of the bores subject to the study.

The bores subject to the study are summarised in Table 1.

Table 1 Bores to be assessed

Town	Bore local id	NSW Water ID
Baradine	Baradine back-up	GW025187
	Baradine Main	GW025187
Bulgardie	Bulgardie	GW001969
Kenebri	Kenebri	GW007716
Dunedoo	Dunedoo Old	GW059164

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1.4 Assumptions

GHD has assumed that the bore identifications reported by ASC Equip (2022a-e) are accurate. It is noted that the construction information documented on the WaterNSW data corresponds closely with the survey records / observations made by ASC Equip.

In completing the condition assessment, GHD has not undertaken a review of production bore performance information such as flow rate, drawdown, and water quality, e.g. physico-chemical quality of the discharge (turbidity, chemistry, suspended solids). Changes in these monitored parameters over time can provide further understanding of bore condition.

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2. Baradine Main Bore

2.1 Bore construction

A summary of the bore construction is provided in Table 2, which indicates that the steel cased bore was installed in the late 2000s to a depth of 216 m. WaterNSW records report a yield of 20 L/s. The DN200 pump house casing was pressure cemented over 190 m, which is surprisingly close to the production zone at 190.5 m, i.e. a risk of contaminating the production zone with cement. A DN150 casing was telescoped below this, with two slotted intervals. The top of the J-latch was set at 181.3 m.

Table 2 Baradine Main production bore summary

Element	Value	
Bore ID	GW273121	
Easting (Zone 55)	697,431	
Northing	6,573,506	
Date completed	19/9/2009	
Total Depth	216 m	
Casing From	0	
Casing To	190 m (pressure cemented)	
Casing Diameter	219 mm (8")	
Casing Type	Steel	
Screen From	190.5	198
Screen To	192	216
Screen Diameter	168 mm OD	
Screen Type	Plasma cut steel (4 mm aperture)	

Notes: N/A – Not available.

2.2 Lithology

The lithology intersected by the production bore is summarised in Table 3. The Narrabri 1:250,000 scale geological map indicates the bore develops the Mesozoic (Jurassic age) Pillaga Sandstone, i.e. Great Artesian Basin (GAB) sediments.

Table 3 Baradine Main production bore lithology

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material
0.0	2.0	2.0	Clay	Clay
2.0	7.0	5.0	Gravel, sandy	Gravel
7.0	12.0	5.0	Sandstone, claybound, white	Sandstone
12.0	17.5	5.5	Sand & Stone	Sand
17.5	24.0	6.5	Sand & Gravel	Sand
24.0	34.0	10.0	Sandstone, yellow	Sandstone
34.0	42.0	8.0	Sandstone	Sandstone
42.0	47.0	5.0	Ironstone	Ironstone

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From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material
47.0	191.5	144.5	Sandstone, white & small Shale bands	Sandstone
191.5	192.0	0.5	Sandstone, fractured	Sandstone
192.0	216.0	24.0	Sandstone	Unknown

2.3 Survey findings

2.3.1 Previous works

The bore was surveyed by ASC Equip (2022a) which reported:

- Headworks were of poor design with respect to sanitary conditions
- Pump depth set at 60 m
- Standing water level of 31 m (similar to when bore originally drilled)
- High turbidity in the water column and iron related bacteria fouling
- Foreign object at 187 m and the J-latch / area of casing reduction at 181.3 m
- The survey could access the majority of the bore, reaching a depth of 215 m, i.e. 1 m above construction depth.
- Large holes in casing at 188 m and at 208.3 m

2.3.2 CCTV review

Some selected imagery from the CCTV inspection is provided in Figure 1. Other observations:

- High surface roughness in the splash zone of the bore, i.e. when water levels are drawn down through pumping. The drawdown in the bore is unknown and therefore an understanding of the splashing is not known.
- Much of the interior surface of the casing from 35 m and below has relatively smooth appearance, with occasional areas of scale or encrustation
- In some areas picture quality was high, e.g. casing labels were visible
- Abundant suspended particles – possibly iron bacteria
- Foreign object at 187 m which resembles a short length of pipe (1” to 2” PVC or galvanised iron pipe possibly used during development?) extends to the base of the bore i.e. ~29 m in length.

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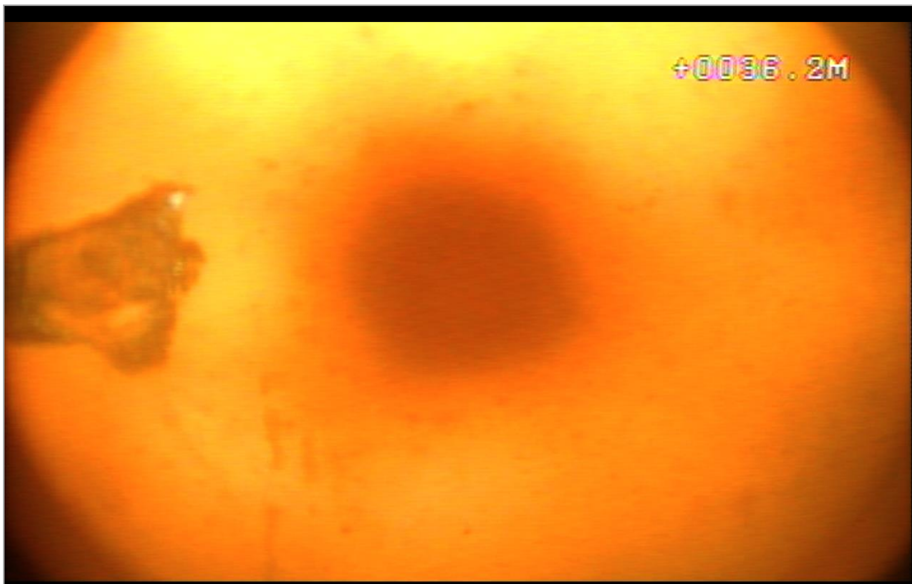	Poor picture quality below the water. Occasion scaling otherwise interior surface condition of casing is relatively smooth.
	Example of a casing joint and relatively high quality imaging. Note suspended particles.
	J-Latch has been partly damaged, likely through passage of drilling rods through this zone.

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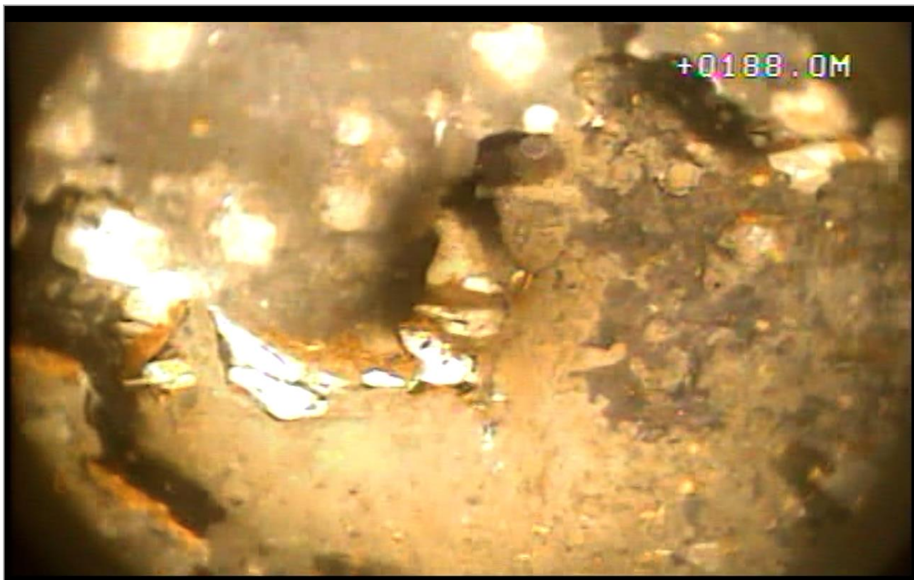	Appears that casing at 188 m has been corroded through. This is part of the section telescoped inside the pressure cemented pumphouse casing.
	Plasma cut vertical slots. Note 'foreign pipe' still present.
	Slot apertures at greater depth are in reasonable condition.

Figure 1 Selected imagery – Baradine Main production bore

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2.4 Discussion

ASC Equip recommended that the bore be cleaned to its base, i.e. expose the full area of the screen, and it be resleeved using a swaged reline. GHD does not support this recommendation and justification is provided later in this section.

The bore construction incorporates pressure cementing to 190 m which provides:

- Some additional protection where there is saline shallow aquifers or aggressive geological materials (e.g. coals, pyrites)
- Collapse resistance where there is high metal loss
- An effective annular seal for environment purposes, e.g. inter-aquifer flow / artesian conditions.

The casing does appear to be partly compromised in the area of cross-over, where the DN150 production casing has been suspended inside of the pressure cemented DN200 casing. However, this will not significantly effect the short term operation of the production bore. Consider that the Baradine Back-Up bore is 40 years older and still operational (albeit in a poorer condition).

The top of the j-latch appears to be partially bent, however, there appears to be sufficient clearance through this zone. Furthermore, approximately 30 m of pipe has been lost down the hole. Care will need to be exercised when drilling contractors enter this area of the bore, or with future inspection works.

The sump has been infilled with 1 m of sediment in the 10 years since its construction which implies it is not getting significant ingress of fine materials.

Unless there has been a deterioration in the bore performance (flow rate / drawdown and physico-chemical) which are other indicators of potential casing issues, the recommended approach for this bore is:

- Decontaminate / pressure wash drilling / work-over plant mobilised to the site
- Mechanical scrub / brush the bore with nylon mandrels
- Air-lift development
- Apply chemical treatment and disinfection
- Air-lift development
- Undertake a specific capacity test
- Implement monitoring program to assess future maintenance actions

The size of the ‘foreign object’ pipe would suggest that it is not restricting flow from the bore. An attempt could be made to fish the pipe from the bore, however, the cost implications would need to be discussed with a drilling contractor, i.e. it could be 1 to 2 days of work-over operations with limited success.

In terms of casing resleeve:

- The existing DN200 and DN150 casing, whilst scaled, is considered to be in a reasonable condition based upon the CCTV survey. Re-survey should be scheduled in 5 years to 10 years, the timing subject to an on-going monitoring program of the bore’s performance.
- On the assumption that Council wish to maximise production from the borehole and maintain a yield of 20 L/s (assumed from construction records), resleeve of the DN200 casing would see a reduction in size to DN150 or smaller. This would unlikely to provide sufficient clearance of the installation of a submersible pump with sufficient capacity.
- An attempt could be made to pull the DN150 and reinstall with a stainless steel screen assembly (slotted stainless). However, the current condition of the DN150 screen would suggest that this would not be required for some time.

The pump depth is located at 60 m and well above the screen interval (below 190 m). GHD considers that there is no practicable reason based on the data provided for installing a shroud on the pump.

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3. Baradine Back-Up Bore

3.1 Bore construction

A summary of the bore construction is provided in Table 4, which indicates that the steel cased bore was installed in the 1968 to a depth of 221 m. A 200NB casing was pressure cemented to 97 m, and the 150 NB casing telescoped to 221 m (landed top of J-latch at 95.8 m). The 150 NB casing was slotted with 3.1 mm apertures. WaterNSW records report a yield of 20 L/s with a standing water level (at completion) of 28 m.

Table 4 Baradine Back-up production bore summary

Element	Value
Bore ID	GW025187
Easting (Zone 55)	697025
Northing	6574748
Date completed	1/7/1968
Total Depth	221
Casing From	0
Casing To	97.1 m (pressure cemented)
Casing Diameter	203 mm OD (8")
Screen From	97.5
Screen To	220.9
Screen Diameter	152 mm OD (6")
Screen Type	Slotted

Notes: N/A – Not available.

3.2 Lithology

The lithology intersected by the production bore is summarised in Table 7. The Narrabri 1:250,000 scale geological map indicates the bore develops the Mesozoic (Jurassic age) Pillaga Sandstone, i.e. Great Artesian Basin sediments.

Table 5 Baradine Back-up production bore lithology

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material
0.00	33.5	33.5	Conglomerate Nominal	Conglomerate
33.5	102.1	68.6	Sandstone Nominal Water Supply, and sand, rock, hard bands, water supply	Sandstone
102.1	211.8	109.7	Shale Grey Nominal Water Supply, Sandstone Sand Rock, Hard Bands	Shale
211.8	220.98	9.15	Sandstone Water Supply	Sandstone

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3.3 Survey findings

3.3.1 Previous works

The bore was surveyed by ASC Equip (2022b) which reported:

– Top of the 150 NB casing at 93.5 m, i.e. ~2 m higher than records
– Casing wall thickness of 10 mm (183 mm ID on the 200 NB pumphouse casing). Standard wall thickness is 8.2 mm for DN200 but sch60 can be 10.3 mm wall thickness. If the measurements are accurate it is beneficial to the bore longevity has the heavier casing grade provides for corrosion losses.
– Survey could only access to 206.6 m, with 14 m of debris in base of bore.
– Standing water level of 30 m
– Pump depth of around 60 m
– Significant biofouling / turbidity (assumed to be iron related bacteria)
– Numerous areas where corrosion had penetrated through the bore casing wall, e.g. 54.7 m, 86.8 m, and parting of joints, indicating casing has reached the end of its useful lifespan. Gravel ingress in bore from slot at 128.3 m.
– High turbidity and suspended particles in the bore
– Telescoped casing inside diameter reported as 140 mm (Bore Details) and 133 mm (inspection notes). Typical size of DN150 is 7.1 mm wall thickness, i.e. 168 mm OD – 14.2 = 153.8 mm. Caliper survey not completed and therefore no confirmation of casing diameter.

3.3.2 CCTV review

Some selected imagery from the CCTV inspection is provided in Figure 2. Other observations:

– High surface roughness in the splash zone of the bore, i.e. when water levels are drawn down through pumping. The drawdown in the bore is unknown and therefore an understanding of the splashing is not known.
– Cable ties were on the water table. These may have been dropped into the bore during pump installation and retrieval.
– Abundant suspended material in water and poor picture quality directly below water level / splash zone.
– Some areas of deep pitting / roughness e.g. 54 m, 80 m to 90 m
– Many of the slots have been enlarged
– Many areas of the DN150 with scaling and pitting

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	Image showing threaded casing. Based on construction records, the upper 90 m has been pressure cemented.
	Very large crusts where casing at the J-Latch / build-up of debris / or top of flared entry has been damaged. Abundant turbidity / suspended sediment in bore below j-latch. Slots appear at 95 m
	Some slots have enlarged over time, with rock visible outside the casing, and rock debris in the slots.

Figure 2 ***Selected imagery – Baradine Back-up production bore***

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3.4 Discussion

ASC Equip (2022b) recommended that the bore be cleaned to its base, i.e. expose the full area of the screen, and it be resleeved using a swaged reline. GHD does not support this recommendation.

The Baradine back-up bore is a 55 year old steel cased bore which is beyond its service life. It is not known how often the bore is operated by the Council or its significance to the town water supply system and this predicates the discussion on the management actions for the production bore below.

It is suspected that the bore has remained open and operational because:

– The bore develops the Pillaga Sandstone, a relatively competent sandstone, which may not be exhibiting a significant collapsing force on the fragile casing (which is likely to offer reduced collapse resistance owing to metal loss).
– ACS Equip (2022b) reported a pump depth of 60 m, which lies within the DN200 casing which is understood to have been pressure cemented. This affords some further protection in the upper part of the bore for the commissioned pump.

This bore should be decommissioned and replaced with an inert cased bore to provide long term security of supply to Barradine township. However, there may be an opportunity for Council to defer the replacement, subject to their risk appetite, i.e. continue to operate the bore and monitor its performance for possible signs of failure. This may provide time for Council to plan and budget for its replacement.

If Council were to consider this approach:

– Baradine Main bore should have undergone its cleaning and redevelopment i.e. confirm that this asset remains a secure supply, and monitoring program implemented.
– There is a risk that the rigors of cleaning and redeveloping the back-up bore catalyse casing collapse. Such bore rehabilitation processes will not extend the bore life, but may restore bore flow rates or reduce pumping issues (if the bore has been experiencing such) or if there has been a gradual decline over time. If the flow rates are currently satisfactory for Council supply requirement, then intervention could be avoided or minimised.
– A monitoring program should be implemented that monitors flow rates, drawdown and water quality. Deviations in the behaviour of the bore may be indicators that the bore has had a casing failure or partial collapse. Care in the operation of the bore, e.g. minimise sudden reductions in the head, can also protect the bore.
– As the metal loss increases, e.g. apertures in the DN150 casing increase, or casing joints fail, sandstone materials may fret and fall into the bore. With further loss of screen as the lower parts of the DN150 become infilled with sediment or collapse, the flow rate in the bore will decline. Additionally, if the sandstone frets, fine grained materials may be aggressive on pump impellors, or emerge in above ground infrastructure (e.g. accumulating in valving or tanks) which may require increased swabbing or scouring etc. These indicators would be the objective of the monitoring program.

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4. Bugaldie

4.1 Bore construction

A summary of the bore construction is provided in Table 10, which indicates that it is a very old steel cased bore. WaterNSW records report a standing water level around 79 m and yield of 0.6 L/s.

Table 6 Bulgardi production bore summary

Element	Value
Bore ID	GW001969
Easting (Zone 55)	701394
Northing	6555292
Date completed	1/2/1927
Total Depth	91.70
Casing From	0
Casing To	81.3
Casing Diameter	152
Casing Type	Steel
Screen From	Open hole
Screen To	91.7

Notes: N/A – Not available.

4.2 Lithology

The lithology intersected by the production bore is summarised in Table 7. The Gilgandra geological map indicates a thin veneer of alluvial sediments, along the alignment of the present day Macullaghs Creek, overlying Jurassic age sandstones (Pillaga Formation). The lithological log indicates the alluvial sediments are very thin.

Table 7 Bugaldie production bore lithology

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material
0.00	0.9	0.9	Soil Black	Soil
0.9	4.9	3.97	Clay Red	Clay
4.9	37.5	32.6	Sand Rock	Sandstone
37.5	39.0	1.5	Boulders Hard	Boulders
39.0	45.1	6.1	Rock Hard	Rock
45.1	48.8	3.7	Sandstone	Sandstone
48.8	52.4	3.7	Sandstone	Sandstone
52.4	54.5	2.1	Rock Hard	Rock
54.5	64.0	9.45	Sand Rock	Sandstone
64.0	67.7	3.7	Sand Rock	Sandstone
67.7	77.7	10.0	Sand Rock	Sandstone
77.7	89.9	12.2	Rock	Rock

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From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material
89.92	91.14	1.22	Sand Water Supply	Sand
91.14	91.74	0.60	Rock	Rock

4.3 Survey findings

4.3.1 Previous works

ACS Equip (2022c) report:

- The bore is cased to 83.5 m, and open hole to a depth of 97.6 m. This depth is greater than the depth recorded at bore completion.
- SWL of 74.4 m
- Pump depth of 90 m which is outside of the casing depth. This presents a significant risk of the pump being jammed in the bore should the rock fret or dislodge from the open hole.
- Casing diameters of 170 mm OD / 160 mm ID. Based on standard steel casing sizes, 170 mm is likely to correspond to a 168.3 mm (DN150 / 6" OD). This usually is supplied in 3.4 mm or 7.1 mm wall thickness.
- Assessment problematic below the water table owing to poor visibility / picture quality.
- Electrical power cable to submersible pump in poor condition

4.3.2 CCTV review

This bore is over 90 years old with a very deep water table, and therefore it is not unexpected that the upper 70 m or more are in a poor condition, i.e. the merit in undertaking an inspection could have been considered questionable. Interior surface had considerable roughness and scaling. However, it is noted that the bore develops a relatively competent sandstone and therefore the casing is arguably present to ensure that production pumps can be safely installed and retrieved from the borehole. However, installing the pump at a depth outside of this casing removes this protection.

Some selected imagery from the CCTV inspection is provided in Figure 3. Visibility below the water table was poor, particularly within the open hole section of the bore casing.

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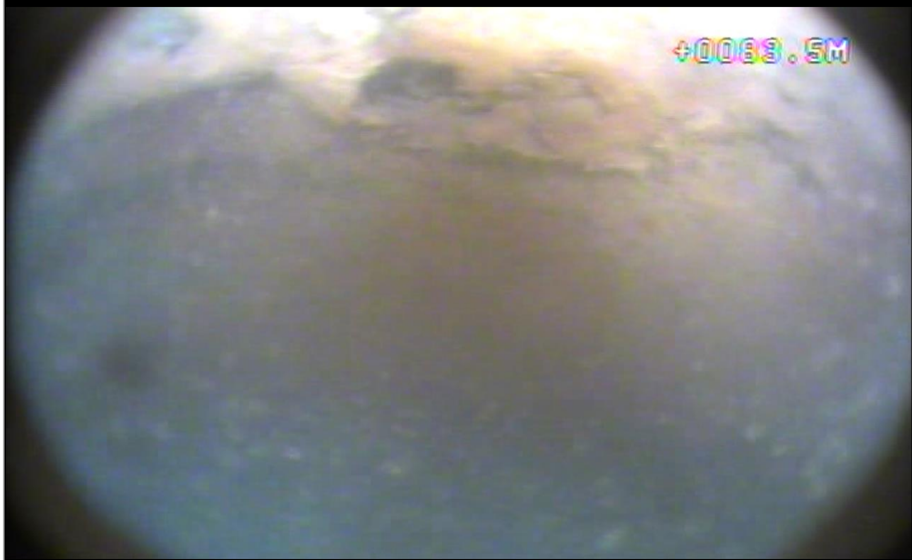
	Discoloured scaling on surface of casing. Poor visibility below water table.
	Bottom of the steel casing
	Example of image quality in the open hole section of the borehole.

Figure 3 ***Selected imagery – Bugaldie production bore***

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4.4 Discussion

This bore develops a porous rock / consolidated sedimentary aquifer system which has a very large unsaturated zone, i.e. deep groundwater levels. The bore is approaching 100 years in age, which is beyond the service life of a steel cased bore.

ASC Equip (2022c) have identified holes in the casing which could lead to a risk of gravel / sand intrusion into the borehole or catastrophic bore collapse. They have recommended the bore be resleeved. In consolidated rock the risk of sands and gravels entering the bore through holes could occur if fretting occurs overtime, however, the rock must be reasonably competent given that it has remained open since construction.

We believe there are two options for this bore, which would be dependant upon the risk appetite of the drilling contractor:

- Re-sleeve with Class 12 DN100 PVC and machine slotted PVC screen.
  This would require running into the existing hole, and landing the PVC with rubber liner flairs. The DN100 provides a 101 mm ID and 115 mm OD i.e. approximate 25 mm annular clearance. This would be a tight fit, and would reduce the available diameter of the production bore and thus the size of submersible pump that could be equipped in the bore. The reporting yield of the bore (0.6 L/s) is achievable using a 4” submersible, however, smaller diameters can compromise installation ease.
- Drill a replacement bore and construct with Class 12 DN150 PVC and machine slotted screen. This provides an opportunity to increase the bore depth to potentially obtain additional bore yield. If the bore depth was extended beyond 120 m, design checks would need to be made regarding the collapse resistance. A Class 18 PVC could be used, however, this may necessitate a larger hole depending upon flow rates (as the wall thickness increases and internal diameter decreases with increased collapse resistance).

Most drilling contractors would prefer to drill a replacement bore as this minimises the construction risk of entering aged steel casing which could be fragile, and potentially unable to withstand the rigors of heavy drilling plant. Another key benefit of drilling a new bore is that it would enable appropriate surface seals to be installed to protect the production aquifer from surface infiltration. Hence it is GHD’s recommended approach.

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5. Dunedoo

5.1 Bore construction

A summary of the bore construction of the Dunedoo Old bore is provided in Table 8, which indicates that it is a very steel cased bore developing sediments to a depth of 38 m. WaterNSW records report a standing water level around 8.6 m and yield of 29 L/s.

Table 8 Dunedoo production bore summary

Element	Value
Bore ID	GW059164
Easting (Zone 55)	725,608
Northing	6,455,743
Date completed	1/12/1983
Total Depth	Drilled to 50 m, constructed to 38 m
Casing From	0
Casing To	31
Casing Diameter	N/A
Casing Type	342
Screen From	31
Screen To	36
Screen Diameter	275
Screen Type	N/A

Notes: N/A – Not available.

Interestingly there is no evidence of a seal being incorporated in the bore design, with rounded gravels backfilled from 0 m to 38 m. This represents a significant sanitary risk to the water supply as surface run-off / land use activities could potentially result in contaminants infiltrating the production zone. Furthermore the WaterNSW records do not record a casing or screen material. The outside diameter (OD) of the casing is reported as 342 mm, which is in between standard steel sizes of DN300 (323.9 mm / 12”) and DN350 (355.6 mm / 14”). No calliper survey was completed to confirm this.

5.2 Lithology

The lithology intersected by the production bore is summarised in Table 9 and principally comprises unconsolidated sediments. The log intersects a shale at 50 m which likely indicates that the bore fully penetrates the alluvial sequence. Based upon the Dubbo 1:250,000 mapsheet these shales may be Palaeozoic (Ordovician). The alluvials appear to be very fine grained over the upper 30 m, with sand beds (production zone) intersected between 30 m to 36 m, with the coarsest, cleanest sands between 32 m and 36 m.

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Table 9 Dunedoo production bore lithology

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material
0.0	1.0	1.0	Driller	(Unknown)
1.0	4.0	3.0	Clay Red	Clay
4.0	13.0	9.0	Clay Grey	Clay
13.0	14.0	1.0	Clay Grey Some Fine Sand	Clay
14.0	18.0	4.0	Clay Grey Some Coarse Sand	Clay
18.0	21.0	3.0	Clay Orange	Clay
21.0	26.0	5.0	Clay Orange Some Fine Sand	Clay
26.0	29.0	3.0	Clay Yellow	Clay
29.0	30.0	1.0	Clay Yellow, Sand White Medium	Clay
30.0	32.0	2.0	Sand White Medium Water Supply, some Clay	Sand
32.0	36.0	4.0	Sand White Medium Clean Water Supply	Sand
36.0	37.0	1.0	Clay White Sandy	Clay
37.0	38.0	1.0	Clay White, Sand Yellow	Clay
38.0	39.0	1.0	Sand Yellow Medium, Clay Yellow	Sand
39.0	45.0	6.0	Clay White	Clay
45.0	48.0	3.0	Clay White, Sand Bands	Clay
48.0	50.0	2.0	Clay Yellow Sandy	Clay
50.0	50.01	0.01	Shale	Shale

5.3 Survey findings

5.3.1 Previous works

ACS Equip (2022d) surveyed the bore in early December 2022 and reported:

– Water level around 4.90 m
– The bore was constructed within DN300 mild steel casing with stainless steel screens (1.5 mm aperture).
– The survey could not access below 33.5 m
– It is implied the bore had issues with the ingress of gravel, based on the submersible pump having an attached shroud, which comprises stainless steel screen
– Submersible pump set at 30 m, i.e. intake close to the top of the bore screen
– Significant biofouling, and holes identified within the bore casing

5.3.2 CCTV review

Some selected imagery from the CCTV inspection is provided in Figure 4. As identified by ASC Equip (2022d) the bore has a high surface roughness and obvious precipitants / crusts over much of the bore. The drawdown in the bore is unknown and therefore an understanding of the splashing is not known.

ASC Equip (2022d) have identified a potential parting in the casing, and areas of dark discolouration which were noted as being holes.

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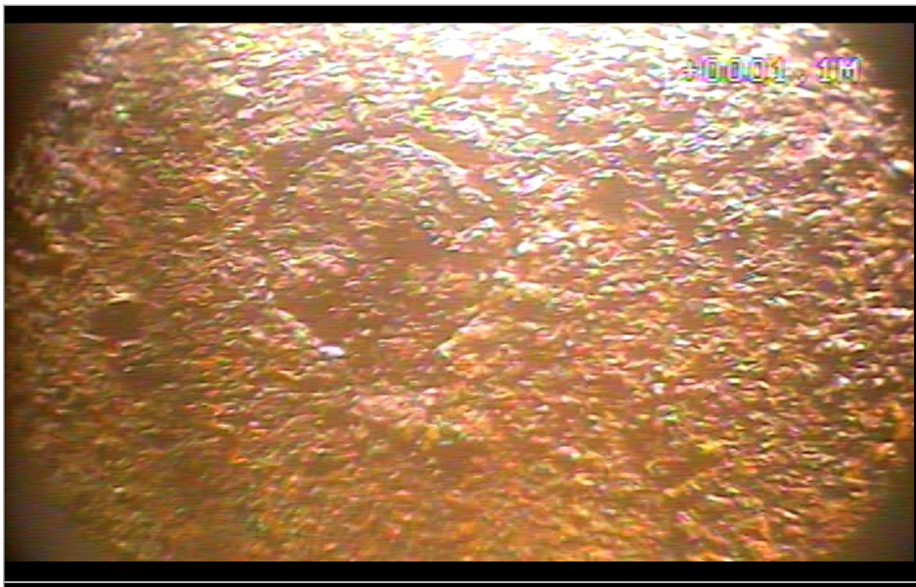
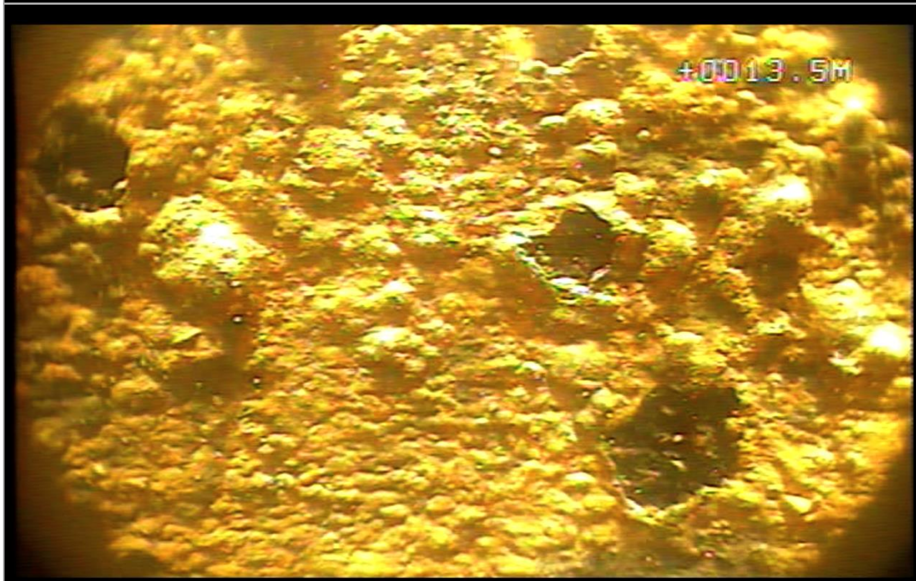
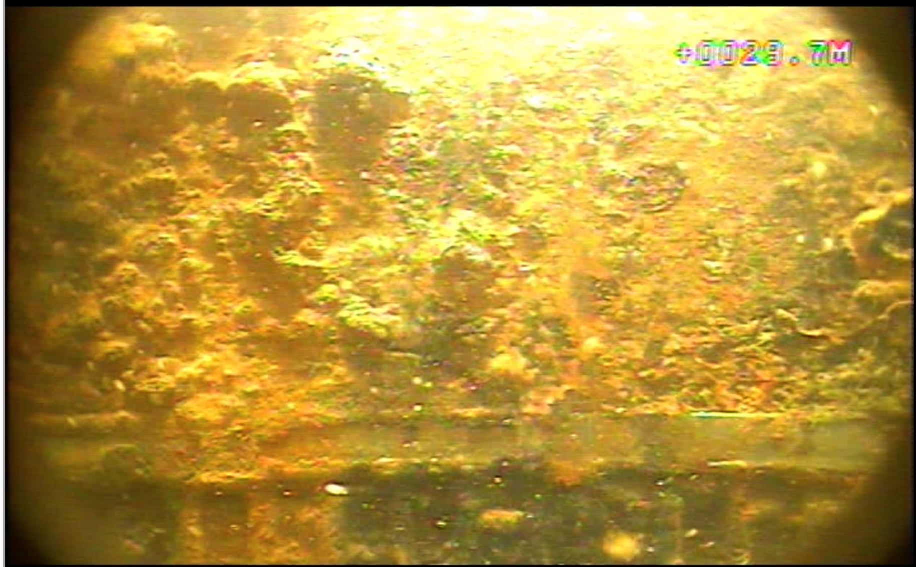
	Such marks were noted at multiple locations in the casing. It is interpreted that these are torch cut holes that were used to elevate the casing into position. The lugs are then hammered back into position and welded. These represent high risk areas for corrosion and ingress of fines into the bore. They result from poor drilling practice – the use of lugs ('dog ears') attached to casing exterior or collars is preferred.
	Casing has considerable crusts formed on the exterior surface. Darker areas could be where the crusts have been knocked by retrieval of the production pump.
	Severe precipitates / crusts forming – high risk area for corrosion (bimetallic) due to welding mild steel casing to stainless steel.

Figure 4 ***Selected imagery – Dunedoo production bore***

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5.4 Discussion

ASC Equip recommended that the bore be cleaned to its base, i.e. expose the full area of the screen, and it be resleeved using a swaged reline. In regards to this resleeve:

- The 315 mm OD and 5 mm wall thickness are unusual sizes from DN300 bore casing. The production pump capacity is not known, but records indicate the bore is capable of 30 L/s. This would require a minimum 8" bore pump and depending upon how this is installed, a DN250 reline (275 mm OD), i.e. approximately 20 mm annular clearance for the resleeve, assuming that the 305 mm ID has been accurately reported by ASC Equip. Tolerances could be increased if the reline was DN200, however, this could result in reduced flow rates. Further reline design would be required.
- The bore is making sediment. This is inferred from:
  - Shroud on the production pump
  - Bore sump (36 m to 38 m) and part of the screen has been blocked by sediment.

  The reline should include a new screen to minimise sediment ingress. It is noted that 2 m of sediment has accumulated in 30 years of operation (assuming no previous bore maintenance has been undertaken).
- The reline / reduction in diameter will reduce the bore efficiency. This is manifest as energy losses, i.e. greater drawdown for the same volume pumped. As the bore pump is positioned above the screen it is assumed that it is already being operated in a manner to maximise the available drawdown.
- The resleeve will not improve the significant sanitary risk that is present with the existing bore construction, i.e. there are no environmental seals in the bore annulus.

At this depth, it would seem far more reasonable (and economically comparable) to construct a replacement bore, using inert casing materials e.g. Class 12 PVC (or the more expensive stainless steel), and continuous slot stainless steel screens. The bore construction should be consistent with NUDLC (2020) guidelines and include formation sampling to accurate size bore screen apertures. Another benefit of the replacement bore drilling is that appropriate annular environmental seals can be incorporated into construction to provide greater wellhead protection and water quality security. Hence, this is GHD's preferred approach to managing the bore.

Whilst the casing condition in parts of the bore are poor, its age relative to some of the other bores documented in this report is much younger, i.e. this bore could perhaps be assigned a lower priority. GHD has not reviewed the production data for the township. If Council is wishing to maximise its production it could consider mobilising a drilling rig to the bore site to complete maintenance activities including:

- Developing the sediment from the bore and exposing the full screen interval and bore sump
- Mechanically brushing the bore to remove encrustations
- Chemical treatment to remove biofouling and scales
- Completing a specific capacity test on the bore (short duration pumping test).

This last activity is recommended for all of Councils assets as it can be used to diagnose fouling issues within a bore. It can be completed using the production pump installed in the bore, and it is recommended that it be repeated every 5 years, or whenever an issue with the pumping performance has been identified. A specific capacity test should be repeatable, and changes in a bore's specific capacity can be evidence of fouling of the screens, and thus a trigger to time maintenance (redevelopment) works.

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6. Kenebri

6.1 Bore construction

A summary of the bore construction is provided in Table 10. WaterNSW records report a standing water level around 25 m and yield of 1.2 L/s.

Table 10 Kenebri production bore summary

Element	Value
Bore ID	GW007716
Easting (Zone 55)	693571 mE
Northing	6592988 mN
Date completed	1/3/1949
Total Depth	47.2 m
Casing From	-0.5 m
Casing To	43.4 m
Casing Diameter	152 mm (6”)
Casing Type	Steel
Screen From	N/A
Screen To	N/A

Notes: N/A – Not available.

6.2 Lithology

The lithology intersected by the production bore is summarised in Table 11 and principally comprises unconsolidated sediments. The Narrabri 1:250,000 scale geological map indicates a thin Cainozoic sequence which overlies sediments of the Great Artesian Basin.

There is no obvious evidence of aggressive materials e.g. peats / ligneous bands, and it is not known whether the bore fully penetrates the alluvial sequence as no evidence of bedrock was reported in the lithological log.

Table 11 Kenebri production bore lithology

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material
0.00	1.5	1.5	Loam Sandy	Loam
1.5	21.3	19.8	Clay Yellow Sandy	Clay
21.3	21.6	0.3	Sand Fine Water Supply	Sand
21.6	42.6	21.0	Clay Yellow Sandy	Clay
42.6	43.5	0.9	Clay Sandy Nodular Water Supply	Clay
43.5	47.2	3.6	Sand Yellow Clay	Sand

6.3 Survey findings

6.3.1 Previous works

ASC Equip (2022e) reported:

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- The bore comprises casing OD of 148 mm and ID of 140 mm (4 mm wall thickness).
- The survey identified slotted casing commencing from 21.0 m
- Standing water level around 17.5 m below surface.
- Pump setting depth of 30 m
- Significant growths and encrustation over slotted apertures
- Casing is threaded
- Large hole at 31.7 m
- The survey could not progress beyond 34.5 m i.e. the bottom 12.7 m is filled with debris (or collapsed).

6.3.2 CCTV review

At over 70 years in age this bore is beyond its service life and expected to be in a poor condition. Water levels are deep (17.5 m) and therefore large proportion of the overall casing is exposed to atmosphere, excluding the splash zone (between the water table and dynamic drawdown level). Selected imagery has been shown in Figure 5.

- Significant, obvious scaling and metal loss in the zone above the water table.
- Image quality below the water table and splash zone was reasonable and the casing interior surface exhibited less rugosity / roughness.
- Slotted sections were difficult to differentiate as in some areas the slots were heavily encrusted.
- Heavily scaled at 23 m, however, no sediment or increased turbidity was noted.
- Duct tape and other debris identified at 34 m.

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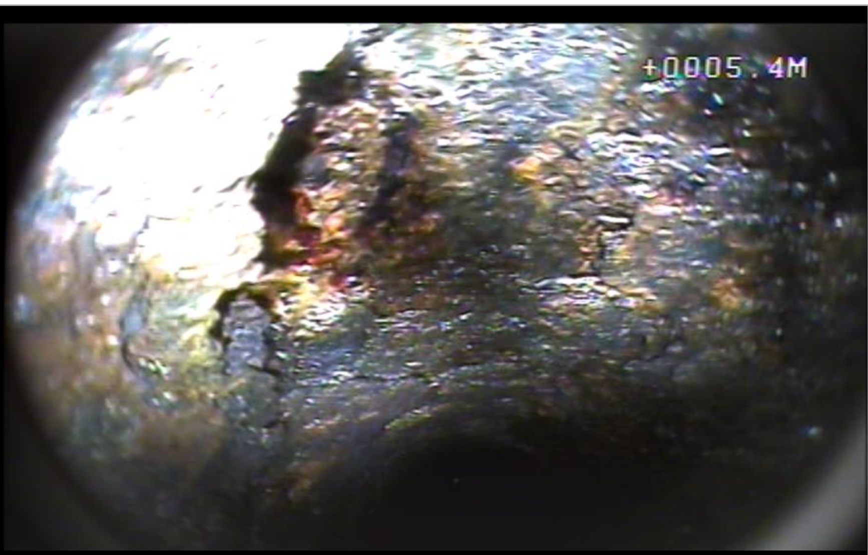	Example of scaling and metal loss in zone above the water table.
	Casing below water table. Image quality was reasonable. Small crusts / precipitates on casing. Note vertical features on left and right hand side may represent slots (or drag marks from pump removal?). Obvious slots (4 x circumferential vertical slots) noted below 21 m.
	Large hole at 31.7 m as identified by ACS Equip (2022e).

Figure 5 ***Selected imagery – Kenebri production bore***

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6.4 Discussion

GHD agrees with the assessment made by ASC Equip (2022d) that the bore is in poor condition and represents a significant risk to Council because:

- Increasing likelihood of additional failure and catastrophic collapse
- Increasing likelihood of the pumping of sedimentary material, resulting in damage to production pumps, and sediment within the tanks and water supply system
- The headworks are insecure from a sanitary perspective

At over 70 years in age, this bore is well beyond its serviceable life.

The recommendation of ASC Equip to resleeve the bore with a stainless steel swage is not supported. Swaging steel in the condition identified is considered to constitute a significant construction risk as the swaging process could result in further bore failure. Furthermore:

- Running drill pipe to clear out the casing to the bottom of the bore could result in further failure given the fragile appearance of the casing in the CCTV.
- Casing resleeves result in a reduction in bore diameter. GHD has not reviewed casing clearances, however, the resleeve is likely to reduce the bore diameter to 100 mm (4”).
- Fitting shrouds (should such even be required) and internal bore clearance become further compromised.
- There is uncertainty over the bore construction and presence of annular seals.

This bore should be decommissioned in accordance with the NUDLC (2022) guidelines and a replacement bore drilled, consistent to the same standard. The replacement bore design should include:

- Inert casing materials, e.g. Class 12 PVC is sufficient for this bore depth
- Continuous slot, wire would stainless steel screen.
  Such screens have a greater open area and with considered bore design, e.g. appropriate sizing of apertures and gravel packing, should result in a more efficient bore, i.e. less drawdown for the same flow. This would necessitate formation sampling and sieve analysis during the drilling program to size screens.
- Bore headworks erected with a concrete slab to support valving, metering and associated equipment e.g. sampling ports, electrical panels.
- Wireline logging, e.g. natural gamma may assist in identifying a screen zone for the bore.
- Pumping test to enable sizing of an appropriate production pump (and determine a specific capacity baseline).

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7. Conclusions

GHD was engaged by the Warrumbungle Shire Council to undertake a review of the casing condition of 5 No town water supply production assets which had been subject to downhole camera inspection.

It is noted that the primary recommendation for each bore was to essentially resleeve the bore which GHD does not support. This is based upon a number of considerations with resleeve designs in general, and their construction activities:

– Available internal diameters. Relines will result in reduced diameter, and can compromise the size of production bores that can fit within the resleeve, i.e. the flows from the bore can be reduced. Thin wall stainless steel can maximise available internal diameters, however, it is an expensive casing material.
– Relines will not fix fundamental flaws in the bore construction, e.g. if the original casing does not have adequate cementing and annular seals, the reline will be as vulnerable to contamination from the surface, or overlying aquifers, as the original bore.
– Swaging requires a competent steel casing to be existent. The pressures generated by swaging can damage fragile bore casing.
– Excessive corrosion can commonly occur where stainless steel casing is attached to mild steel casing. This raises the question of where to swage (attach) the reline, or does the reline need to incorporate a screen assembly too.
– The bore, which has casing that is in poor condition, will need to be redeveloped, possibly mudded up, and subject to several passages of downhole drilling equipment to enable the reline to occur. This can create forces on the casing, particular very old fragile steel casing, that present a risk of collapse during construction activities. Drilling contractors will factor this into the pricing of such work. Under these circumstances, for shallow bores, reline costs can be comparable to bore replacement, e.g. consider cost per metre of stainless steel to PVC.

The other reporting (ASC Equip 2022a-e) has also made a number of other recommendations, some of which are valid, e.g. redevelopment and chemical treatments, and review of bore headworks with respect to sanitary conditions, potential use of flexible rising main, and disinfection. Attaching shrouds to pumps should only be considered where there is a risk of overheating where adequate water cannot pass by the motor. This would seem an unusual recommendation for some of the town bores, e.g. Baradine.

Some of the reporting imagery regarding the bore headworks suggest sanitary risks may be present. However, GHD has insufficient information to make an informed decision regarding the headworks condition.

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8. Recommendations

This report makes the following recommendations:

– Key actions for each bore are summarised in Table 12.

Table 12 Recommendations for town bores

Town	Bore local id	Recommendation
Baradine	Baradine Main	Bore GW273121 undergoes cleaning (mechanical scrubbing / treatment) and development. Monitoring program implemented.
	Baradine back-up	Bore GW025187 Short term – Continue to operate and monitor whilst planning replacement. Mid term – Decommissioned and replaced with an inert cased bore.
Bulgardie	Bulgardie	Bore GW001969 is decommissioned and replaced with an inert cased bore as a high priority.
Kenebri	Kenebri	Bore GW007716 is decommissioned and replaced with an inert cased bore as a high priority.
Dunedoo	Dunedoo Old	Bore GW059164 Short term – Redevelop bore, expose screens and sump, specific capacity test. Long term – Replace with inert casing bore. Attention required on selection of screen aperture sizing.

– Council consider incorporating a program of specific capacity tests on their groundwater production bores. These could be repeated every 5 years to aid diagnosis of potential downhole issues and the timing of future inspections and condition assessments.

– There are a range of treatment chemicals available to rehabilitate production bores. Before any chemical treatments are added to bores, the groundwater chemistry should be reviewed for compatibilities.

– Given the prevalence of iron fouling in a number of the bores, it is recommended that drilling and other downhole equipment is decontaminated between bores.

– Future bore casing inspections consider the use of additional tools such as:

  - Natural gamma log: to aid formation evaluation should redrilling of the bore required
  - Caliper log: to determine the available internal diameter to inform resleeve design
  - Casing Collar Locator (CCL): to aid with resleeve design (for steel cased bores)
  - Optical Televiewer (OTV) and Acoustic Televiewer (ATV) tools: these provide views at right angles to the vertical axis of the borehole, i.e. complete image of the interior of the bore casing. The ATV can be used where water quality is poor such that CCTV and OTV are ineffective. Outputs are less subjective compared to CCTV surveys.

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9. References

ASC Equip, 2022a: *Warrumbungle Shire Council Baradine Back-up Bore Assessment Report*

ASC Equip, 2022b: *Warrumbungle Shire Council Baradine Main Bore Assessment Report*.

ASC Equip, 2022c: *Warrumbungle Shire Council Bulgardie Bore Assessment Report*.

ASC Equip, 2022d: *Warrumbungle Shire Council Kenebri Bore Assessment Report*.

ASC Equip, 2022e: *Warrumbungle Shire Council Dunedoo Old Bore Assessment Report*.

National Uniform Drillers Licencing Committee (NUDLC), 2020: *Minimum Construction Requirements for Water bores in Australia.* 4th Edition

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