THE ART OF DIAGNOSING AN UNHEALTHY TOWN WATER BORE

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ABSTRACT

Australian Drinking Water Standards require that the water sources are tested to meet very strict requirements for drinking water.

But do we test for the health of bores (wells)? When a water bore is drilled into an aquifer and a pump installed, a number of processes come into play.

- The pumping of the water bore lowers the water level in the bore and introduces oxygen into the system favouring aerobic bacteria.
- Even water with low nutrient concentrations in an aquifer, the pumping of water allows bacteria access to more nutrients as the water travels closer to the bore at increased flow rates. This allows bacteria to thrive and grow prolifically, potentially clogging the gravel pack and screen
- If the bore has not been developed fully, with the introduction into the aquifer of natural clay and drilling muds, these clays may not be removed potentially reducing the yield.

To determine the health of a Town's Water Bore, the tools and monitoring techniques can include:

- Measuring the specific capacity, defined as the bore yield per unit of drawdown with time provides a measure of the well performance and may signal when it needs rehabilitation. Evaluation of flow rates and groundwater drawdown are critical for determining how healthy the bore is.
- Biological testing – BART testers provide an indication of the type of bacteria and a semi quantitatively measure of the level of bacteria present in the bore, and gravel pack.
- Inspections of bores by video surveys and cased hole geophysical techniques such as acoustic televiewer and optical imager.

This paper presents techniques for assessing a well's long-term health for town water bores and their rehabilitation.

1.0 INTRODUCTION

In New South Wales over 250 regional towns depend on fully or partially on extracting groundwater from town water bores. NSW Groundwater Strategy 2022 (Ref 1) Of these around 150 rely totally on groundwater for their water source NSW Groundwater Management (Ref 2)

All towns have legal responsibility to ensure that the water supply meets the Australian Drinking Water Guidelines to ensure water supply meets community expectation of a Healthy supply. No specific legal responsibility applies to the Health of the Water Bore.

2.0 DIAGNOSING HEALTH ISSUES WITH A WATER BORE

2.1 Natural Conditions within Aquifer.

Groundwater Aquifers in a natural state have low concentration of nutrients and the dissolved oxygen in water decreases with depth. Bacteria levels are low and tend to be higher in concentration in the more permeable areas of the aquifer.

2.2 Conditions Introduced with the Drilling of a Water Bore

Once a water bore is drilled, prior to development the borehole wall, it is protected from collapsing by a wall cake. This allows the possibility that both natural clays and drill muds will infiltrate the aquifer near the borehole wall.

To extract groundwater the bore needs to be developed to remove the drill mud and fine sand material surrounding the screen area of the water bore.

2.3 Pumping of a Water Bore.

Once the bore is developed and a pump is installed in the bore, then every time a bore pump is started and draws down the water level this leads to introducing a column of air, increasing the exchange capacity between the air and the water column.

An increase in 1 mg/litre of oxygen increases the biofouling and plugging of the bore by about a factor of 10. Neil Mansuy (Ref 3)

2.4 Microbiology of a Water Bore.

A myth to dispel is that Iron Related Bacteria infect wells and that it can be introduced by drilling equipment or bore pumps. A well that experiences Iron bacteria problems is from natural in situ bacteria that thrive on the conditions provided by a bore. In only rare instances can a drill rig or pump introduce bacteria to a water bore. Neil Mansuy (Ref 3)

Iron bacteria are not just located in the bore; they form finger like growths through the gravel pack that might grow 15 cm to a metre in length into the nearby aquifer. This occurs as the water flowing to the well is moving in variable flow paths towards the well.

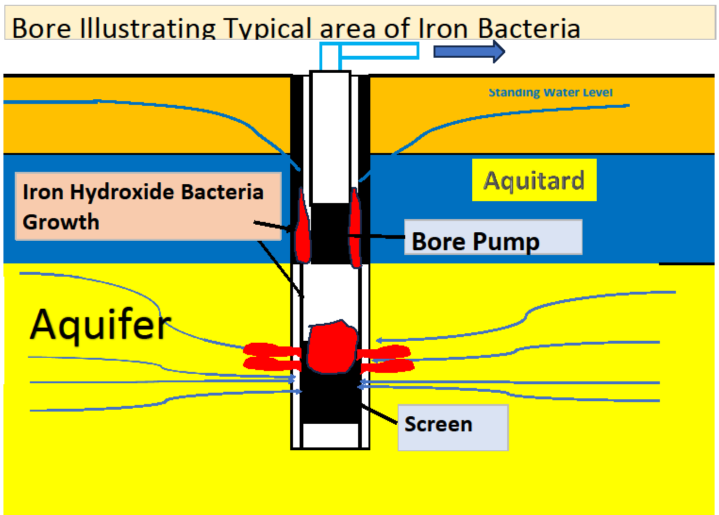

Figure 1 Illustrating Typical areas of Iron bacteria growth around pump and bore screen.

When treating a bore with chemical, it will follow the path of least resistance. If the bacteria have clogged the pathway, then the chemical may not react with all the Iron Bacteria. This is why it is important to have physical agitation in the well to push the chemical out into the aquifer and minimise the limitations where the chemical bypasses the flow pathway. Mansuy (Ref 3) see section 4.0

2.5 Bore Corrosion

Corrosion in a water bore is complex. In fresh water aquifers associated with town water bores the principal cause of corrosion is the oxygen concentration cell. Carbon Steel and Stainless steel both develop a coating once exposed to Oxygen in the bore water. Steel provides a stable coating that electrochemically passifies the surface of casing inhibiting corrosion. With carbon steel this coating is less effective on carbon steel. The corrosion process is initiated when a bacteria growth shield's a small area like a grain of sand or a biofilm patch. Smith (3). These growths can prevent oxygen accessing below them allowing Sulfate Reducing Bacteria to cause the process of corrosion pitting on the bore casing.

In fresh water wells the problems of dissimilar metals causing corrosion is more likely to occur at welds such as when a mild steel casing has been welded to a stainless steel screen. The corrosion only occurs a few millimetres in length from the weld. Figure 2

Figure 2 Corrosion at dissimilar metals mild steel casing and stainless steel screen welded.

3.0 Well Performance Indicators

3.1 Hydraulic Monitoring Bore and Pump Performance Specific Capacity

Specific capacity is defined by unit flow rate divided by unit drop in water level during pumping. Typically, units used are litres per second per metre of drawdown. It is good practice at least twice per year to measure the drawdown and yield of the bore and compare with previous readings. An indicator that the bore yield is impacted when the specific capacity reduces by 15% for a given previous standing water level.

In the example case Figure 4 it at the eleventh year it would be wise to program removing the pump and undertaking an inspection on the bore and plan a chemical/mechanical treatment.

3.2 Biological Monitoring of a Water Bore

Biological monitoring is useful to tell if bacteria are present, what type of bacteria and biofouling may be occurring and is the amount of biofouling increasing with time?

A cost effective method that can provide the above answers is a culturing media Biological Activity Reaction Test (BART) prepared by Droycon Bio-concepts in Canada. (Ref 5)

Barts can be sourced that measure Iron Bacteria (IRB) Aerobic Bacteria and Slyme Bacteria SLYM. Figure 5.

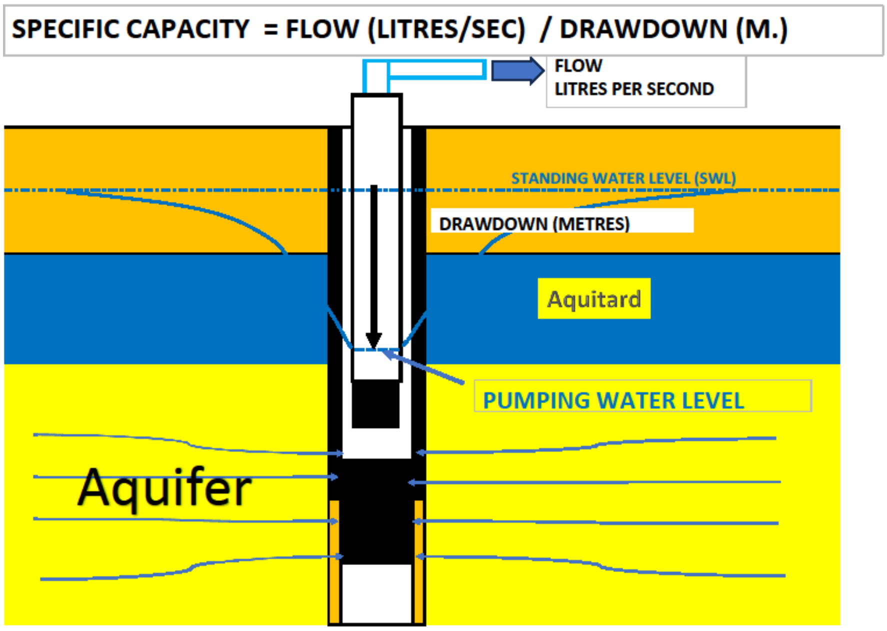

Figure 3 Demonstrating Specific Capacity is Flow rate divided by unit of drawdown

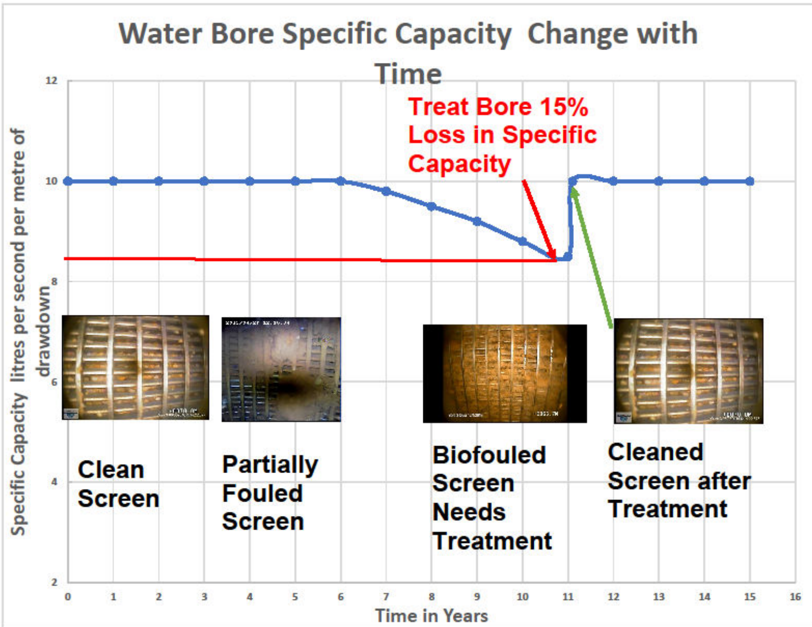

Figure 4 illustrating the specific capacity of a bore being impacted by biofouling with time.

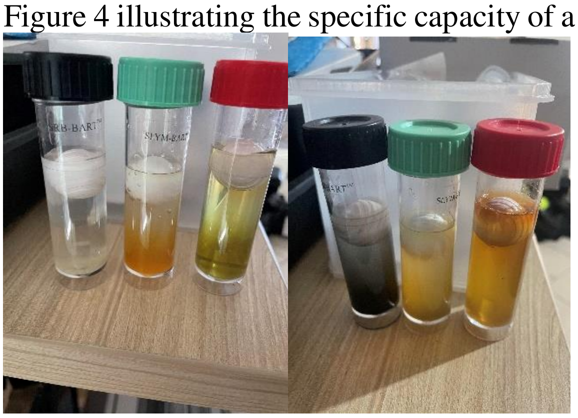

Figure 5 showing BART Kit after day 1 on the left and Day 8 on the right of a water bore. After Day 8 photo on the right reaction to Sulphate Reducing Bacteria SRB (Black Lid) and Iron Bacteria IRB (Red lid) are apparent in this bore.

Samples can be taken of the water a few minutes after starting a pump and then sample and fill the tube with bore water. They are then monitored for eight days to see what reaction occurs. If a reaction occurs in the first day or two, then the bore is likely to be badly fouled. If it reacts closer to eight days then this indicates bacteria are present but at lower levels.

3.3 Chemical monitoring over time.

Monitoring over time the chemistry of a water bore can indicate conditions are changing.

A minimum water chemistry of soluble Fe^{2+}. Total Fe, Total Mn, Sulphur Dioxide-, pH, Oxidation Reduction Potential (Eh) and temperature. If chemistry conditions change, this can be an indication that biofouling or incrustation may be occurring in the bore.

3.4 Bore casing condition assessment

3.4.1 Video bore camera inspections are quite common and useful for determining potential biofouling inside a water bore and any obvious defects are occurring. Video camera is not as useful in corrosion studies of bore casing, compared to the acoustic televiewer. Superficial corrosion can be misleading as to how much metal loss has occurred in that location. Often the visibility of the water is low and other more sophisticated Geophysical tools can be used to determine bore casing condition. These include:

3.4.2 Acoustic Televiewer

The Acoustic Televiewer has a number of advantages. It can find casing defects in turbid water including biofouling, holes in casing, corrosion and it can provide a measure of apparent metal thickness of the casing. It can more clearly define holes in casing due to corrosion then a colour video camera can. See Figure 6.

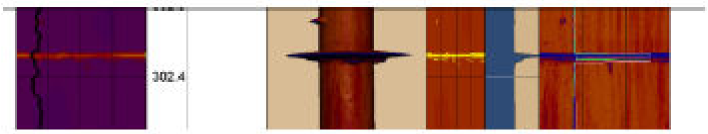

Figure 6 Acoustic televiewer yellow streak is corrosion at casing join confirmed by video

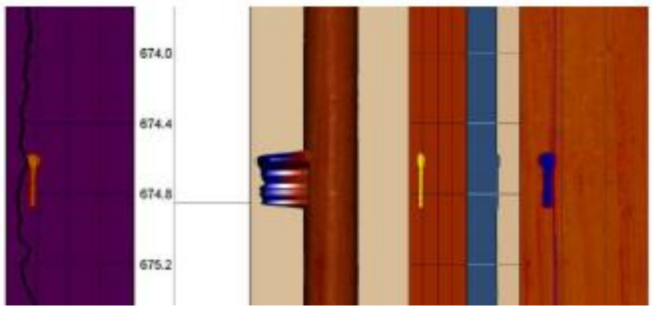

Figure 7 Acoustic televiewer image of slotted casing at 675 metres Moree Bore Baths bore

3.4.3 Optical Imager

The optical imager provides a two-dimensional image of a bore scanning the bore as it travels down the bore. The optical imager does not see through turbid silty water. It is useful to identify visual features for the whole bore on one image at convenient scales.

4.0 Rehabilitation Techniques

Eighty percent of biofouling of water bores causing well blockage is estimated by some extent to be biological growth. Glotfelly (Ref **6)**

When rehabilitating a bore due to Biofouling, it is important to treat the gravel pack and near well conditions in the aquifer. This requires more than just a chemical treatment. A mechanical treatment is also required. It is important to ensure the contractor uses techniques that comply with standard water well development practices as outlined in the Australian Drilling Industry Manual or Sterrett. (Ref 7 and 8) Common techniques include Bail and Surge, Jetting and Air Lifting. Each method requires an experienced drilling contractor skilled in bore development techniques and having due care needed to avoid breaching the gravel pack.

Chemicals used include a variety of acids and proprietary chemicals summarised by Sterrett and Smith (Ref 7 and 4).

5.0 Economic impact of bore fouling

For a bio-fouled bore that has a reduced fifteen specific capacity (section 3.1) the total pumping head costs will increase for the same drawdown. The Bore in Figure 5 if it pumped at fifty litres per second the additional power costs would be just over $5,000 per year. Increasing to nearly $12,000 per year for a 30% loss in specific capacity. When considering the annualised costs over a number of years the benefits of bore rehabilitation treatment is significant. The Methodology and formula to calculate the additional power costs with reduced specific capacity is outlined in M Glotfelly Ref 6. Additional costs in pump failure from biofouling, incrustation and sand pumping on bore pumps would also apply.

6.0 CONCLUSION

The art of assessing if a water bore is unhealthy is outlined. Typical Aquifer Conditions and changes with the installation of a bore are described. The impact of installing a water bore providing the interface between the engineering of a town water supply and the environment is explained. These include biofouling from microbes, incrustation from chemical changes and corrosion of metal casing and screens.

Physical and chemical Well Performance Indicators are outlined as part of a preventative maintenance program.

7.0 REFERENCES

1 NSW Groundwater Strategy December 2022 Department of Planning and Environment
2 NSW Guide to Groundwater Management June 2022 Department of Planning and Environment
3 Neil Mansuy Water Well Rehabilitation – A Practical Guide to Understanding Well Problems and Solutions 1999
4 S Smith and A Comeskey Sustainable Wells Maintenance Problem Prevention and Rehabilitation 2010
5 Droycon Bioconcepts Website BART kits. https://www.dbi.ca/BARTs/index.html
6 Marvin F Glotfelty R. G. 2019The Art of Water Wells. Technical and Economic Considerations for Water Well Siting, Design and Installation.
7 Ed R Sterrett Groundwater and Wells Third Edition Johnson Screens
8 The Drilling Manual Australian Drilling Industry Manual 4th Edition