Maintenance of Well Yield in the Long Term

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Abstract

Over time, well yield can reduce, water quality alter and operational costs increase, however with appropriate well maintenance these problems can be remediated or avoided altogether. Well maintenance comprises activities undertaken to allow a well to continue to operate at maximum efficiency, thereby prolonging well life. If such measures are not undertaken, well rehabilitation such as pump replacement or well screen replacement may be necessary.

In order to avoid loss of a strategic groundwater supply, regular performance evaluation is necessary to establish a baseline against which future performance can be compared. Therefore well maintenance begins with regular inspections and monitoring of well yield, water quality and pumped water level.

Diagnosis of a problem requires review of well construction details and ongoing monitoring data in combination with more specific water quality analyses and CCTV inspection to examine the well casing and screen. Maintenance may require chemical treatment of the well, physical cleaning or development or re-evaluation of the pumping regime.

Keywords: Groundwater supply, well performance, development methods.

Introduction

Good well maintenance practise can be cost effective and assist in providing the optimal yield from groundwater wells in the long term.

Common causes of reduced well performance include chemical encrustation or biological fouling of the screen and formation, plugging of the screen (or fractures within a rock aquifer) with fine sediments, entrainment of sand particles through the screen, corrosion due to chemical reactions between the groundwater and steel, and inappropriate pumping regimes.

In order to avoid loss of a strategic groundwater supply, regular performance evaluation is necessary to establish a baseline against which future performance can be compared. Therefore well maintenance begins with regular inspections and monitoring of well yield, water quality and pumped water level. Should well performance reduce by 10 % to 15%, maintenance is required; if performance is reduced by 25%, rehabilitation may be necessary. Diagnosis of the problem requires review of well construction details and ongoing monitoring data in combination with more specific water quality analyses and CCTV inspection to examine the well casing and screen. Maintenance may require chemical treatment of the well, physical cleaning or development or re-evaluation of the pumping regime.

This paper considers some simple low cost methods of checking and maintaining your well to maximise performance in the long term.

The Importance of Well Maintenance and Development

Drawdown in a production well is affected by two factors: formation/aquifer loss and well loss. Aquifer loss is controlled by the hydraulic characteristics of the targeted aquifer and in most cases these conditions cannot be improved by development.

Head losses are associated with the entrance of water through the well screen and the axial flows of water toward the pump intake are known as well losses. These losses are caused by turbulent flow conditions and vary with the square of the velocity. Well losses are affected by factors such as screen design, filter material and pump rate. Well losses often increase over time but with careful maintenance they can be reduced to that which was recorded when the well was new.

The results of insufficient well development or lack of well maintenance over time have proved to have a significant affect on the performance of pumping wells. Comparison of stepped rate well tests carried out before and after a mechanical development programme demonstrates that well performance can be significantly improved by relatively simple methods.

A new well constructed in Canterbury was initially developed by the contractor using mechanical surging. Following the initial development the well operated under sand free conditions, but the specific capacity was lower than expected. Instead of constructing another well to provide the required yield, further well development was recommended. A development programme was proposed consisting of high velocity jetting, air-lift pumping and surging and finally over-pumping with a submersible pump. This procedure resulted in removal of a significant amount of fine material from the formation and the subsequent stepped rate well test resulted in a well equation indicating an improvement of the well by more than a factor of 2. Well yield improved from 15 l/s to 33 l/s.

Monitoring

Frequent water quality sampling is a good way to monitor the condition of a well. The water quality can often provide useful information about what development methods, or chemical treatment should be applied to improve the specific capacity and most often also the water quality. Collecting a water sample and getting it analysed for key determinants such as iron, manganese, total dissolved solids and turbidity is a cost-effective method of monitoring well condition, and allows for the frequency of any necessary treatments to be optimised.

Water quality samples (including microbiological analyses) collected from existing wells in the Central North Island have shown elevated iron values and the presence of iron bacteria. Iron bacteria often occur because of an excessive drawdown in the pumping well. Development such as air lift pumping followed by over-pumping with a submersible pump has been shown to improve the specific capacity of the well, resulting in a smaller drawdown (and thereby limiting aeration of the pumped aquifer). This development in combination with a shock chlorination to kill the remaining iron bacteria has proven an effective development method extending the life of relatively old production wells.

Long term monitoring of the pumping water level should be included as part of the overall monitoring programme in order to observe whether the water level in the well is slowly creeping over time.

Pumping Testing

It is good practise to carry out a pumping test programme consisting of a stepped rate pumping test followed by a constant rate pumping test and recovery monitoring when a new well is constructed (Figures 1 and 2). By deriving the specific yield, the well loss factor, and the formation loss factor, the well condition can be evaluated.

Figure 1. Pumping yield measured by orifice weir

Figure 2. Typical pumping testing set up

Annually a stepped rate pumping test should be undertaken to compare the well loss factor and the formation loss factor with the values calculated from the original stepped rate pumping test. This is a good measure to evaluate how much the performance of the well has decreased and an effective tool for determining how often development activities are required.

A stepped rate well test can be conducted in 4 to 5 hours and should be carried out after completion of development in order to check the effect of the development.

Well Maintenance Techniques

Physical Development

Development is essential when a well is constructed but it can also play an important role when treating a clogged or partially clogged screen. High velocity jetting combined with air lift pumping and perhaps a mechanical surge tool has proven to be an effective way to flush the screen and the surrounding formation and remove particles from the well.

Figure 3. Well development by excessive air lift pumping.

The key is to create flows in and out of the well screen so that not only the inside of the screen is cleaned, but also the formation around the screen. There are many different physical development methods (over-pumping, surging, backwashing) and the selected development method depends on the particular conditions of the well (screen slot size and open area, use of drilling fluids etc) and the nature of the aquifer.

Common development methods involve air lifting at a low rate and slowly working up to the intended long term yield. However a range of examples from new and existing wells have shown that the most effective (and most timely) results are obtained if the well is developed at pumping rates exceeding the anticipated yield (over pumping) when the well is put back in operation.

CCTV

A CCTV (Closed Circuit Television) inspection is normally carried out by slowly winching a small camera and a light source down the well. Most cameras can tilt the head and look sideways if particular details of interest are encountered. Generally the well should be taken out of operation at least 24 hours prior to the inspection in order to allow the water to recover to static water level and limit turbidity in the water standing in the well.

When the well is cleaned up by physical and chemical treatment it is good practice to check if there is any physical damage to the inside of the screen, the sump or the casing. This can easily be done by undertaking a CCTV inspection of the inside of the well. A CCTV inspection can normally be completed in a couple of hours and it provides information about the welding, the connection between casing and screen, any damage to the screen and if there is any material or alien object present in the well sump.

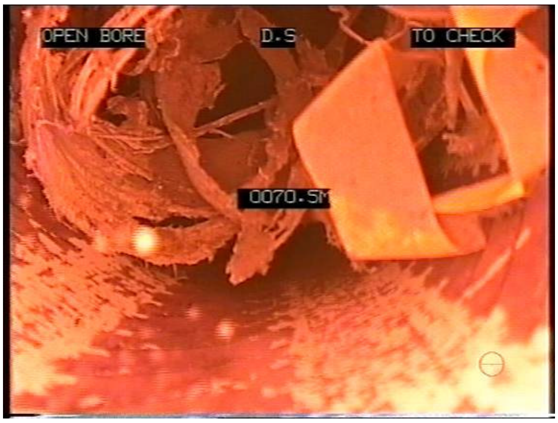

Figure 4. CCTV of a poorly maintained well.

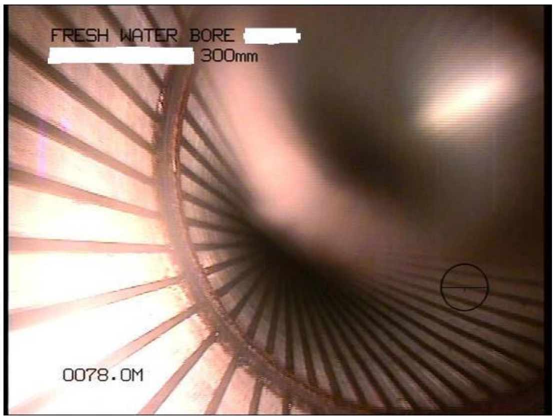

Figure 5. CCTV of a well maintained well.

Chemical Treatments

Chemical and biological encrustation of well screens is one of the major causes of well failure, and where identified a chemical treatment (usually in conjunction with physical development) may be required. The type of encrustation, and hence the treatment, is largely dependent on the water quality of the aquifer and therefore a good understanding of the nature of the aquifer and natural water quality is required for diagnosis.

The most common causes of encrustation are the precipitation of iron, manganese, magnesium and calcium, or biofouling caused by slime producing organisms such as iron bacteria. Treatment generally comprises repeated dosing of the well with an acid or oxidising agent such as chlorine.

Chemical treatments can also be used to address the physical plugging of the screen or surrounding formation (where fine particles have migrated over time into the open area surrounding the screen).

Chemical treatments have been found to be more effective when combined with physical development. Generally such treatments will be required on a regular basis and will comprise part of the long term maintenance plan.

An Example

The measures described above were used to diagnose and treat iron bacteria identified in a public water supply well in the Western Bay of Plenty. The well, screened through weak ignimbrite and derived soils, was constructed in 2005 with initial pumping testing suggesting a long term yield of 50 l/s for 31 m drawdown. Water quality sampling at that time indicated elevated levels of iron and manganese, with treatment measures put in place to achieve compliance with DWSNZ 2005. The well was put into production approximately 18 months later, after completion of the reticulation and treatment plant, however during pumping testing it was noted that a maximum discharge of just 40 l/s could be achieved resulting in some 42 m of drawdown (i.e. a 35% increase in drawdown).

A CCTV inspection was undertaken that revealed growth of a gelatinous mass over 30% of the screen, and suspended solids in the water column. Based on the physical appearance of the mass, and the elevated iron levels in the water it was considered that the growth could be iron bacteria, clogging the screen and reducing well performance.

In order to confirm this, the bore water was sampled (from the depth with the greatest encrustation, as indicated by the CCTV) and sent away for microscopic analysis, which confirmed the presence of filamentous iron bacteria.

The following course of action was recommended:

1. The bore should be developed to clear the water of suspended material and if possible to remove encrusting material from the walls and base of the well. During development the water should be sampled and tested for iron bacteria;
2. Chlorination of the well could be undertaken at the same time to treat for the iron bacteria;
3. A second CCTV inspection should be undertaken, once the well has been cleared to carefully examine the condition of the casing, screen, the join between them and the base of the hole.

Development comprised both airlifting and jetting, with a significant proportion (60%) of the development time focused on the lower screen (most heavily encrusted). Three samples were collected, after 1 minute, 1 hour and 39 hours of development (Table **1**).

Table 1 - Summary Results of Water Quality Testing

Determinant	**Result**		
	1 Minute Into Development	**1 Hour Into Development**	**End of 39 Hours Development**
Microscopic Examination			
Filamentous bacteria (true iron bacteria)	Abundant Heavily encrusted	Rare – abundant Lightly encrusted	Absent – rare V. lightly encrusted
Other	Iron particles	Iron particles	-
Culture Results			
Iron precipitating bacteria (cfu/ml)	52000	13000	30

The results of the water sampling confirm that iron bacteria were present in high numbers prior to re-development of the well. The results of the sampling also indicate that development of the well resulted in a significant reduction in the quantity of bacteria present. At the end of development, iron bacteria numbers were reduced to low but detectable levels.

In order to reduce the iron bacteria, a 'shock chlorination' was undertaken over a 3-day period. Shock chlorination comprises repeated dosing of the well with hydrochloric acid and sodium hypochlorite to maintain a set residual chlorine content and pH (for 72 hours) necessary to break down iron bacteria.

A repeat CCTV inspection and microbiological assessment was then undertaken. The CCTV inspection showed almost no iron encrustation. Some isolated iron bacteria sheaths were observed, however these did not appear to be blocking the screen apertures.

Following the treatment, the pump was reinstated and subsequent testing indicated that the capacity of the well had returned to that first indicated by pumping tests.

Although the chlorination and re-development of the well significantly reduced the amount of iron bacteria in the well, it is possible that the presence of iron bacteria may not be permanently eradicated and so a maintenance programme was developed and recommendations for long term operation made.

Conclusion

With a small effort, well maintenance measures offer increases in well productivity and longevity, avoiding the need for expensive repairs and re-drilling, whilst improving the quality and reliability of your drinking water supply.

Maintaining your well with a regular programme can increase the yield of the well and reduce the electricity usage and running costs. Furthermore it can eliminate the need for drilling a new well thereby saving a large sum with minimal downtime.

The case study from the Western Bay of Plenty demonstrates the effectiveness of appropriate maintenance measures, A CCTV inspection in conjunction with water quality sampling is a relatively quick and cost effective way of diagnosing well problems, allowing the specification of targeted chemical and physical treatment to improve well yield.