Selection of Steel Casing and Well Screen for Brackish Ground Water Production Boreholes

Introduction

When the proposed Mmamabula wellfield is completed and comes on line, it will provide a source of water supply for the Mmamabula Energy Project for an estimated 40 years. The wellfield is expected to consist of 12 to 14 high-capacity production wells that will each yield approximately 100 cubic meters per hour (m^3/hr). Based on information collected from test wells that were drilled and installed during the pre-design exploratory phase of the wellfield project, the depths of the production wells will be on the order of 250 meters (m). The wells will pump brackish ground water that contains total dissolved solids (TDS) of +/- 2,500 milligrams per liter (mg/l). Water is brackish if it TDS ranges from 1,000 to 5,000 mg/l. TDS is defined as the residue of a filtered water sample after evaporation. For ground water most of the residue consists of inorganic salts.

Production wells, such as those proposed for the Mmamabula wellfield, are typically designed to meet specific criteria for tensile and collapse strengths, durability, longevity, production capacity, and efficiency. While those design parameters should be carefully considered for every well design, they are even more important when the reliability of the water supply is as vital as it will be to the Mmamabula Energy Project. Strength, durability, longevity, and efficiency can be built into a well design by selecting a type of steel for blank casing and well screen that meets the criteria established by the designer. For the Mmamabula wellfield, durability of the steel casing and well screen are vitally important because of the potential for corrosion of the steel caused by long-term exposure to brackish water.

This technical information paper discusses the selection of steel casing and well screen for the Mmamabula wellfield in consideration of the design parameters as they are described above.

Corrosion Resistance

Steel water well casing and well screen are susceptible to corrosion above the water table (i.e., within the “splash” zone) and within the submerged zone. The splash zone is the area between the static and pumping levels that can be the site of severe corrosion. When pumping begins the water level in the well is lowered and exposes the wetted surface of the casing to oxygen in the air. This alternating dry and wet cycle, with high and low oxygen levels, corrodes the steel service in contact with the low dissolved-oxygen ground water.

In the submerged zone, both potable water and non-potable water (such as brackish water) can be corrosive depending upon the water chemistry. The principal chemical and physical properties of water that cause corrosion are dissolved gases and dissolved salts. With regard to dissolved salts, the higher the TDS, the greater the potential for steel to corrode over time. Therefore, the brackish ground water of the Mmamabula wellfield requires the use of corrosion-resistant steel for well casing and well screen.

In water wells, as steel oxidizes it corrodes which reduces its structural integrity (i.e. strength). Frequently, well casing or screen exhibit some or all of the following effects as the steel corrodes:

1) Screen apertures (i.e., slots) become wider as steel is lost along the edges of the slots. This typically leads to sand production in alluvial or granular aquifers.
2) Holes may develop on the walls of casing and screen. This will reduce tensile and collapse strengths and can allow sand production to occur.
3) Wall thickness is diminished. This will reduce tensile and collapse strength, which could lead to structural failure.

Types of Steel for Water Wells

Water well casings and well screens are manufactured from various types of steel which offer different levels of corrosion resistance and strength. However, the design criteria of the Mmamabula wellfield combined with its brackish ground water effectively eliminate from consideration all low corrosion resistant steels such as low-carbon steel and copper-bearing steel.

Stainless steel exhibits excellent corrosion resistance and high strength. Stainless steel derives corrosion resistance from its passivity (defined as metal displaying more noble behavior; or simply stated, the metal does not corrode when it should). Type 316L is an austenitic stainless steel, which contains 16% chromium (Cr), 10% nickel (Ni), and 2% molybdenum (Mb) that make it more resistant to general corrosion and pitting than conventional chromium-nickel stainless steel such as Type 304. Type 304 stainless steel is appropriate for water containing TDS up to 2,000 mg/l. Type 316L stainless steel will handle water with TDS up to 10,000 mg/l and resists pitting and crevice corrosion in water.

During the lifetime of the Mmamabula wellfield, each well will be redeveloped periodically (e.g., every 5 years) to remove the natural build-up of biological material and encrusted matter from the interior of the well casing and well screen. This cleaning is usually performed with stiff wire brushes and strong chemicals, such as phosphoric acid. Experience has shown that stainless steel is particularly well suited to be cleaned by chemical methods because it is able to tolerate short-term exposure to acid. This is an important consideration, particularly for wells that will be in service for 40 years.

Well Screen Efficiency

Well efficiency (expressed as a percentage) is the ratio of the drawdown in the aquifer to the drawdown in the well. A typical range of efficient wells is from 70 to 80% (or greater). An efficient well screen will allow ground water to flow from the aquifer(s) through the gravel pack (if installed) and into the well through the well screen with a minimum of head loss. Factors pertinent to well efficiency are related to the well construction, the well screen, and well development. A major benefit of an efficient well is its lower cost of operation. Generally speaking, an efficient well exhibits less drawdown and its pump requires less energy (e.g., electrical or diesel fuel) to lift the water from its pumping level to ground level or other point of discharge. Louvered screen is inherently efficient and functions effectively in high-capacity wells.

Durability for Well Development

Water wells must be aggressively developed during construction after the casing, well screen, and filter pack (if used) have been installed. Development methods remove from the borehole wall residual drilling fluids and cuttings. Any such remnants that remain on the borehole wall will likely inhibit the free flow of ground water from the aquifer(s) into the well. If water wells are not fully developed by aggressive methods such as surging and stressful pumping, they will yield only a small fraction of their potential. Therefore, it is imperative that the well should be stressed to enhance its final production.

Various methods can be used for well development. One of the most effective development methods is swabbing. Swabbing is performed with a tight-fitting single or dual surge block that is raised and lowered above and within the well screen. This method is a forceful process that causes stress to the well as water is rapidly pulled from the aquifer through the well screen and then forced back out the screen where it agitates and loosens cuttings and fluids that adhere to the borehole wall. The dual swab method combines the aforementioned motion with periodic airlift pumping that removes the drilling remnants from the well for discharge. Louvered screen is extremely durable and easily accepts development tools and stressful development methods. This point is made because less durable types of well screen, such as wire-wrapped screen, can be easily damaged by impact from a development tool. This, unfortunately, occurs all too often and can cause severe damage to the well screen.

Entrance Velocity

Two types of well screens are available for construction of high-capacity water wells. Among these, the most commonly installed in production wells for municipal, industrial, and agricultural uses are louvered screens and wire-wrapped screens. Both screens offer a range of open area per linear foot, as determined by the number of openings (i.e., slots) per linear foot and their dimensions (i.e., length and width). Laboratory and field tests conducted on louvered screen and wire-wrapped screens have shown that both types of screen will exhibit low entrance velocities at high pumping rates. Aquifer modeling tests showed that the entrance velocity of louvered well screen is well within the recommended upper limit of 0.46 m/sec established by the American Water Works Association in its Water Well Standard (ANSI/AWWA A-100-06). The anticipated production rates for the proposed Mmamabula wells will be within the acceptable range for entrance velocities as defined by AWWA.

CONCLUSION

The Mmamabula wellfield will be in operation for several decades and will be required to provide reliable service. As described herein, the brackish ground water conditions at the wellfield demand an appropriate level of corrosion resistance so as to build in the durability and strength that are needed for long-term, reliable service of the wells. Stainless steel, Type 316L is the best choice as the material from which to manufacture all blank casing and louvered well screen for the wells.

REFERENCES

1. *An Introduction to Stainless Steel*, American Society for Metals
2. *Corrosion Control in the Chemical Process Industries*, C.P. Dillon, McGraw-Hill Book Company
3. Entrance Velocity - Its Importance to Well Design, Technical Memorandum 006-6, Roscoe Moss Company
4. *Handbook of Ground Water Development*, 1990, Roscoe Moss Company, John Wiley and Sons, New York, NY

5. Materials Selection for Corrosion Control, ASM International
6. Technical Data: Blue Sheet – Stainless Steels: Chromium-Nickel, 1998, Allegheny Ludlum Corporation
7. Technical Data: Blue Sheet – Stainless Steels: Chromium-Nickel-Molybdenum, 2006, Allegheny Ludlum Corporation
8. Water Wells, AWWA Standard, 2006, ANSI/AWWA A100-06

About the Author

Robert Turnbull is the Chief Hydrogeologist of Roscoe Moss Company. In this capacity he provides technical support, as needed, to consultants, municipalities, and water districts to plan and design water supply wells. He can be contacted for such information or to answer inquires regarding this technical memorandum via email at rturnbull@roscoemoss.com. His website is www.blthydro.com. The corporate website for Roscoe Moss Company is www.roscoemoss.com.