Examination of the Construction and History of the Salt River Project Production Wells Phoenix, Arizona

Executive Summary

The Salt River Project (SRP) is two companies: the Salt River Project Agricultural Improvement and Power District (District), a political subdivision of the State of Arizona; and the Salt River Valley Water Users' Association (Association), a private corporation. The District provides electricity to retail customers in the Phoenix area. It operates or participates in seven major power plants and numerous other generating stations, including thermal, nuclear and hydroelectric sources. The District currently serves more than 724,000 electric customers. The Association delivers nearly 1 million acre-feet of water to a service area in central Arizona. An extensive water delivery system is maintained and operated by the Association, including reservoirs, wells, canals and irrigation laterals.

Since 1900, the SRP has continuously delivered ground water from wells to meet the needs of its constituents. Today SRP operates approximately 250 wells that can produce in excess of 850,000 acre-feet. The system would not be pumped at this capacity, however, due to operational constraints. The majority of these wells (over 75%) were constructed over 40 years ago. The service longevity of these wells can be attributed to factors such as steel composition of the well casings and well screens, ground water chemistry, and maintenance. The importance of constructing wells using corrosion resistant steels is readily evident when the operational and financial benefits are realized following several decades of service without need for replacement.

Introduction

Established in 1900, the SRP serves water for domestic, industrial, and agricultural uses to more than 724,000 customers in Phoenix, Arizona. The purpose of the SRP is to provide a secure water supply for the customers in its 240,000-acre service area. When established, the SRP was primarily a ground water-based provider with wells tapping the aquifers replenished by the Salt River. SRP augmented its water supply with the completion of Roosevelt Dam in 1911. As the population around Phoenix grew, so did the need for additional water supplies. To meet the growing need for water, the SRP decided that the most cost-effective method to meet the demand was to increase production from the ground water basin.

In 1910, the Roscoe Moss Company was contracted to construct several wells for the Salt River Valley Water Users' Association. The wells were drilled using cable-tool equipment; the well casing materials were constructed of "hard-red" steel. Some of these wells remain active today. The Roscoe Moss Company continued to construct wells for the SRP for the next 60 years. Over this period, the drilling methods changed from cable tool to rotary techniques and 20- to 30-foot sections of casing were used in place of the 4-foot sections of double-wall casing. In 1980, Roscoe Moss Company ceased its drilling operations in order to focus on manufacturing, but remained the supplier for casing and well screen materials.

However, a constant which remained throughout the well construction history of SRP was the use of corrosion-resistant steels. This report will review some of the historical facts concerning well drilling and casing materials used for the construction of the early and recent SRP wells.

Well Casing and Well Screen Materials

During the era of cable tool-constructed wells, the casing had to meet the rigors of pounding and jacking during installation. To meet the strength requirements, the steel sheets from which the casing sections were made were subjected to special rolling techniques. To provide added life, copper was introduced to the steel. The result was steel that was hard and possessed a reddish color which gave the material its name "hard red steel". It chemistry is included in Table 1. The first noted use of this type of steel for wells was around 1860 and was continued under the name "hard red" until the conclusion of World War II when it ceased being produced by Alan Wood Steel Company. Other steel producers such as Bethlehem Steel, U.S. Steel, and Kaiser Steel continued to supply the steel with virtually identical chemical and physical properties. Cable tool wells drilled by the Roscoe Moss Company, including those for the SRP, were constructed with Kai-Well steel furnished by Kaiser Steel. Roscoe Moss Company' rolled sheets of this steel into four-foot long sections. These sections, or joints, were used to construct the double well casings that were standard for cable tool-drilled wells at the time.

Table 1 - Chemical Composition (%) and Physical Properties of Steels Used

Constituent	"Hard Red"	Kai-Well	Copper-Bearing	High Strength Low Allow (ASTM A606 Type 4)
Carbon	.20 - .30 (.25)	.20 - .30 (.24)	.30 max	.09
Manganese	.85 – 1.30 (1.00)	.85 – 1.15 (.95)	.30 – 1.0	.38
Phosphorous	.05 max (.03)	.05 max (.037)	.04 max	.09
Sulphur	.05 max (.03)	.05 max (.03)	.05 max	.033
Silicon	.12 max (.08)	.12 max (.09)	.12 max	.48
Copper	.20 min (.27)	.20 min (.27)	.20 min	.41
Chromium				.84
Nickel				.28
Physical Properties				
Yield Strength	55K – 70K psi	61,000 psi	35,000 psi	50,000 psi (min)
Ultimate Strength	80K – 95 K psi	86,000 psi	60,000 psi	70,000 psi (min)
Elongation (8")	17-25%	21%	24 – 30%	
Rockwell "B" Hardness	80 – 90	86.5		
Elastic Ratio	69 – 73	71		

Note: (1) Values in parentheses represent typical composition percentages

In the 1950's, rotary drilling which had been strictly used in the oil industry made its introduction into the water well market. Rotary drilling rigs could accommodate longer lengths of well casing depending upon the capacity of the individual rig. By the middle of the decade, Roscoe Moss Company was manufacturing corrosion-resistant steel casing and screen called “Kopr-well”. Kopr-well steel was fabricated in 12-foot lengths and could be welded into a single section up to 48 feet long. Casing and screen were available in various thicknesses from 3/16- to 5/16-inch and in diameters from 10 to 48 inches. The rotary drilling method also permitted the use of pre-perforated casing that allowed for better placement in water-bearing formations, higher numbers of perforations, and most importantly, specific tolerances for the size of perforations as compared to casing perforated by down-hole tools.

Corrosion-resistant steel that is commonly specified today is known in the industry as “copper-bearing steel”. Its chemical composition and physical properties of the aforementioned steels are summarized in Table 1.

Table 1 also summarizes the types and compositions of steel used for the SRP wells. Review of the data reveals the close similarity in the chemical composition of the steels even though the time period of their use spanned nearly 100 years. It also becomes apparent that the additional copper content does contribute significantly to the longevity of the well’s service.

Water Quality

The chemical nature of the ground water produced by the SRP wells is characterized as slightly alkaline and fairly high in total dissolved solids (TDS). Calcium and carbonate are the predominant cations and anions, respectively. Table 2 summarizes the general water quality of the ground water pumped by the SRP wells.

Table 2 - General Water Quality of SRP Wells

Constituent	Concentration (mg/L) Range (1)	Concentration (mg/L) Typical (2)
Total Dissolved Solids	268 – 2,160	1,600
Calcium	9 – 277	92.1
Hardness	36 – 1,410	383
NCO_3	0 – 1,283	41
pH	7.2 – 8.7	7.4
HCO_3	49 – 487	417

Note: (1) Includes all active wells
(2) Values from Well 7E1N, largest producer from 1989 – 1998

SRP Well Maintenance

The active production wells have been monitored on a regular basis by SRP for more than 30 years. Well redevelopment was commonly done on an as-needed basis; but, the introduction of down-hole cameras have permitted the SRP to better assess the condition of its wells and schedule well rehabilitation.

In 1995, the SRP developed a program to prioritize its well maintenance activities. The program initially categorizes the wells into three groups based on use, as follows:

- Group 1 (highest priority): contract, city distribution, sole source, and power plant supply wells.
- Group 2 (second priority): wells located upstream of any power plant
- Group 3 (lowest priority): irrigation

Each well in each group then receives a pump rating, well rating, and water quality rating. The top 10 wells from each group are then scheduled for maintenance over the course of the next year. Group 1 wells receive the most attention when maintenance work is scheduled. This rating method allows the SRP to better track its maintenance costs and to align them with the type of use and water demand. This method also provides increased flexibility to decide which wells should be redeveloped and/or rehabilitated in a given year.

The SRP owns and operates its own well maintenance equipment that currently includes one cable tool rig and two pump rigs. A cable tool rig has always been a mainstay at the SRP. The pump rigs have served the SRP since the 1980's. Typical redevelopment procedures performed on the wells include:

- Pull the pump
- Perform a down-hole video survey
- Assess the condition of the casing and screen
- Determine the presence and amount of scale
- Sonar jet the casing and screen
- Apply dry ice
- Brush
- Install patch(es) or liner(s) as necessary

Replacement of Wells

Over the years, the SRP has abandoned or destroyed water wells when necessary. However, the available well records in the SRP files do not always explain the reasons for such actions. According to SRP personnel, urban expansion rather than the degradation of the steel casing and screen is the primary reason that SRP has had to replace existing wells. These recently constructed wells and those planned for the near future have or will replace existing wells affected by road and highway widening and construction. Most of these wells would not otherwise require replacement. Another reason for well replacements is in response to changes in water quality. In some instances, the water produced from an SRP well has been negatively impacted and is no longer desirable or suitable for potable purposes.

Summary of Active Salt River Project Wells

Age of Existing Wells

This section provides additional details such as age and production for active wells over the past decade. Only 23 of the 250+ wells in the Salt River Project have been constructed over the last 30 years. This is a testament to the longevity of the existing SRP wells. A summary of the ages of the active wells is shown on Figure 1.

Figure 1 - Age of Active Salt River Project Wells

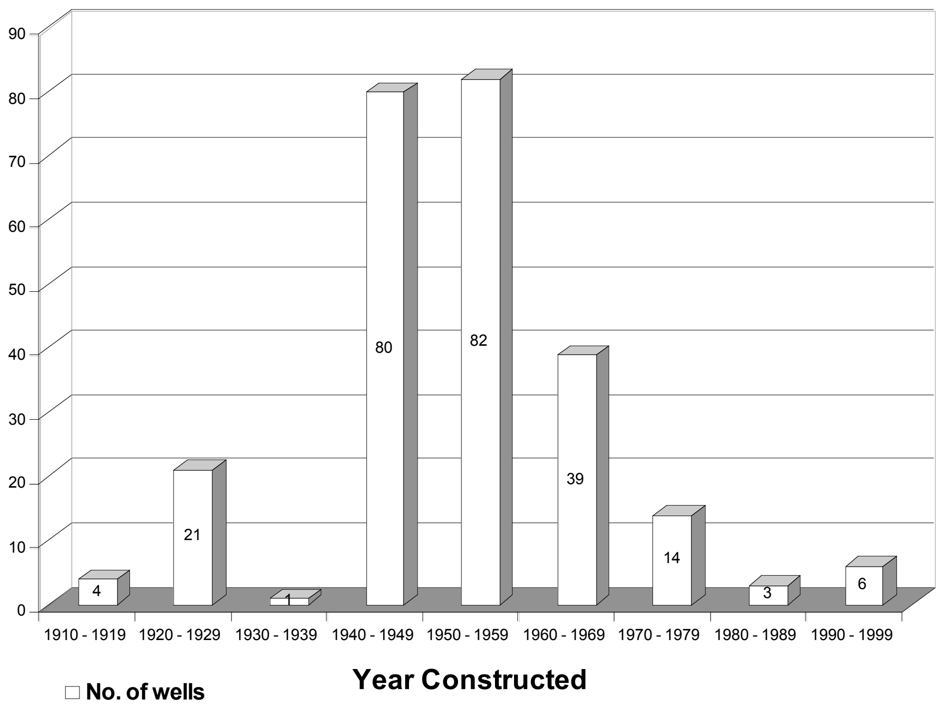


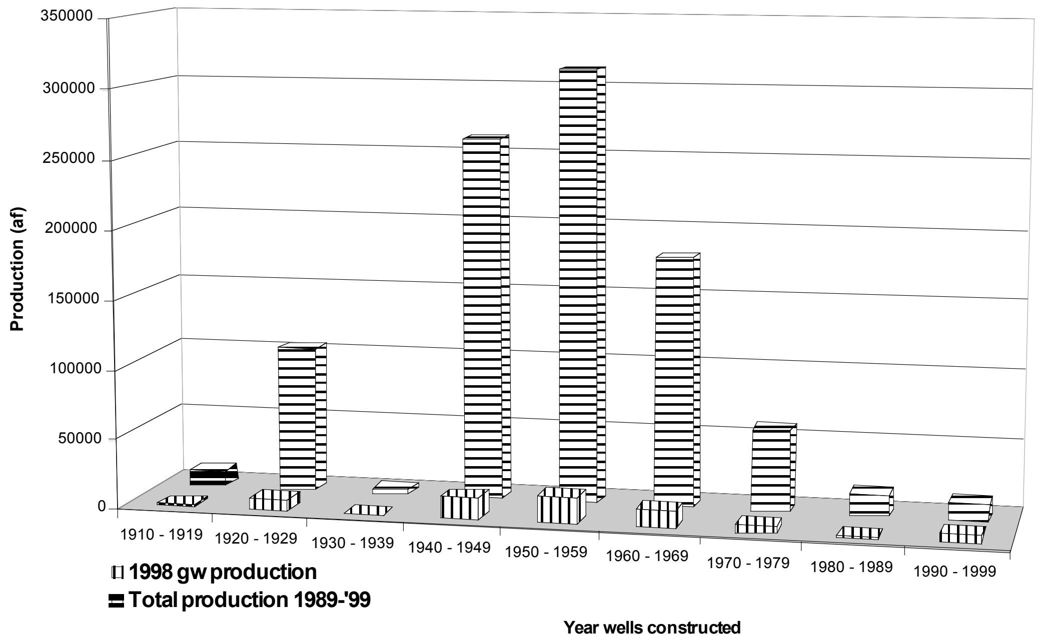
Figure 1 shows that the majority of currently active SRP wells were originally drilled within a 20-year period from 1940 to 1960. The age of these wells clearly demonstrates the longevity of corrosion-resistant steel.

Ground Water Production

Sixty-five percent of the wells are 40 to 50 years old, and 80% of the wells exceed 30 years of age. Remarkably, the wells that are 40 to 50 years old produce the majority of the ground water supplied by the SRP.

The combined production of the wells constructed prior to 1969 accounted for 80% of the ground water produced in 1998 and 90% of the ground water produced from 1989 to 1998. Figure 2 shows the ground water production totals in acre-feet per age group.

Figure 2 - 1998 and Ten Year Production Summary



Findings

SRP's experience shows that water wells can be expected to realize long and productive service lives if they are constructed with corrosion-resistant steel. This same steel chemistry that provided corrosion resistance and strength to the SRP wells and resulted in 80 years of service to the SRP is still available for water well casing and screens. These steels are commonly known as corrosion-resistant copper-bearing steel and high strength low alloy (HSLA) steel (ASTM A 606). Both of these non-stainless steels provide increased corrosion protection compared to mild steel. Field studies conducted for another major water utility in California demonstrated that the corrosion resistance of copper-bearing steel is 4 times greater than that of mild steel. High strength low alloy steel has been shown to have 9 times the corrosion resistance of mild steel in actual submerged conditions (Geoscience Support Services, 1999).

Conclusions

The benefits of using high quality steel in water well casing and well screen are summarized as follows:

- Water wells constructed with corrosion-resistant steels need less frequent replacement.
- Corrosion-resistant steel is more suitable for aggressive redevelopment and rehabilitation procedures. For instance, they possess the strength to withstand the pressures of swaging patches, if necessary.

- Aging wells can be successfully relined because the integrity of the original casing and well screen is more likely to remain intact despite the presence of a hole or separation.

References

Geoscience Support Services, 1999, “Corrosion Field Test of Steels Commonly Used in Well Casing and Screen”.