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TECHNICAL MEMORANDUM

Date: 5 January 2004

To: Dr. Stuart Styles, ITRC, Director

From: Gary Wilson, ITRC, Senior Engineer

Subject: Well Efficiency Class in Tulare, California on November 13, 2003

The Irrigation Training and Research Center (ITRC) arranged a well efficiency demonstration at the Southern California Edison AgTAC building in Tulare, California in November 2003. The class was organized for Southern California Edison customers.

Class Agenda

The session began with Edd Schofield of Johnson Screens, giving a PowerPoint presentation on well efficiency. Rod Gosling of West Side Pump Co., next gave a presentation of his company's well screen cleaning process called Sonar-Jet. Zack Smith and Mel Bradshaw of Kern County Water Agency (KCWA), followed with a presentation of the results of KCWA's efforts to improve well efficiency in four wells in their Pioneer Project. Larry Naffziger of USA Hydrowash, was unable to attend the class so Edd Schofield gave another presentation specifically on well screen cleaning.

Background

Well efficiency indicates the difference between the drawdown outside the well and gravel pack, divided by the drawdown inside the well (refer to Figure 1).

$$\text{Well Efficiency} = \frac{\text{Drawdown outside the well casing}}{\text{Total drawdown inside the well}} \times 100$$

Thus, if there are no losses across the gravel pack and well screen, the well efficiency is 100%. However, in practice it is not possible to have a well that is 100% efficient since there is always a head loss across the gravel pack and well screen as water flows into the well during pumping. Figure 1 shows how the head loss across the gravel pack and well screen lowers the pumping level. Plugging of the gravel pack and/or well screen can increase the head loss during pumping, resulting in less water pumped, a deeper pumping level, or both. This will drive up pumping costs, similar to a decrease in pump efficiency.

The *specific capacity* of a well is determined by knowing the flow rate and the overall drawdown within a well. These two values are relatively easy to obtain in the field.

$$\text{Specific Capacity (GPM/ft)}= \frac{\text{Pumping Rate, Q in GPM}}{\text{Total Drawdown in Feet}}$$

For example, a well that pumps 100 gpm and has a drawdown of 20 feet from the static water level would have a specific capacity of 5 gpm/ft. Specific capacity can be directly related to well efficiency since as the well efficiency decreases over time the specific capacity also decreases.

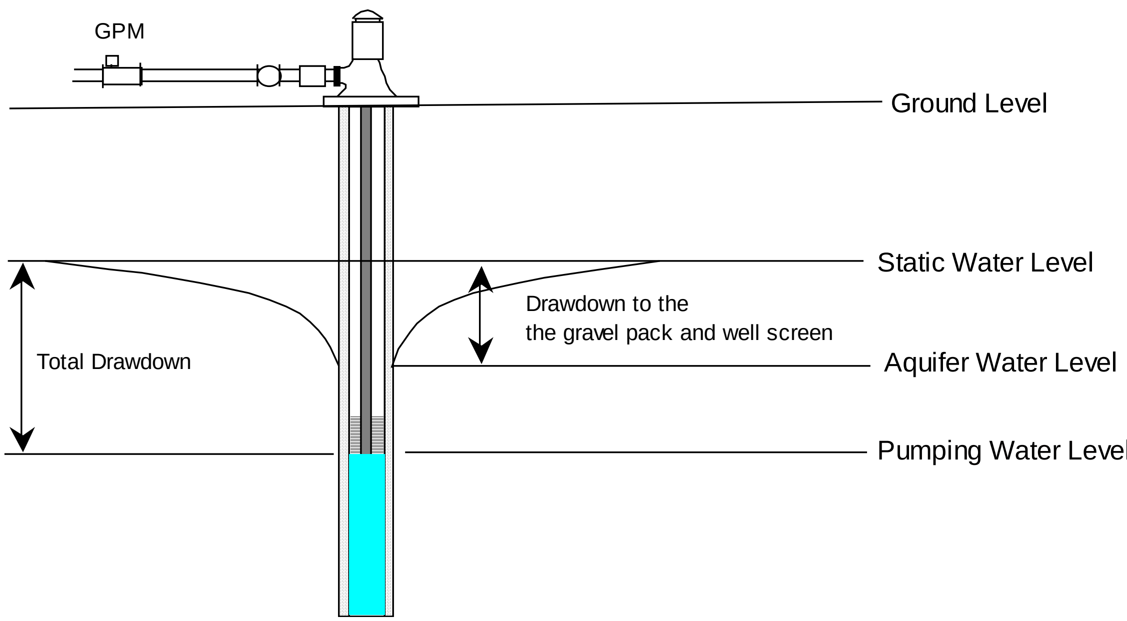


Figure 1. Typical well and pump configuration

The value of the drawdown to the gravel pack and well screen, a component of theoretical well efficiency, is difficult to obtain. The theoretical well efficiency is actually not as important as the *change* in well efficiency over time. It can be assumed that the best well efficiency for any given well is right after it is drilled and developed (therefore, the proper design, construction, and development of the well is very important). Over time, bacteria activity and other changes associated with pumping water out of the well will cause the gravel pack and well screen to plug. Laboratory analysis can determine the type of biological and chemical activity that would affect the well's performance and what measures should be taken to clean and maintain the well. A good record of the specific capacity of the well over time will show what the level of plugging is and will help determine what actions should be taken and what the potential improvement might be.

When well efficiency decreases by 20-30% from the initial construction of the well, it is relatively easy to rehabilitate with physical and/or chemical cleaning. When well efficiency decreases more than 50% it may be difficult-to-impossible to rehabilitate a well for more than a very short time. This is because the plugging can be deep within the gravel pack where it becomes difficult to impossible to mechanically or chemically remove the plugging. Therefore, good record keeping is essential to help identify when to take action before it may not be possible to rehabilitate a well.

The steps to having a good well efficiency are:

- Start with a well that has been properly constructed. Document the initial performance (including Specific Capacity) of the well.
- Use the Specific Capacity to evaluate the well efficiency (reported on standard pump tests by SCE or a local pump tester).
- Keep a history of the well's performance to identify a reduction in well efficiency.
- Use laboratory analysis to determine what the problem is and how to control the problem.
- Clean the well before specific capacity drops 20-30% from initial levels.

Summary of Presentations

Figure 2. Mel Bradshaw, Edd Schofield, and Zach Smith (L-R), speakers at the Well Efficiency Class.

Water Well Design, by Edd Schofield of Johnson Screens

When it comes to well efficiency, the first point to consider is the aquifer. The gravel pack and well screen should be designed to get the most potential out of the aquifer. The initial cost of drilling a well is generally only a fraction of the cost of operation. Adopting proper design, construction, development and maintenance practices will ensure the most cost effectiveness over the life of the well.

Some of the main points presented by Edd Schofield concerning water well design were:

- Good records of the history of a well are important to maintaining the well efficiency. Included in this history are the well construction data, operation data, well maintenance data, and water chemistry data.
- Well blockage can develop over time reducing the specific yield and includes mineral blockage and bacteriological blockage.
- Proper gravel pack thickness and materials is important. A gravel pack thickness of 3 inches is optimal. Thicker gravel packs become harder to develop and thinner gravel packs are difficult to place evenly. Gravel packs should also be made out of 90-95% silica material to resist chemical cleaning.
- When cleaning the well screen, physical cleaning (using brushes, swabs, jetting, etc.) should be done first. If the casing looks clean and structurally sound (well casing inspected using a video camera), then chemical cleaning for the outside of the well screen should be done.
- Dispersant chemicals can help remove fines, such as drilling mud that wasn't removed during well development, that are causing mechanical plugging. It is important to use phosphate-free dispersant chemicals since phosphate is a food source for bacteria.

Sonar-Jet ™ Well Cleaning, by Rod Gosling of Westside Pump

Rod Gosling has a long history cleaning and rehabilitating wells, as well as improving pump efficiencies, for Westside Pump in San Joaquin, California. In the past, he has used brushes, swabs, acid, and other well screen cleaning methods. Presently, Westside Pump uses Sonar-Jet™ Well Cleaning, a proprietary method of exploding low-energy explosives in a sequential manner that produces harmonic pressure waves.

First, the well casing is mechanically cleaned with brushes. Next, primer cord used as the low-energy explosive is lowered into place with the aid of a video camera. The primer cord is only placed in the perforated area. A basket is located at the bottom of the primer cord to collect any debris that falls off the screen after the explosion.

There are no studies on how effective the Sonar-Jet™ method is in improving well efficiency. However, after the Sonar-Jet™ well cleaning and pump rehabilitation there usually is a noticeable improvement in the flow rate from the well. No wells Rod has worked on have been damaged yet because of the Sonar-Jet™ process, however, a waiver must be signed releasing liability from Westside Pump prior to the work. Rod feels the risk from well casing damage using the Sonar-Jet™ process is low, but the process should probably not be used for old wells with weak casings.

The cost per foot to clean a well casing varies with the length of perforations as follows:

100 feet of perforations - $24~~1~~.00/foot ($2,400 total)

200 feet of perforations - $15.50/foot ($3,100 total)

600 feet of perforations - $10.50/foot ($6,300 total)

Case Studies in Well Cleaning, by Zach Smith and Mel Bradshaw of KCWA

Zach Smith and Mel Bradshaw, from the Kern County Water Agency (KCWA), presented case studies of well cleaning done in the KCWA's Pioneer Project area. Four (4) wells had the pumps pulled, the pumps and motors repaired, and three of the four had the well screen cleaned. One well (KCWA-10) underwent chemical cleaning without removing the pump and motor.

The three wells where the pumps and motors were pulled and the well screen cleaned showed significant improvement in the cost per acre-foot (AF) of water pumped. How much this improvement was due to the well cleaning and how much was due to the pump and motor repair was not clear. Different rehabilitation methods were used for each of the wells, as listed below:

Well No.	Rehabilitation Method Used	Cost*
KCWA-1	Pressure wash casing with water, casing swabbed.	$9,000
KCWA-2	No pressure or chemical wash (used as a control).	$0
KCWA-3	Pressure wash and chemical wash by swabbing.	$24,942
KCWA-5	Pressure wash and chemical wash by swabbing.	$35,111
KCWA-10	Chemical wash without removing the pump.	

*Well rehabilitation methods varied and the costs are based on pressure washing, chemical washing, swabbing, and airlifting as noted.

According to Zach Smith, one of the difficulties KCWA had in analyzing the data was the influence of nearby wells during the tests. The Pioneer Project well field is part of a groundwater banking program and had not been extensively pumped since the early 90's due to low demand for the water. During the above test period, the well field was again being pumped. The changing water level may have had an influence on specific capacity that was not easily quantified. Accurate flow measurement and water level sounding are integral parts of monitoring well efficiency. KCWA has yet to make a determination of the effectiveness of the well cleaning alone because of the change in static water level from the pre-repair pump tests done in 2001. Still, there was a significant improvement in specific capacity that appears related to well cleaning.

Well Number	Type of Well Cleaning	Pre-Repair Specific Capacity, GPM/ft	Post-Repair Specific Capacity, GPM/ft	Specific Capacity Improvement
KCWA#1	Pressure Wash	99.7	174.9	75%
KCWA#2	None (control)	93.8*	127.4	36%
KCWA#3	Pressure and Chemical Wash	70	90.4	30%
KCWA#5	Pressure and Chemical Wash	53.5	127.2	138%
KCWA#10	Chemical Wash	33.6	75.2	124%

*KCWA#2 had a pump repair that was done which raised the pumping capacity but the improvement to the specific capacity was likely due to the higher water table.

***Well Cleaning*, by Edd Schofield of Johnson Screens**

Edd Schofield ended the session by covering the topic of Well Cleaning. Important points in Edd's presentation were:

- Bacterial growth is responsible for the majority of the plugging in well screens and gravel packs.
- Laboratory testing is essential for determining the best method to maintain and rehabilitate wells. Included in this testing should not only be the identification of bacteria present, but the recommended methods and chemicals to use to rehabilitate the well.
- It is easy to rehabilitate wells where the specific capacity has been reduced less than 20 to 30%.
- It is very difficult to improve wells where the specific capacity has been degraded by greater than 50%.

Edd gave an interesting overview of different methods used for mechanically cleaning wells. He also gave some pointers on how to chemically clean wells, including diluting acids before injecting them into a well. Concentrated acid will not dilute as might be expected when poured into a well, but instead sinks directly to the bottom. The high concentration of acid at the bottom of the well may damage the well casing, while not having any cleansing effect in the screened portion of the casing, as desired.

Edd noted that it is also important to monitor the pH of the well water when using an acid cleaner. If the pH rises above 3, the effectiveness of the acid drops off considerably. In fact, precipitate that is brought into solution by the acid can re-precipitate out if the pH were to rise much above 3. For this same reason, the acid should not be neutralized in the well, but extracted and neutralized in a holding tank.

Edd pointed out some interesting anecdotes, including the case of a well that was not properly developed after it was constructed. For over 20 years, the well performed much below what surrounding wells did. A review of the well's history showed it was drilled during a drought when the well driller was most likely pressed to get the well into production as soon as possible. It was highly likely the drilling mud was still coating the outside of the hole. Chemically and mechanically cleaning the well to deflocculate and remove the drilling mud improved the specific capacity dramatically, to a level similar to the other wells in the region. The well now pumps over 3,000 gpm whereas in the past it could only pump 800 gpm.

Summary

Well efficiency is a measure of the head loss across a well's gravel pack and screen. A properly designed and constructed well will have the highest well efficiency when it is new. Over time, mechanical and bacteriological plugging can reduce the well's efficiency, which will increase the cost of pumping just like a reduction in pump efficiency would. There are various methods available, both mechanical and chemical, that can effectively clean wells. The actual effectiveness of any one method depends on the specific cause of plugging.

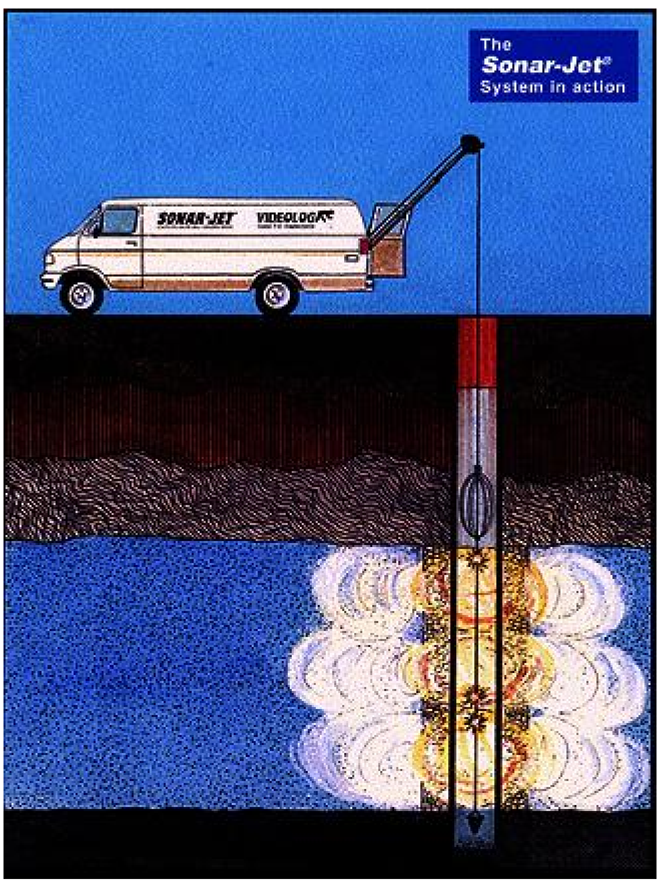
The most important thing an owner of a well can do to combat a decrease in well efficiency is to keep good records of how the well efficiency changes over time so that remedial action can be taken before it is too late.

Attachment A: SONAR-JET®

Sonar-Jet® is a system used to restore a well's specific capacity, reopening perforations and stimulating deep into surrounding water bearing formations. Sonar-Jet® has been used on all types of mineral, bacterial, fine sand, and other deposits that materially restrict the flow of water entering a well. The patented Sonar-Jet® system accomplishes this by combining a mild "harmonic" frequency of shock waves with pulsating, horizontally directed gas pressure "jets." The shock waves loosen crust-like deposits and the gas jets repetitively surge the well's own fluid back and forth through the perforations to deep clean the surrounding aquifer.

Sonar-Jet® consists of two controlled physical actions working simultaneously:

1. A mild harmonic frequency of shockwaves gently loosens all mineral, bacterial or other type deposits-even heavy "gyp".
2. Pulsating, horizontally directed gas pressure jets fluid at high velocity back and forth through the perforations to deep clean the productive aquifers.



The purported key to Sonar-Jet®'s success is in the coordinated timing of the two actions and the fact that it does not stop with perforation cleaning only.