**REVIEW OF MONITORING WELLS EXHIBITING
ELEVATED pH IN F AND H AREA**

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REVIEW OF MONITORING WELLS EXHIBITING ELEVATED pH IN F AND H AREA

Introduction

Several of the monitoring wells installed at the Savannah River Plant in the past few years exhibit pH values of 8 or higher. These pHs are significantly higher than average values for the aquifers involved and are also higher than expected for natural waters (Price, 1984). They are also inconsistent with observations in nearby wells. It is therefore suspected that the high pHs are not representative of true aquifer conditions.

Two previous studies conducted at SRP (Price, 1984; Schreeder, 1986) conclude that high pH readings in M-Area monitoring wells and Z-Area piezometers are the result of contact between groundwater and grout. Price bases his conclusion on water chemistry. Schreeder's evidence is the relationship between pH and amount of water withdrawn from the piezometers-- an initially high pH drops as more water is removed. This conclusion is supported by laboratory measurements on water samples collected from cement-bentonite grout which show pH values of 13 (Colangelo and Lytwynyshyn, 1987).

This investigation was undertaken to evaluate contamination by grout and drilling fluid as a possible cause of elevated pH in monitoring wells at SRP and to develop techniques to rehabilitate the affected wells. FSB and HSB wells were used in this study. Historical data for wells with elevated pH are listed in Table 1.

Possible Causes of Elevated pH

The elevated pHs detected in some wells are not typical of natural formation waters and are not consistent with measurements made in nearby wells. There is no pattern to the location of the wells which would indicate the possibility of a high pH plume. In fact, most of these wells are located in areas which are characterized by low pH. These facts indicate that high pH measured in the wells is not the result of actual contamination of the groundwater. The other alternative is contamination of certain wells through what Walker (1983) refers to as "installation trauma".

Wells experiencing installation trauma exhibit anomalous levels of chemical constituents which were introduced during well construction. The intensity of the trauma depends on the chemical differences between the natural groundwater and the materials used for drilling fluid, seals, and backfill. The wells considered in this study were constructed using bentonite in the drilling fluid and a cement-bentonite grout. Bentonite contains sodium and hydroxol ions, and cement contains calcium hydroxide. Water which contacts either one of these substances will take hydroxol ions into solution, resulting in an increase in pH of the water. Thus the installation

TABLE 1

Historical data for FSB and HSB Wells with Elevated pH

<u>Well #</u>	<u>pH</u> <u>4087</u>	<u>pH</u> <u>1088</u>	<u>pH</u> <u>2088</u>
FSB91C	10.7	9.1	10.2
FSB94C	10.6	11.5	11.6
FSB95C	6.7	6.8	10.7
FSB96A	11.5	11.6	11.9
FSB97A	9.8	7.9	7.6
FSB97C	11.0	10.6	10.5
FSB97D	10.9	8.4	9.0
FSB98A	11.2	11.3	11.3
FSB98D	8.1	9.1	11.4
FSB99A	8.8	7.0	9.0
FSB100A	9.8	10.3	10.7
FSB101A	9.4	6.9	--
FSB110C	6.9	9.6	9.6
HSB69A			9.5
HSB84B		9.5	--
HSB84C		10.2	--
HSB85B		9.1	10.6
HSB101C		7.0	9.1
HSB101D		9.1	9.4
HSB104C		8.9	9.3
HSB115C		11.4	11.2
HSB118A		8.7	7.2
HSB119A		9.9	9.8
HSB120A		8.9	9.2
HSB121A		9.2	9.4
HSB124A		11.9	11.6
HSB126C			8.2
HSB127C			8.5
HSB130C			8.4
HSB131C			8.3
HSB133C			10.8
HSB135C			9.2
HSB139A			9.7

trauma in this case will consist of elevated pH and elevated levels of the associated cations, calcium and sodium. The anomalous constituents typically stabilize over time at normal levels for the formation. The rate at which stabilization occurs depends on the volume of substances introduced during drilling, the duration of development pumping, and the yield of the formation. In some cases, stabilization can take one year or more (Walker, 1983).

Water which enters a well can contact grout or drilling fluid in several ways. If the grout seal around the well casing fractures during curing, or if it shrinks away from the casing, pathways may be created for water to percolate down through the grout and move into the screen zone. This is an important consideration because other contaminants from higher horizons may also enter the well in this manner. Water which has contacted the outside of the grout column can diffuse down from higher in the formation. Alternatively, the grout itself can penetrate into the filter pack and contact water as it enters the well. This is especially likely to happen if the grout is placed under excessively high pressure or if the bentonite seal on top of the filter pack is improperly placed or is not allowed to set for a sufficient length of time. Drilling fluid can remain in the well bore because of improper or insufficient development of the well. It is also possible for drilling fluid to penetrate into the formation. This is likely to happen in highly permeable zones or when high pump pressure forces the fluid out of the borehole.

Characterization of Wells with Elevated and Normal pH

Assuming that installation trauma is the cause of elevated pH in the wells in this investigation, it remains to determine whether grout, drilling fluid, or a combination of these is the prime contributor, and whether there is any pattern which can explain why only certain wells are affected. This will be done by considering a series of parameters including water chemistry, physical properties of the formation, and installation and sampling factors.

Water Chemistry: Elevated pH caused by the dissociation of hydroxides in grout and drilling fluid should lead to elevated levels of the associated cations. In the case of contamination by grout, high levels of calcium and possibly of sodium are expected. High levels of sodium are expected if the cause is drilling fluid. One way to determine if a particular constituent is present at anomalously high levels is to look at the behavior of the ratio of that constituent to another chemically related species which is not affected by installation trauma (Walker, 1983). This type of analysis was performed on Mg/Ca ratios for wells in F and H Areas. For pHs above 10, the Mg/Ca ratios are much lower than those for normal wells. This indicates that calcium content is much higher in the very high pH wells, suggesting contamination by grout. For pHs between 8 and 10, Mg/Ca ratios vary from lower to higher than normal wells. This variation suggests that grout has a lesser

impact on these wells. In order to try to separate the effects of grout and drilling fluid, a similar comparison was made for Ca/Na ratio. The presence of sodium in the contaminant plume must be accounted for when considering wells located in the plume. Ratios were separated by aquifer for purposes of comparison (Table 2).

A wells: Mg/Ca ratios for normal wells have a small range. Wells with pH of 9.9 and above have significantly lower ratios, indicating contamination by grout. Wells with pH between 8 and 9.8 have Mg/Ca ratios which vary from below to above the normal range, indicating varying influence of grout. High pH wells have lower Ca/Na ratios than normal wells, with one exception. This indicates a higher sodium content and suggests that drilling fluid impacted most of these wells, sometimes in combination with grout. Well HSB118A has an anomalously high Ca/Na ratio due to what appears to be an anomalously low Na analysis.

C wells: Mg/Ca ratios show significantly more variation than in A wells, which could be due to the presence of calcareous zones. Wells with pH above 10 have significantly lower ratios, indicating contamination by grout. Wells with pH between 8 and 10 have Mg/Ca ratios which vary from below to within the normal range, indicating varying influence of grout. Ca/Na ratios are highly variable due to the combined effects of calcareous zones and the contaminant plume. Wells with high pH have ratios in the same range or higher than normal wells, indicating that grout may have more control than drilling fluid, although the variability makes this inconclusive.

D wells: Mg/Ca ratios are highly variable. Some of the FSB wells show significant changes in ratios between quarters, possibly indicating a longer stabilization period for water table wells or some problems with analyses. The single well with pH over 10 has a significantly lower Mg/Ca ratio than the normal wells. The other high pH wells, FSB98D and HSB101D, are within the normal range. Ca/Na ratios are also highly variable, probably due to the influence of the contaminant plume. FSB98D is at the low end of the normal Mg/Ca range and has a high Ca/Na ratio, indicating that grout may be the problem. HSB101D has a very low Ca/Na ratio, indicating contamination by drilling fluid.

Jennings (1986) reports that one of the effects of drilling fluids on groundwater chemistry is an elevated sulfate level. The highest sulfate levels in F Area and H Area are in wells with high pH. However, not all of the high pH wells have high sulfate levels, and there are a few wells with normal pH which have high sulfate.

Grain Size of Formation: Grain size can have different effects on the level of pH contamination, depending on the source of contamination. Grout can penetrate coarse-grained material more easily than fine material. According to Driscoll (1986), grout

TABLE 2

Chemical Ratios for Normal and Elevated pH Wells, Separated by Aquifer

Normal pH Wells				Elevated pH Wells				
Well	pH	Mg/Ca	Ca/Na	Well	pH	Mg/Ca	Ca/Na	Source
FSB76A	7.1	.026	8.03	FSB96A	11.5	.002	0.096	Ca,Na
FSB78A	3.7	.029	11.74	FSB97A	9.8	.043	0.75	Na
FSB79A	5.6	.034	9.52	FSB98A	11.2	.003	1.00	Ca,Na
FSB87A	6.7	.029	11.81	FSB99A	8.8	.05	1.12	Na
				FSB100A	9.8	.069	0.15	Na
				FSB101A	9.4	.032	5.69	Na
HSB83A	6.9	---	17.25	HSB69A	9.5	---	3.36	Na?
HSB117A	7.4	.028	6.83	HSB118A	8.7	.022	42.06	Ca?
HSB122A	7.8	.024	5.84	HSB119A	9.9	.0048	1.06	Ca,Na
HSB123A	7.5	.025	5.62	HSB120A	8.9	.015	2.89	Ca,Na
				HSB121A	9.2	.012	1.91	Ca,Na
				HSB124A	11.9	.00082	5.04	Ca
				HSB139A	9.7	.098	3.15	Na
FSB76C	6.1	.051	3.80	FSB91C	10.7	.007	0.79	Ca,Na?
FSB78C	3.9	.17	1.67	FSB94C	10.6	.002	0.18	Ca,Na?
FSB79C	3.4	.55	0.15	FSB97C	11.0	.010	0.74	Ca,Na?
FSB87C	6.7	.10	2.56					
FSB88C	5.8	.082	1.25					
FSB89C	6.7	.070	0.50					
FSB90C	7.1	.16	1.51					
FSB93C	6.1	.22	0.69					
FSB95C	6.7	.13	1.70					
FSB98C	3.5	.31	0.088					
FSB99C	6.8	.19	0.45					
FSB110C	6.9	.11	0.75					
HSB103C	5.2	.55	0.032	HSB104C	8.9	.21	---	?
HSB105C	6.4	.091	2.25	HSB115C	11.4	.0013	---	Ca
HSB106C	6.9	.11	0.75	HSB126C	8.2	.036	4.57	Ca
HSB107C	6.8	.076	0.65	HSB127C	8.5	.031	3.62	Ca
HSB109C	7.2	.050	4.24	HSB130C	8.4	.028	---	Ca
HSB110C	6.0	.20	---	HSB133C	10.8	.0074	21.35	Ca
HSB111C	5.6	.20	1.00	HSB135C	9.2	.21	4.13	?
HSB112C	7.2	.11	1.09					
HSB113C	6.5	.17	0.82					
HSB114C	4.9	.46	0.15					
HSB116C	6.7	.12	0.0086					

TABLE 2 (CONTINUED)

Normal pH Wells				Elevated pH Wells				
Well	pH	Mg/Ca	Ca/Na	Well	pH	Mg/Ca	Ca/Na	Source
HSB125C	6.8	.052	4.57					
HSB132C	5.6	.36	0.26					
HSB134C	6.3	1.83	1.69					
FSB87D	5.0	.43	0.59	FSB97D	10.9	.005	3.77	Ca
FSB88D	4.7	.15	0.24	FSB98D	8.1	.082	1.03	Na
FSB89D	5.0	.21	0.08					
FSB90D	6.3	.020	0.26					
FSB91D	3.1	.21	0.096					
FSB92D	3.2	.67	0.17					
FSB93D	6.8	.083	0.39					
FSB99D	3.6	.17	0.59					
FSB108D	7.7	.023	6.09					
FSB109D	5.7	.22	0.35					
HSB100D	6.3	.25	--	HSB101D	9.1	.28	0.0013	Na
HSB103D	4.3	.98	--					
HSB104D	3.9	.45	0.059					
HSB105D	3.8	.47	--					
HSB106D	4.0	.28	--					
HSB107D	4.8	.59	0.058					
HSB108D	4.6	.34	0.069					
HSB109D	5.5	.32	--					
HSB110D	4.0	.11	0.56					
HSB113D	4.2	.018	1.45					
HSB114D	3.8	.16	0.19					
HSB115D	6.4	.055	--					
HSB116D	4.2	.010	0.086					
HSB117D	6.2	.30	0.23					
HSB130D	7.7	.027	10.19					
HSB131D	5.7	.22	2.43					
HSB132D	6.5	.12	1.42					
HSB133D	7.0	.12	1.49					

NOTES: FSB Data are for Fourth Quarter 1987. HSB Data are for First Quarter 1988. Possible Sources of Contamination for Elevated pH Wells are Listed on the Far Right (Ca=gROUT, Na=drilling fluid).

should not penetrate sand which is finer than .6 mm. Drilling fluid may penetrate coarse material more easily, but it may be more difficult to remove from fine material.

Inspection of grain-size data from screen zones (taken from well records of wells which had sieve analyses) shows very little difference in grain size between normal and high pH wells. All grain sizes are in the fine to medium sand range, except FSB101A which is coarse sand. The finest grain sizes are found in high pH wells. Most wells in the 100-140 sieve size range (.0059-.0041 inches) have been impacted by drilling fluid, bearing out the idea that fluid may remain in fine material.

The grain size of the filter pack may have more influence on grout penetration than the grain size of the formation. The filter packs for the wells under consideration are .6-.7 mm or less. This is close to or less than Driscoll's limit for grout penetration. It should therefore be difficult for grout to penetrate the filter pack except under unusual conditions.

Hydraulic Conductivity: Hydraulic conductivity provides a measure of the capacity of the formation to transmit water. The amount of drilling fluid able to penetrate the formation should increase with the hydraulic conductivity, so that formations with higher hydraulic conductivity should be more susceptible to high pH. On the other hand, at least a small amount of drilling fluid is likely to penetrate any formation. Low hydraulic conductivity could impede the flushing of drilling fluid from the screen zone by water moving through the formation, thus prolonging the occurrence of high pH. The majority of the wells with high pH are in the Congaree, which has higher hydraulic conductivity. However, a number of them are in the McBean or water table, which have a significantly lower hydraulic conductivity.

Date of Installation: A large number of FSB and HSB wells were installed in 1987. All but three of the wells recording elevated pH were installed at this time. The majority of the wells in this group have normal pH. There is no separation in time between the installation of wells with elevated pH and wells with normal pH. In other words, the problem cannot be explained by pointing to a group of poorly constructed wells all installed at the same time. It is also important to note that these wells have been in place for less than one year.

Well Yield: Current sampling protocol requires the evacuation of four well volumes of water prior to sampling. However, some wells pump dry before the requisite four volumes are removed (Tables 3A and 3B). There are two possible reasons for this. First, the well could be placed in a formation which yields very little water. Second, grout could be blocking the screen.

TABLE 3A

Number of Well Volumes Evacuated Before Sampling of FSB
Wells, Fourth Quarter 1987

<u>Well</u>	<u>Well</u> <u>pH</u>	<u>Volumes</u>	<u>Well</u>	<u>pH</u>	<u>Well</u> <u>Volumes</u>
FSB76	5.6	4	FSB91C	10.7	0.7
FSB76A	7.1	4	FSB91D	3.1	6
FSB76B	6.6	4	FSB92D	3.2	11
FSB76C	6.1	4	FSB93C	6.1	6
FSB77	4.0	4	FSB93D	6.8	0.4
FSB78	4.0	4	FSB94C	10.6	6
FSB78A	3.7	4	FSB95C	6.7	4
FSB78B	6.9	4	FSB96A	11.5	0.7
FSB78C	3.9	0.5	FSB97A	9.8	5
FSB79	3.2	4	FSB97C	11.0	0.7
FSB79A	5.6	4	FSB97D	10.9	0.7
FSB79B	6.6	4	FSB98A	11.2	7
FSB79C	3.4	4	FSB98C	3.5	8
FSB87A	6.7	4	FSB98D	8.1	0.4
FSB87B	6.4	4	FSB99A	8.8	9
FSB87C	6.7	4	FSB99C	6.8	15
FSB88C	5.8	7	FSB99D	3.6	12
FSB88D	4.7	6	FSB100A	9.8	1
FSB89C	6.7	5	FSB101A	9.4	22
FSB89D	5.0	15	FSB108D	7.7	0.6
FSB90C	7.1	0.9	FSB109D	5.7	14
FSB90D	6.3	0.5			

TABLE 3B

Number of Well Volumes Evacuated Before Sampling of HSB
Wells, First Quarter 1988

Well	pH	Well Volumes	Well	pH	Well Volumes
HSB65	4.5	4	HSB104C	8.9	6
HSB65A	6.9	4	HSB104D	3.9	10
HSB65B	7.7	4	HSB105C	6.4	5
HSB65C	5.0	4	HSB105D	3.8	7
HSB66	5.2	5	HSB106C	6.9	5
HSB67	3.8	5	HSB106D	4.0	6
HSB68	3.6	4	HSB107C	6.8	4
HSB68A	6.9	4	HSB107D	4.8	8
HSB68B	7.3	1	HSB108C	7.2	3.5
HSB68C	6.2	1	HSB108D	4.6	7
HSB69	3.5	4	HSB109C	6.7	5
HSB70	5.0	4	HSB109D	5.5	8
HSB71	3.6	4	HSB110C	6.0	0.7
HSB83A	6.9	4	HSB110D	4.0	9
HSB83B	6.3	4	HSB111C	5.6	5
HSB83C	5.2	4	HSB111D	4.9	7
HSB83D	4.8	4	HSB111E	4.2	11
HSB84A	3.5	4	HSB112C	7.2	6
HSB84B	9.5	4	HSB112D	5.3	10
HSB84C	10.2	0.6	HSB112E	6.1	0.9
HSB84D	3.8	4	HSB113C	6.5	5
HSB85A	6.9	4	HSB113D	4.2	10
HSB85B	9.1	0.5	HSB114C	4.9	5
HSB85C	4.9	5	HSB114D	3.8	9
HSB86A	6.7	4	HSB115C	11.4	0.6
HSB86B	7.0	4	HSB115D	6.4	3
HSB86C	4.7	4	HSB116C	6.7	5
HSB86D	3.6	6	HSB116D	4.2	9
HSB100C	5.9	5	HSB118A	8.7	11
HSB100D	6.3	8	HSB119A	9.9	8
HSB101C	7.0	10	HSB120A	8.9	11
HSB101D	9.1	13	HSB121A	9.2	4
HSB102C	6.0	7	HSB122A	7.8	4
HSB103C	5.2	5	HSB123A	7.5	5
HSB103D	4.3	7	HSB124A	11.9	0.8

Seventeen of the nineteen wells which pump dry are screened in the McBean and Barnwell Formations. These formations are predominantly low-permeability clayey sand. The Barnwell Formation also contains sandy clay, silty sand, and sand lenses. Water flow in these formations is inhibited by high clay and silt content. Only two wells in the Congaree Formation pump dry. This formation is predominantly sand and has relatively high permeability and good well yields. Flow velocity in the Congaree is much higher.

The pH of these low-yield wells varies, but a clearer pattern emerges when they are separated by formation. Both normal and elevated pHs are found in low-yield McBean and Barnwell wells. pHs for the low-yield Congaree wells range from 9.8 to 11.9; these are within the theoretical range for water in contact with calcium hydroxide.

The data suggest that both mechanisms leading to low yield are represented here. Low permeability and flow velocity are the primary problems in the McBean and Barnwell Formations. This is complicated in less than half of the cases by grout and/or drilling fluid which may block the screen, indicated by elevated pH. On the other hand, low yields in the Congaree Formation appear to be caused by grout in the screen zone and not natural properties of the formation. Methods for clearing grout and drilling fluid from the screen zone are discussed below. However, if low yield is due to formation properties, there is little that can be done to improve production without altering natural conditions in the aquifer.

Summary: Mg/Ca and Ca/Na ratios show that wells with elevated pH also have elevated levels of calcium, indicating contamination by grout, and sodium, indicating contamination by drilling fluid. Several of the sodium levels were inconclusive due to the influence of contaminant plumes. About half of the wells appear to be affected by grout and half by drilling fluid, sometimes in combination. Any wells with pH of 10 or over appear to be impacted by grout.

Wells considered in this investigation are screened in three different aquifers which exhibit a range of grain sizes and hydraulic conductivities. Elevated pH is found in all of these aquifers, regardless of formational properties. However, there are a few trends which can be noted. All wells where 50% of the sample weight had a grain size less than .0059 inches (100 sieve) have elevated pH and appear to be impacted by drilling fluid. Fine grain size could contribute to elevated pH by making removal of drilling fluid from the formation more difficult. The grain size of the filter pack is theoretically too small for grout to penetrate. If grout is getting into the filter pack, it must be coming in under high pressure or else leaking through an ineffective bentonite seal. Most of the drilling fluid contamination is found in the A wells which are in a formation with higher hydraulic conductivity. This could be because more drilling fluid is able to circulate into the formation during drilling.

Low well yield may be indirectly related to elevated pH because the materials which cause the pH to rise can also block the well screen. However, low yield can often be attributed to natural properties of the formation.

Recommendations for Further Action

Prevention

The most obvious way to prevent the problem of elevated pH in monitoring wells is not to use cement grout and not to add bentonite to the drilling fluid. Unfortunately, this is not really practical at SRP. Boreholes are subject to collapse without a thickened fluid to hold them open, and the structural support provided by cement grout is necessary. The following construction techniques should help to alleviate the problem.

- Use as little bentonite as possible in the drilling fluid. This will leave a thinner filter cake, which has a better chance of complete removal during development.
- Minimize the time that fluid sits in the mud pit without circulating. When bentonite sits still, it becomes stiffer, and the increased pump pressure required to resume circulation could force the fluid into the formation (Driscoll, 1986)
- Develop the well as soon as possible after installation to improve the probability of complete removal of drilling fluid.
- Extend the time of development.
- Extend the filter pack for at least two feet above the screen (Colangelo, 1988), if the stratigraphy allows. This increases the potential for dilution of hydroxol-rich solutions percolating through the grout column, thus lowering the pH of these waters before they reach the screen zone.
- Use a thicker bentonite seal to increase the probability of an effective seal. Colangelo (1988) recommends a minimum of 5 feet of bentonite pellets.
- Allow a longer hydration time for the bentonite seal. Colangelo (1988) recommends a minimum hydration time of 6 hours. Other sources suggest a hydration time of 24 hours. Under conditions at SRP, a long hydration time may not be practical. The added hours can significantly increase the cost of installing a well. There is also the possibility that the hole may cave if it is left standing for a long time.
- Use the proper mix of cement, bentonite, and water in the grout to insure a good seal without shrinking, fracturing, or excess water. Colangelo (1988) suggests a mix of 94 pounds of portland cement, 5 pounds of bentonite, and 6 to 8 gallons of water. The amount of

water should be minimized because free water not used in hydrolysis will contain hydroxol ions (Colangelo, 1988). At the same time, the grout cannot be too thick or the pressure required to pump it could force it through the bentonite seal and into the filter pack.

Rehabilitation

Investigations into installation trauma by Walker (1983) indicate that most wells recover on their own over a period of several months to several years. Six M-Area well clusters (47, 49, 51, 52, 53, 54) installed in October, 1987 illustrate this phenomenon. Stabilization measurements made following installation show that out of 14 wells, six had pH over 8 (Horvath, 1987). All of the wells except MSB52B stabilized at normal values. PH measurements from the first quarter of 1988 show that all of these wells except MSB52B and 54C now have normal pH. First quarter pHs are lower than final stabilization pHs in nine of the 14 wells.

When wells do not recover quickly on their own, it is desirable to accelerate the natural rehabilitation process. One way to do this is to pump the affected wells for an extended period of time. Previous onsite studies (Schreeder, 1986; Horvath, 1987; Janssen and Olson, 1987) show that pH drops as more water is removed from a well. In these tests, the wells were pumped for extended periods with pH measurements taken at intervals. Pumping continued until pH stabilized. In most cases, pH dropped to normal levels for formation water. However, no follow-up measurements were made to determine whether the drop in pH was a short-term effect or actual rehabilitation. Two rehabilitation techniques are outlined below.

1. Pump the well until pH stabilizes, taking pH measurements at intervals of one well volume. After pumping stops, allow the well to recharge and measure the pH. If the pH does not rise again, the well is rehabilitated. If the pH returns to an unacceptably high level, then the process should be repeated. As long as the peak pH is lower than the previous peak, continue the pumping-recharge-pumping process until the well stabilizes. If the peak pH does not drop, but the well stabilizes at a normal value after pumping, the well will just have to be pumped every time it is sampled. If the pH never drops to normal, try another method.

Analyses for calcium, sodium, and sulfate can be done in conjunction with the pumping process in order to better define the relationships of these constituents to elevated pH. Behavior of these constituents relative to pH level can be characterized by sampling at initial water, low pH point, and post-recharge high pH point.

2. Redevelopment may help lower the pH, especially in cases where residual drilling fluid is a suspected cause of contamination. Take a sample following normal procedures (removing four well volumes), and measure the pH. Redevelop the well. Sample again

according to normal procedures. If the pH is normal, no further action is necessary. If the pH is still elevated, try the pumping process described above.

3. If the pH cannot be lowered, the well should be replaced. Replacement should be a last resort as there is no guarantee that the new well will not have the same problem.

The pumping method of rehabilitation was used on well FSB101A over a five day period from June 23 to June 27, 1988 (Table 4). On June 23, the pH started at 8.99 after pumping 30 gallons and dropped to 7.11 after pumping 1110 gallons. The well was allowed to recharge overnight. On June 24, the pH started at 7.85 after pumping 30 gallons and dropped to 7.25 after pumping 550 gallons. The well was then allowed to stand for two days. On June 27, the pH started at 7.19 after pumping 50 gallons and dropped to 6.69 after pumping 200 gallons. Each time the well recharged, the peak pH was lower; each time it was pumped, it reached a lower value. This well responded positively to repeated extended pumping. Future pH measurements will determine whether the well is truly rehabilitated.

The effectiveness of these methods in rehabilitating wells has not been fully tested. Some trial-and-error experimentation in the field will be necessary to determine the best procedure. It is possible that some combination of pumping and redeveloping may be most effective in reducing pH.

TABLE 4

Results of Extended Pumping Remediation on FSB101A

Gallons Pumped	6/23/88		6/24/88		6/27/88	
	pH	Cond.	pH	Cond.	pH	Cond.
30	8.99	160	7.85	140		
50					7.19	160
90	8.68	160	7.42	140		
100					6.96	150
130	8.30	150	7.35	130		
150					6.60	150
170	8.08	140	7.36			
190	7.87	150				
200					6.69	160
230	7.82	150	7.33			
250	7.83	150				
300	7.63	150				
510	7.24	140				
550			7.25			
1110	7.11	130				

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